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ANNUAL SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1991

12/01/92

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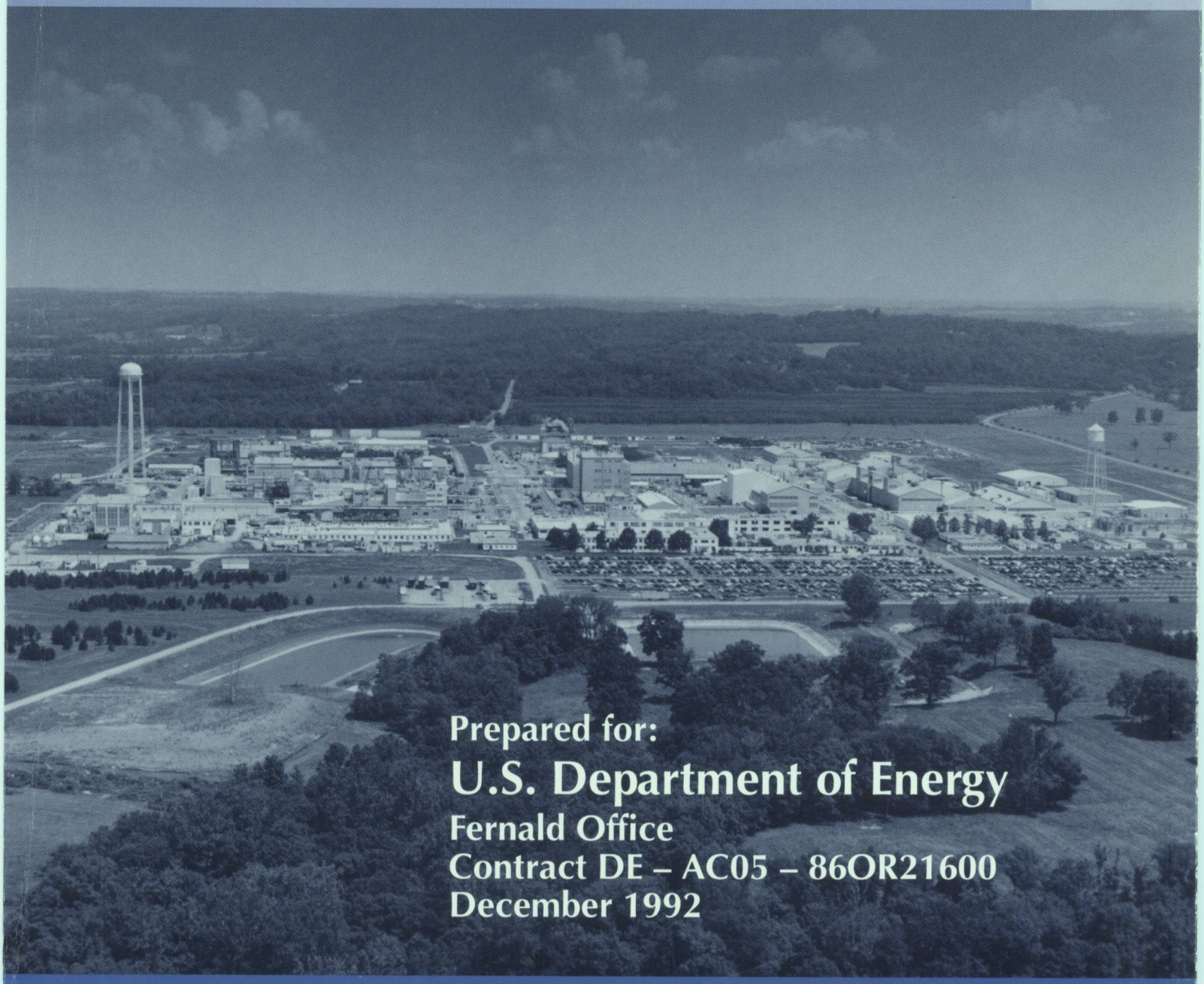
REPORT

FEMP–2275
SPECIAL
UC–707

Fernald Environmental Management Project

Annual Site Environmental Report for Calendar Year 1991



Prepared for:

U.S. Department of Energy

Fernald Office

Contract DE – AC05 – 86OR21600

December 1992

by the
Environmental Management Department
Westinghouse Environmental Management Company of Ohio

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Environmental Management Department
Environmental Monitoring Section
Radiological Environmental Monitoring Group

December 1992

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Table of Contents

List of Figures v
List of Tables vi
Acronyms vii
Conversion Table ix

Summary

Executive Summary xiii
Environmental Monitoring xiv
Air Pathway xiv
Radon Monitoring xv
Liquid Pathway: Effluent and Surface Water xv
Liquid Pathway: Groundwater xvi
Estimated Radiation Doses for 1991 xvi
Dose from Radon xvii
Cleanup xvii
Remedial Investigation and Feasibility Study xvii
Waste Management Activities xx

Introduction

Chapter 1 – Introduction to the Site 3
The FEMP Mission: Changing from Production to Restoration 4
Handling and Storing Radioactive and Hazardous Materials 6
An Overview of Production Operation 6
Purpose of the Environmental Monitoring Program 7
Local Geography 11
Geologic History 11
Lithology 12
Groundwater Hydrology 14
Surface Hydrology 14
Meteorology 17
Biology 20
Demography and Land Use 20
Exposure Pathways to People 22
Air Pathway 23
Liquid Pathway 24
Environmental Standards and Guidelines 26
Chapter 2 – Fundamentals of Radiation and Health Hazards 29
The Atom 30
Radioactivity and Radiation 31
Radioactive Decay 31
Alpha Particles 34
Beta Particles 34
Gamma Rays 34
Interaction with Matter 35
Units of Measurement 35
Activity 35
Dose Equivalent 35
Exposure to Background Radiation 38
Effects of Radiation 41
Somatic Effects 41
Genetic Effects 42
Health Hazards at the FEMP 43
Hazardous Definitions 43
Laws Regulating Health Hazards 44
Types of Health Threats 45
Summary of Radiation and Health Hazards 46

4

Compliance

Chapter 3 – Environmental Compliance Summary 49
Compliance Status 50
CERCLA 50
SARA 51
RCRA 53
Clean Air Act 54
Clean Water Act 54
NPDES Effluent Regulation 54
NPDES Stormwater Regulation 56
Safe Drinking Water Act 57
Toxic Substances Control Act 57
Ohio Solid Waste Act 58
Federal Insecticide, Fungicide, and Rodenticide Act 58
National Environmental Policy Act 58
Endangered Species Act 58
Executive Order 11988, "Protection of Wetlands" 59
Executive Order 11990, "Floodplain Management" 59
National Historic Preservation Act 59
Current Accomplishments and Issues 60
CERCLA 60
Completed Removal Actions 60
Ongoing Removal Actions 62
RCRA 64
Thorium Management 64
RCRA Closures 65
Land Disposal Restricted Waste 65
Clean Air Act 65
Radon Sources 65
Safe Drinking Water Act 66
Toxic Substances Control Act 66
NEPA 67
Environment, Safety, and Health Assessments 67
Environmental Permits 68
Air Permit Applications 68
Water Permit Applications 68
RCRA Permits 68

Environmental Monitoring

Chapter 4 – Air Pathway Monitoring 71
Monitoring for Radioactive Pollutants 74
Air Sampling for Radioactive Particulates 74
Soil Sampling for Uranium 76
Grass Sampling for Uranium 81
Produce Sampling for Uranium 81
Milk Sampling for Radionuclides 82
Monitoring for Nonradioactive Pollutants 85
Summary of Air Pathway Monitoring for 1991 86
Chapter 5 – Liquid Pathway: Effluent and Surface Water Monitoring 87
Monitoring for Radioactive Pollutants 89
Effluent Sampling for Radionuclides 89
Sources of Effluent During 1991 89
Sampling Methodologies 92
Results of Laboratory Analyses 94
Surface Water Sampling for Radionuclides 95
Sampling Methodologies 96
Results of Laboratory Analyses 96
Sediment Sampling for Radionuclides 98
Fish Sampling for Uranium 102

Monitoring for Nonradioactive Pollutants 104
NPDES Summary for 1991 104
Surface Water Sampling for Water-Quality Indicators 104
Summary of Liquid Pathway: Effluent and Surface Water Monitoring 105
Chapter 6 – Liquid Pathway: Groundwater Monitoring 107
History of Groundwater Monitoring at the Site 108
Monitoring for Radioactive Pollutants 109
Private Well Sampling for Uranium 109
Comprehensive Sampling for Radionuclides 113
Monitoring for Nonradioactive Pollutants 116
Private Well Sampling for Metals 116
Comprehensive Sampling for Hazardous Substances 116
Detections above Primary Standards 117
Detections above Secondary Standards 122
The RCRA Groundwater Assessment Program 123
Summary of Liquid Pathway: Groundwater Monitoring 123
Chapter 7 – Estimated Radiation Doses for 1991 125
Environmental and Dose Modeling 127
Air Pathway Dose Calculations 128
Estimated Doses from Airborne Emissions 128
Estimated Dose from Eating Produce Grown near the FEMP 130
Estimated Doses at the Air Monitoring Stations 131
Liquid Pathway Dose Calculations 132
Estimated Dose from Drinking Groundwater from Well 15 132
Estimated Dose from Drinking Well Water in the Area around the FEMP 132
Estimated Dose from Drinking Great Miami River Water 133
Estimated Dose from Eating Fish from the Great Miami River 133
Direct Radiation Dose 134
Total of Doses to a Maximally Exposed Individual 134
Significance of Estimated Radiation Doses for 1991 135
Summary of Estimated Radiation Doses for 1991 136
Chapter 8 – The Radon Monitoring Program 137
Introduction to Radon 138
Radon in the Environment 140
Outdoor Concentrations 140
Indoor Concentrations 140
Radon at the FEMP 141
Radon Monitoring at the FEMP 142
Methodologies 142
1991 Radon Monitoring Results 146
Estimated Radiation Dose from Radon 148
Control of Radon at the FEMP 148
Summary of the Radon Monitoring Program 149
Chapter 9 – Quality Assurance for the Environmental Monitoring Program 151
Data Quality Objectives 152
Quality Assurance: Field Activities 152
Field Analysis 152
Field QA/Representative Sampling 153
Sample Custody 154
Field Documentation 154
Analytical Laboratory Quality Assurance 155
Analytical Methods 155
Analytical Performance 155
Detection of Data Problems and Corrective Action 156
Independent Evaluations of FEMP Laboratories 156
DOE's Environmental Measurements Laboratory 157
USEPA's Discharge Monitoring Report 157
Commercial Proficiency Environmental Testing 158
Ohio Department of Health Split Samples 158
Contract Laboratory Quality Assurance 159
Summary of Quality Assurance Activities 160

Cleanup

Chapter 10 – Waste Management Activities 165
Categories of Waste at the FEMP 167
Low-Level Radioactive Waste Management 169
Storing Low-Level Radioactive Wastes 169
Disposing of Low-Level Radioactive Wastes 170
Scrap Metal Activities 171
Managing Thorium at the FEMP 171
Hazardous or Mixed Waste Management 173
Performing RCRA Closures 173
Underground Storage Tank Investigation 174
Conventional Industrial Waste Management 175
Pollution Prevention and Waste Minimization 175
Summary of Waste Management Activities 177
Chapter 11 – The Remedial Investigation and Feasibility Study 179
The RI/FS Process 180
Scoping 181
Remedial Investigation 183
Feasibility Study 183
OU Summaries in this Chapter 184
Operable Unit 1 – Waste Pit Area 184
Description of Operable Unit 1 184
RI/FS Activities 184
Remedial Action Alternatives 186
Operable Unit 2 – Other Waste Units 187
Description of Operable Unit 2 187
RI/FS Activities 189
Remedial Action Alternatives 189
Operable Unit 3 – Former Production Area 190
Description of Operable Unit 3 190
RI/FS Activities 192
Remedial Action Alternatives 192
Operable Unit 4 – Silos 1 – 4 192
Description of Operable Unit 4 192
RI/FS Activities 194
Remedial Action Alternatives 194
Operable Unit 5 – Environmental Media 195
Description of Operable Unit 5 196
RI/FS Activities 196
Remedial Action Alternatives 197

Appendices

Appendix A – FEMP Environmental Data for 1991 ..... A – 1
Appendix B – Chemical Release Information for 1991 ..... B – 1
Appendix C – References ..... C – 1
Appendix D – Glossary of Terms ..... D – 1

List of Figures

1 FEMP and Vicinity 5
2 Former Site Production Process 8
3 FEMP Site Perspective 9
4 Cross-Section of the New Haven Trough, Looking North 13
5 Buried Valley Aquifer Underlying the FEMP and Vicinity 15
6 Great Miami River Drainage Basin 16
7 1991 Wind Rose Data, 10 Meter Height 18
8 1991 Wind Rose Data, 60 Meter Height 19
9 Annual Precipitation Data, 1981 – 1991 19
10 Major Communities in Southwestern Ohio 21
11 General Air Pathways to People 24
12 General Liquid Pathways to People 25
13 Structure of the Atom 30
14 Types of Ionizing Radiation 34
15 Comparison of Disintegration Rate 36
16 Organs Affected by Substances Found at the FEMP 37
17 Exposure to Background Radiation 38
18 Breakdown of Average U.S. Radiation Exposures 39
19 Total Kilograms of Uranium to Air, 1987 – 1991 54
20 NPDES Effluent and Stormwater Monitoring Locations 55
21 Air Monitoring Locations 75
22 Average Uranium Concentrations in Air, 1987 – 1991 77
23 Average Thorium–232 Concentrations in Air, 1987 – 1990 78
24 Soil and Grass Sampling Locations 79
25 Range of Total Uranium Occurring in Surface Soils 80
26 Produce Sampling Locations 83
27 Great Miami River, Paddy's Run, FEMP Outfall Ditch, and Effluent Line 90
28 FEMP Liquid Effluent Flow Diagram 91
29 Area of Controlled Stormwater Runoff 93
30 Continuous Sampling at Outfall 001 94
31 Total Uranium (in Kilograms and Curies) Discharged through Outfall 001, 1987 – 1991 95
32 Surface Water Sampling Locations 97
33 Average Uranium Concentrations in Surface Water, 1987 – 1991 99
34 Sediment Sampling Locations 101
35 Fish Sampling Locations 103
36 Private Well Locations 111
37 Average Uranium Concentrations in Private Wells, 1987 – 1991 112
38 Well Diagram 114
39 Monitoring Well Depths and Screen Locations 115
40 1000–Series Wells 118
41 2000–Series Wells 119
42 3000–Series Wells 120
43 4000–Series Wells 121
44 Department of Energy Dose Limits 129
45 Well 15 Dose 132
46 Great Miami River Dose 133
47 Decay Chains 139
48 Offsite and Fenceline Radon Monitoring Locations 144

49 Real-time Radon Monitoring Locations 145
50 Radon Monitoring Locations Near the Silos 147
51 Milk/Uranium QA Samples, 1991 161
52 Drum Equivalents 165
53 FEMP Waste Management Areas 168
54 Overpacking of Drums 169
55 FEMP Backlog Waste, 1991 170
56 The RI/FS Process 181
57 FEMP Operable Units 182
58 Operable Unit 1 (OU1) 185
59 Operable Unit 2 (OU2) 188
60 Operable Unit 3 (OU3) 191
61 Operable Unit 4 (OU4) 193

List of Tables

1 Meteorological Data, 1991 ..... A – 2
2 Uranium in Air, 1991 ..... A – 3
3 Uranium in Grass and Soil, 1991 ..... A – 4
4 Uranium in Produce and Soil, 1991 ..... A – 5
5 Uranium in Milk, 1991 ..... A – 7
6 Radionuclides Discharged to the Great Miami River, 1991 ..... A – 8
7 Radionuclides in Surface Water, 1991 ..... A – 9
8 Radioisotopes in Great Miami River, Paddy's Run and Storm Sewer Outfall Ditch Sediments, 1991 ..... A – 11
9 Uranium Concentrations in Fish from the Great Miami River, 1991 ..... A – 12
10 NPDES Data, 1991 ..... A – 13
11 Anions in Surface Water, 1991 ..... A – 16
12 pH Values for Surface Water, 1991 ..... A – 17
13 Uranium in Private Wells, 1991 ..... A – 18
14 Comprehensive Groundwater Samples with Uranium Concentrations above DOE Guidelines, 1991 ..... A – 19
15 Metals in Private Wells, 1991 ..... A – 20
16 Nonradioactive Substances above Primary Drinking Water Standards, 1991 ..... A – 22
17 Summary of Radiation Dose Due to 1991 Emissions ..... A – 24
18 Estimated Airborne Emissions for FEMP, 1991 ..... A – 25
19 Estimated Population Distribution within 80 km (50 miles) of the FEMP, 1991 ..... A – 26
20 Estimated Committed Effective Doses at Air Monitoring Stations, 1991 ... A – 27
21 Direct Radiation Dose, 1991 ..... A – 28
22 Radon in Air, 1991 ..... A – 29
23 DOE Quality Assessment Program for Environmental Radionuclide Analyses FEMP Laboratories Performance Results, 1991 ... A – 30
24 USEPA Quality Assurance Program for Waste Water Analyses FEMP Laboratories Performance Evaluation, 1991 ..... A – 31
25 Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1991 ..... A – 32
26 FEMP – ODH Uranium Sampling Comparison, 1990 ..... A – 33

Acronyms

AHF	Anhydrous Hydrogen Fluoride
ALARA	As Low As Reasonably Achievable
AMS	Air Monitoring Station
ANSI	American National Standards Institute
ASER	Annual Site Environmental Report
ARAR	Applicable or Relevant and Appropriate Requirement
BAT	Best Available Technology
BDN	Biodenitrification Facility
BOD,5	Five-Day Biochemical Oxygen Demand
BOD,C	Carbonaceous Oxygen Demand
BMP	Best Management Practices
BSL	Biodenitrification Surge Lagoon
CERCLA	Comprehensive Environmental Response, Compensation,and Liability Act
CFR	Code of Federal Regulations
COC	Chain of Custody
CX	Categorical Exclusion
DCG	Derived Concentration Guide
DE	Drum Equivalent
DOE	Department of Energy
DQO	Data Quality Objective
EA	Environmental Assessment
EDL	Economic Discard Limit
EE/CA	Engineering Evaluation/Cost Analysis
EIS	Environmental Impact Statement
EM	Environmental Monitoring
EML	Environmental Measurements Laboratory
ES&H	Environment, Safety, and Health
FEMP	Fernald Environmental Management Project
FFA	Federal Facility Agreement
FFCA	Federal Facility Compliance Agreement
FMPC	Feed Materials Production Center
FONSI	Finding of No Significant Impact
FS	Feasibility Study
HSL	Hazardous Substances List
HWMU	Hazardous Waste Management Unit
ICRP	International Commission on Radiological Protection
LDR	Land Disposal Restriction
LLW	Low-Level Radioactive Waste
MGD	Million Gallons per Day
NAAQS	National Ambient Air Quality Standards
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
OAC	Ohio Administrative Code
ODH	Ohio Department of Health

OEPA	Ohio Environmental Protection Agency
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PCB	Polychlorinated Biphenyls
PEIC	Public Environmental Information Center
PET	Proficiency Environmental Testing
PACD	Proposed Amended Consent Decree
PMP	Project Management Procedure
PTI	Permit To Install
PTO	Permit To Operate
QA	Quality Assurance
QF	Quality Factor
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SSLS	Storm Sewer Lift Station
S&DM	Sample and Data Management
SU	Standard Units
SWMU	Solid Waste Management Unit
SWOAPCA	Southwestern Ohio Air Pollution Control Agency
SWRB	Stormwater Retention Basin
TLD	Thermoluminescent Dosimeter
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
USEPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compounds
WEMCO	Westinghouse Environmental Management Company of Ohio

Conversion Table

In this report, the metric system is used to measure length, volume, and mass, while the English system units are often presented in parentheses for the reader's reference. To measure radioactivity, exposure, and dose, the traditional radiological units (Curie, Roentgen, rad, and rem) are used; for conversion to the Systeme International units (Becquerel and Sievert), use the conversion factors in this table.

Length

1 centimeter (cm)	=	0.3937 inches
1 meter (m)	=	1.09 yards
1 kilometer (km)	=	0.62 mile
1.61 km	=	1 mile

Volume

1 milliliter (mL)	=	1 cubic centimeter (cm^3)
	=	0.061 cubic inch
	=	0.0338 fluid ounce
1 mL of water	=	1 gram
1 liter of water	=	1 kilogram (kg)
1 liter (L)	=	1000 mL
	=	0.264 gallons
	=	1.057 quarts
1 cubic meter (m^3)	=	35.3 cubic feet (ft^3)
1 Drum Equivalent (DE)	=	55 gallons
	=	0.21 m^3
	=	7.4 ft^3

Mass

1 gram (g)	=	0.0353 ounce
	=	0.0022 pound
1 kilogram (kg)	=	2.2 pounds

Activity

1 picocurie (pCi)	=	1×10^{-12} Curies
	=	2.22 disintegrations per minute (dpm)
	=	0.037 Becquerel
1 microcurie (µCi)	=	1×10^{-6} Curies
	=	3.7×10^{4} disintegrations per second (dps)
	=	2.22×10^{6} dpm
1 Curie (Ci)	=	3.7×10^{10} dps
	=	2.22×10^{12} dpm
	=	rate of decay of 1 gram of radium–226
1 Becquerel (Bq)	=	1 dps
	=	27 pCi

Exposure

1 Roentgen	=	2.58×10^{-4} coulombs per kg of air
	=	amount of gamma or X-rays required to produce 1 electrostatic unit of electrical charge in 1 cm^3 of dry air under standard conditions

Dose

1 millirem (mrem)	=	0.001 rem
1 rem	=	0.01 Sievert (Sv)

For Natural Uranium in Water

1 microgram (µg) U/L	=	1 part per billion (ppb)
	=	0.6757 pCi/L
1 milligram (mg) U/L	=	1 part per million (ppm)
	=	675.7 pCi/L
1 pCi U/L	=	1.48 ppb

For Natural Uranium in Soil

1 µg U/g	=	1 ppm
	=	0.6757 pCi/g
1 pCi U/g	=	1.48 ppm

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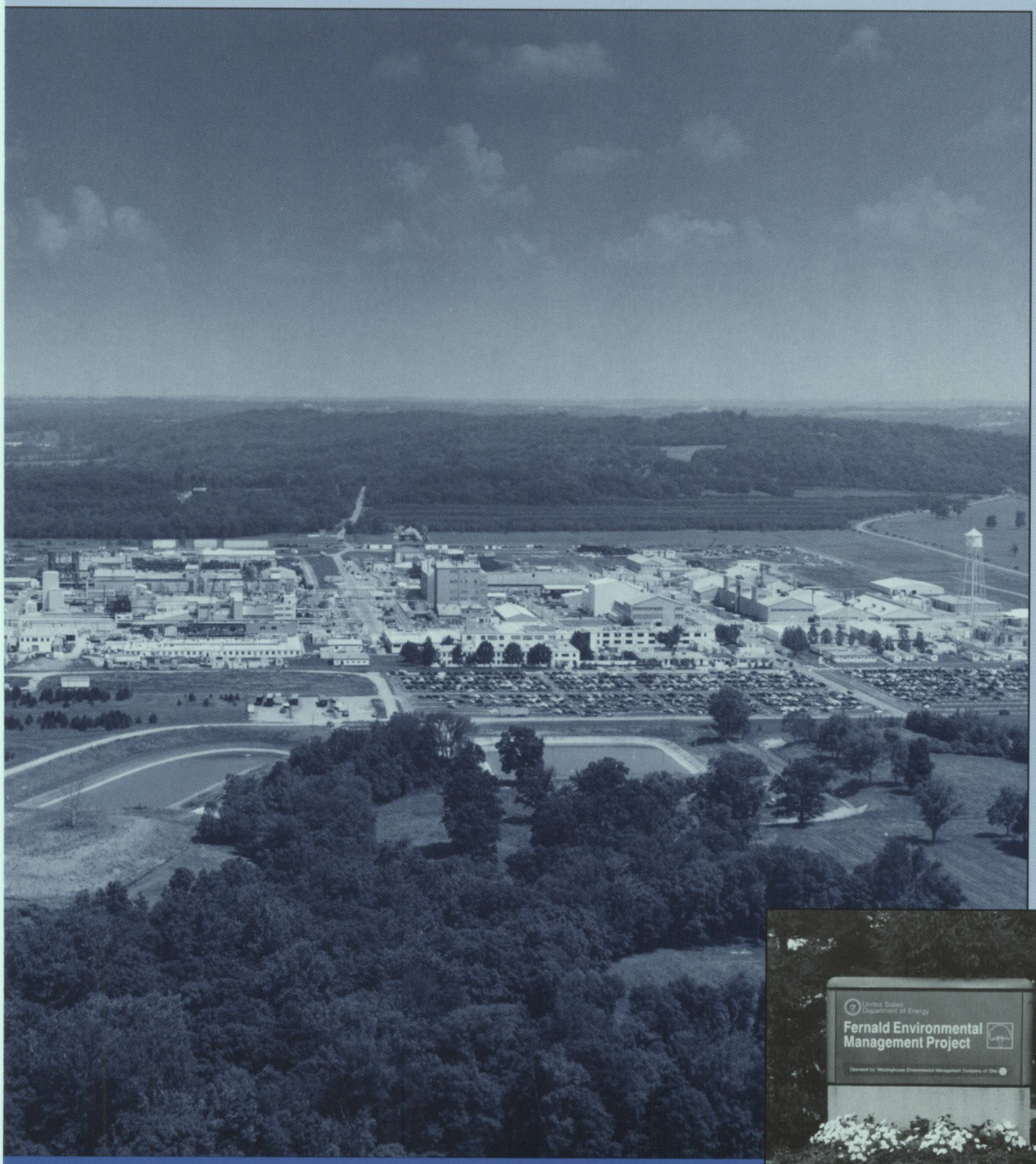
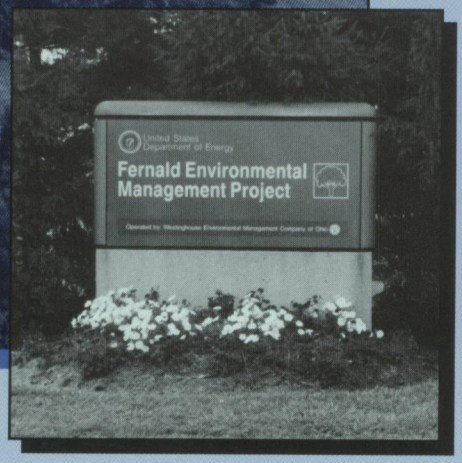
Summary





Summary

The purpose of this Annual Site Environmental Report (ASER) is to inform the public of the activities and progress made at the Fernald Environmental Management Project (FEMP) during calender year 1991. Site activities and environmental impacts are monitored by the FEMP's Environmental Monitoring Program. This program monitors the air and liquid pathways as a result of the many state and federal regulations and guidelines. Analysis of the data from the Environmental Monitoring Program allows scientists to calculate an estimated dose for the residents living near the FEMP. This report also includes information concerning the extensive waste management and cleanup activities onsite in accordance with the FEMP's remediation objective.

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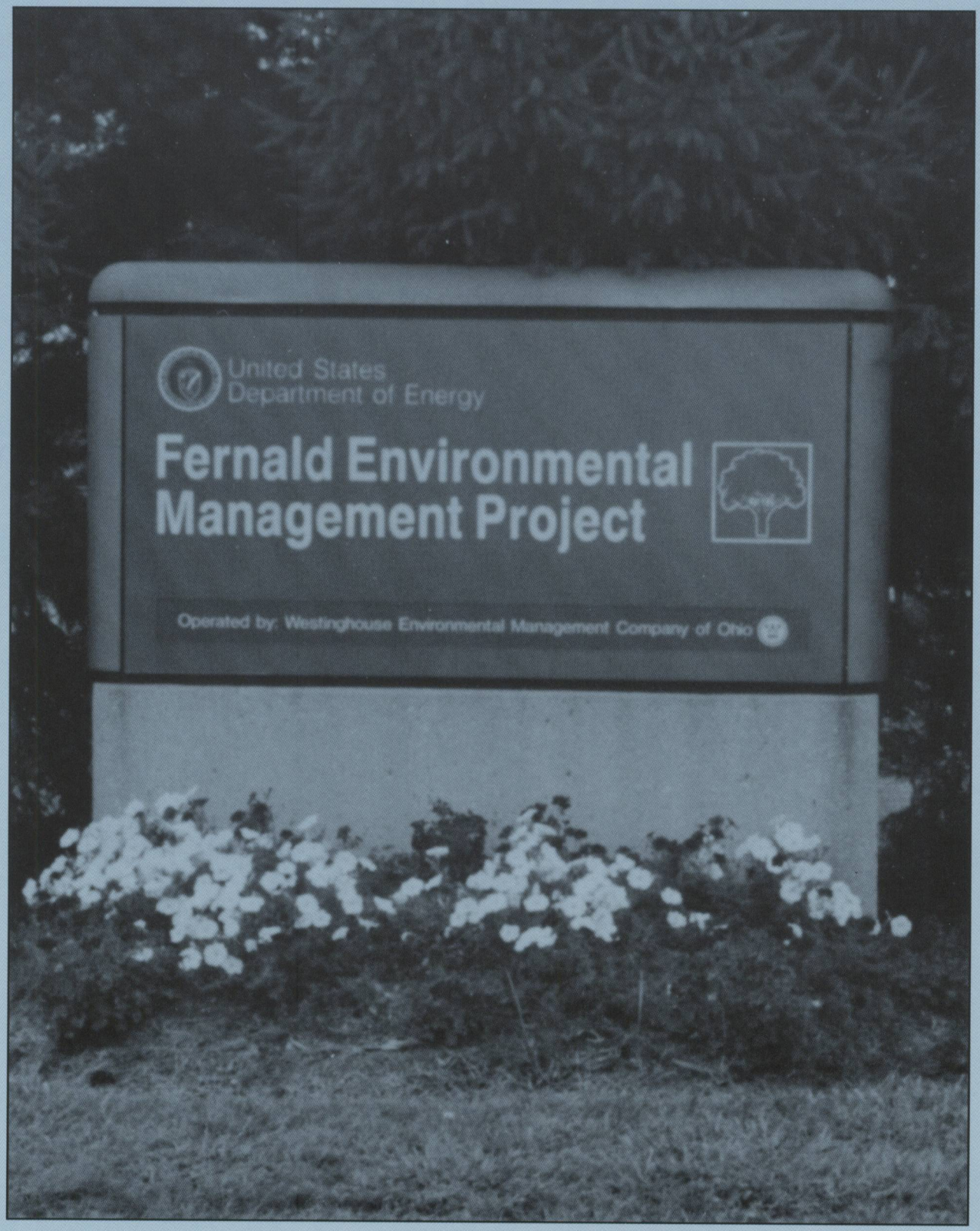
Executive Summary



Executive Summary

The Feed Materials Production Center (FMPC) was a DOE site that produced high-quality uranium metals for military defense for many years. In February 1991, DOE announced its intention to formally end uranium metal production at the site (rather than suspend it). DOE then submitted a closure plan to Congress. This closure plan became effective in June 1991. At this time, the mission of the site changed to environmental cleanup and restoration. To reflect the new cleanup mission at the Fernald site, DOE officially changed the name of the facility to the Fernald Environmental Management Project (FEMP) on August 23, 1991. Concurrently, Westinghouse Corporate changed the name of its Fernald subsidiary to Westinghouse Environmental Management Company of Ohio (WEMCO).

This section is a summary of the 1991 Annual Site Environmental Report. The chapters following this summary provide more detail about the year's activities, including: FEMP environmental monitoring results, compliance activities, cleanup, and restoration progress.

Due to problems with the laboratories during 1991, some of the data for the 1991 ASER was unavailable at the time of printing. Missing or incomplete data are addressed in the affected chapters. These data will be made available in the 1992 ASER.

Delays in laboratory analysis also contributed to the late publication of the 1991 ASER. Laboratory contracts are being reviewed in an effort to prevent this problem in the future.

Data in this report are current from January 1, 1991 to December 31, 1991 with the exception of Chapter Three, Environmental Compliance Summary, which contains information through April 1, 1992.

Environmental Monitoring

The FEMP's 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 at the FEMP primarily examines air and water as possible routes through which pollutants, particularly radionuclides, may leave the site. Other program components address contamination risks associated with cleanup procedures. A summary of air and liquid pathway results are presented below.

Air Pathway

Monitoring the air pathway incorporates results from not only the air monitoring stations but also from soil, grass, produce, and milk sampling. The boiler plant emissions also affect the air pathway. (Radon is discussed separately below.) In general, the air monitoring data from 1991 were either consistent with or lower than last year's results.

Data collected from fenceline air monitoring stations show that average concentrations of uranium were all less than 1% of the DOE guideline. Emissions from the FEMP's Boiler Plant were well below permit limits in 1991, with the exception of minor opacity excursions.

Some onsite and nearby offsite soil samples continue to show elevated uranium concentrations due to deposition of airborne particles from past operations. Uranium concentrations in grass for 1991 were higher than 1990 data at most locations. Since 1991 airborne emissions were lower than 1990 emissions, this increase is attributed to different analytical techniques used by offsite laboratories.

Uranium concentrations in produce were consistent with previous years' data. In addition, there were no significant differences in uranium concentrations between produce grown near the plant and produce grown at locations distant from the plant. Analysis of milk samples by offsite laboratories continued to experience quality assurance problems. The initial sample results from June through December were considered invalid because of poor quality assurance performance by the offsite laboratory. As a result of the Quality Assurance Program, the problem was identified and new contracts were established with additional contract laboratories. This process enabled the FEMP to acquire more reliable milk data. Analysis of duplicate milk samples from the dairy next to the FEMP and the background dairy (23 miles from the FEMP) indicated that uranium concentrations in milk were below laboratory detection levels and, in addition, were similar at both locations.

Radon Monitoring

Radon is regulated separately from other components of the air pathway, and it is monitored closely at the FEMP by a routine Radon Monitoring Program that uses both alpha-track etch and real-time radon detectors on- and offsite. The 1991 average fenceline concentration of 0.90 pCi/L including background levels, is approximately 30% of the DOE guideline (3 pCi/L).

Although some of the radon concentrations for 1991 were slightly higher than those for 1990, they are still well below the DOE guidelines. At times during 1991, concentrations at background locations were higher than concentrations at onsite locations. The difference is primarily due to varying meteorological conditions.

Liquid Pathway: Effluent and Surface Water

The effluent and surface water component of the liquid pathway is monitored to determine any impacts from the FEMP on the Great Miami River and Paddy's Run. The Environmental Monitoring Program examines the effluent and surface water results, along with sediment and fish results.

In 1991, there was a slight reduction in the amount of uranium discharged to the Great Miami River as compared to 1990. Downriver uranium concentrations were lower than 1990 and less than 1% of the DOE guideline. Uranium was detected in Paddy's Run because of stormwater runoff from the site. However, the average uranium concentration at the nearest offsite sampling location on Paddy's Run was less than that for 1990 and below 1% of the DOE guideline.

Radionuclide concentrations in the Great Miami River and Paddy's Run sediments for 1991 were generally consistent with previous years' data. Fish caught at and downstream of the effluent line showed no greater uranium concentrations than 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 FEMP effluents discharged to the Great Miami River and Paddy's Run. The FEMP samples met or were better than the NPDES daily maximum and monthly average permit limits more than 99% of the time during 1991.

Liquid Pathway: Groundwater

Groundwater is the second component of the liquid pathway monitored at the FEMP. The FEMP monitors for more than 50 radioactive and nonradioactive pollutants at over 200 locations on- and offsite in order to track the movement of these pollutants through the Great Miami Aquifer.

Only three private wells, none of which are now used as a source of *potable* water, exceeded the 1991 DOE guideline of 22 pCi/L for uranium in water. Four offsite FEMP monitoring wells and 18 onsite wells also had uranium concentrations above the guideline.

The South Groundwater Contamination Plume is an area immediately south of the site with known levels of uranium contamination. This plume was identified as a result of the groundwater monitoring over the past seven years. The FEMP has initiated a removal action to control further southward movement of the plume, to limit access and exposure to contaminated groundwater, and to protect the groundwater environment.

Analyses for nonradiological parameters showed that metals and volatile organic compounds (VOCs) are restricted, for the most part, to the waste pits and former production area onsite. Widespread high concentrations of iron, manganese, and total dissolved solids, all of which are known to be naturally occurring, were also detected. Exceptions to the onsite detections were arsenic concentrations in an industrial area south of the site. These detections are unrelated to site activities. This area has generated its own contaminant plume for which OEPA is conducting a separate Remedial Investigation and Feasibility Study (RI/FS).

Estimated Radiation Doses for 1991

Offsite radionuclide concentrations determined through environmental monitoring and sampling are entered in mathematical models, and potential radiation doses to nearby residents from various sources are calculated.

In 1991, the hypothetical maximally exposed individual living nearest the FEMP, exclusively eating local produce, beef, and fish, along with drinking Great Miami River water could have received a maximum committed effective dose of 9.1 mrem, exclusive of the dose received from radon. This dose is less than 10% of the 100 mrem limit for all pathways established by the International Commission on Radiological Protection and adopted by DOE. (This limit also excludes dose attributable to radon.)

Dose from Radon

Of the 0.90 pCi/L radon concentration measured at the FEMP fenceline in 1991, the concentration attributable to the FEMP is 0.31 pCi/L (the remainder is background). The effective dose for a concentration of 0.31 pCi/L is approximately 93 mrem. For purposes of comparison, the average annual dose received from naturally occurring radon is nearly 200 mrem.

Cleanup

The FEMP concentrates the majority of its efforts on remediation and cleanup activities. The RI/FS process (driven by CERCLA) and the Waste Management Program (regulated primarily by RCRA) are the two main FEMP activities geared toward site cleanup.

Remedial Investigation and Feasibility Study

In order to remediate facilities such as waste pits, sludge ponds, groundwater, storage silos, and process buildings, the FEMP began its RI/FS in 1986. The RI/FS process is outlined by CERCLA legislation and is conducted according to USEPA regulations. The RI/FS process provides a list of alternatives as well as a mechanism for choosing an alternative for remediation. The final choice is reviewed by the public and approved by USEPA.

The RI/FS divides facilities to be cleaned up into "Operable Units." There are five operable units at the FEMP, which are described below. A sixth Sitewide Operable Unit was identified in 1991 under the Amended Consent Agreement and encompasses all the operable units. This ensures that actions taken under the individual operable units are protective of human health and the environment on a sitewide basis.

Cleanup activities at the FEMP continue according to schedules and specifications contained in the 1991 Amended Consent Agreement. The DOE and USEPA reached this agreement in September 1991 to revise the scope and schedule of cleanup activities. As part of this amended agreement, many "removal actions," designed to accelerate cleanup, were identified. They are summarized below.

The major RI/FS activities for ***Operable Unit 1*** (OU1) conducted in 1991 were sampling and analysis of the pit berm soils; measurement of radon flux from waste pits 1, 2, and 3; repair to the Waste Pit 5 liner; and sampling of the waste pit area to characterize the waste.

On December 13, 1991, workers began dismantling the Experimental Treatment Facility to prevent the potential spread of contamination beyond the immediate area of Waste Pit 5. This project was completed in March 1992.

The Waste Pit Area Stormwater Runoff Control Removal Action was designed to prevent runoff from the waste pit area from reaching Paddy's Run Creek. This removal action consists of eight construction phases. Three of these phases were completed at the end of 1991. Project construction is scheduled for completion by July 1992.

The RI sampling for ***Operable Unit 2*** (OU2) included surface water and sediments, subsurface soils, and groundwater. Additional sampling was conducted in the landfill, Inactive and Active Flyash Piles, South Field Disposal Area, and the Lime Sludge Ponds.

A revised Treatability Study Work Plan was submitted to USEPA in August 1991. Information gained from this study will be used to support OU2 treatment technology selection and remedy implementation. The revised OU2 Initial Screening of Alternatives Document was approved by USEPA in June 1991.

The objective of the Active Flyash Pile Control Removal Action is to mitigate potential wind and water erosion at the Active Flyash Pile. A technical review of current utility industry practices for disposing of flyash was transmitted to USEPA in September 1991. This report was completed consistent with the terms of the 1991 Amended Consent Agreement.

The work plan for the Inactive Flyash Pile Control Removal Action was approved by USEPA in November 1991. Installation of an access control barrier around the perimeter of the area was completed in December 1991.

As specified in the Amended Consent Agreement, RI/FS activities in ***Operable Unit 3*** (OU3) are to include decontaminating and decommissioning/dismantling facilities within the former production area. A RI/FS Work Plan Addendum is being written to define the work activities necessary to complete the RI/FS for OU3.

The removal action for the contaminated water beneath buildings in the former production area was initiated to minimize the potential for contaminated groundwater to reach the underlying aquifer. Pumping and treatment of Plant 6 perched groundwater became operational on July 23, 1991. Pumping at Plant 9 was initiated in August 1991 and at plants 2/3 and 8 was initiated in October 1991.

The revised work plan for the Plant 1 Pad Continuing Release Removal Action was approved by USEPA in August 1991. The first phase of the three-phase construction plan began at the end of 1991.

To support the removal of waste inventories in OU3, a document summarizing existing FEMP procedures for the characterization, packaging, storage, and shipment of low-level waste was submitted to OEPA and USEPA in August 1991. A second document was submitted in October 1991 for review.

Two additional OU3 removal actions were in the early stages of development at the end of 1991. They are the Uranyl Nitrate Processing Emergency Removal Action and the Safe Shutdown Removal Action.

During 1991, ***Operable Unit 4*** (OU4) activities included vertical borings into the earthen berms that surround the K–65 silos, low-angle borings to sample underneath the silos, and resampling of the silo residues. The four vertical borings into the earthen berms were completed in June 1991. Resampling of the contents of silos 1 and 2 was successfully completed in August 1991, and analytical results are scheduled to be available in 1992.

The K–65 Decant Sump Tank Removal Action was completed in April 1991 when approximately 8,000 gallons of contaminated water were pumped from the K–65 sump tank to above-ground tanks in Plant 2/3. Also, the removal action for silos 1 and 2 was completed in November 1991 with the installation of bentonite clay over the residues in the silos. Preliminary results indicated that this action reduced radon emissions.

Soils, flora and fauna, surface water and sediments, and groundwater (including perched groundwater) are the environmental media that make up ***Operable Unit 5*** (OU5). During 1991, the FEMP conducted an investigation into the way in which Paddy's Run interfaces with the Great Miami Buried Valley Aquifer at locations south of the South Groundwater Plume. Information resulting from this study will help determine what type of remedial action may be warranted.

The South Groundwater Contamination Plume Removal Action is designed to protect public health by limiting access to the use of uranium-contaminated groundwater in an area south of the FEMP. This removal action is divided into five parts, and field work for part one was completed in September 1991. Construction and continuation with the remaining four parts of the removal action were planned for early 1992.

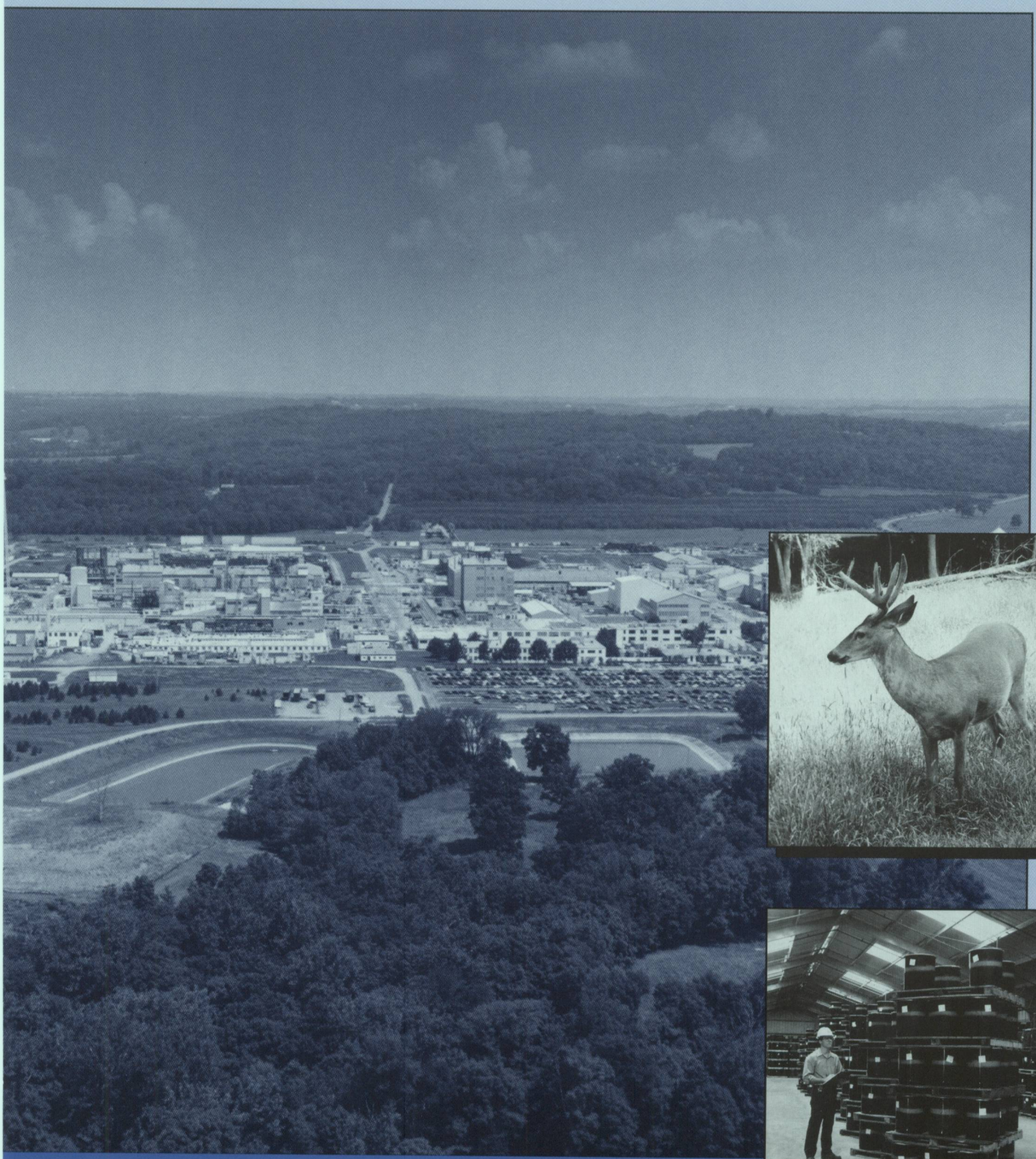
Under the 1991 Amended Consent Agreement, a Sitewide Operable Unit was established (OU6) to ensure that actions under the individual operable units are protective of human health and the environment on a sitewide basis. OU6 encompasses OU1 through OU5.

Waste Management Activities

The Waste Management Program remains a key element in preventing the release of pollutants into the environment. Generally, the program seeks to characterize, store, treat (as necessary), and dispose of radioactive, hazardous, mixed, and sanitary waste from the site in a safe and environmentally sound manner while complying with all applicable regulations. There is also an active Waste Minimization Program.

Significant advances were made in waste management activities in 1991. During the year, 47,000 drum equivalents (DEs) of low-level waste were shipped to the Nevada Test Site (NTS). Additionally, NTS renewed its approval for continued waste shipments. The final stage of a three-phase plan to improve the temporary storage conditions for the thorium inventory was begun in 1991. This plan significantly reduces the potential for any accidental releases.

Introduction



Introduction

The Fernald Environmental Management Project (FEMP) has the responsibility to inform the public of all activities onsite. One way the FEMP does this is through the ASER. In order to effectively understand all material presented in the 1991 ASER, a basic knowledge of the site is helpful.

The FEMP concentrates on achieving environmental compliance and restoration now that the site is no longer in production. The environmental monitoring done onsite is largely affected by the local geography. As a result, both the air and liquid pathways are examined as possible routes for contamination to reach the public and the environment. Also, all the restoration and monitoring activities must abide by a series of environmental standards and guidelines.

Even though the FEMP is no longer in production, radioactive and hazardous substances are still stored onsite. Therefore, both radiological and non-radiological hazards must be addressed to the public as well as onsite workers. It is important to understand the basics behind radioactivity, radiation, and other health hazards. It is also important to understand how humans are affected by alpha particles, beta particles, and gamma rays, as well as substances such as carcinogens, corrosives, explosives, flammables, irritants, and poisons/toxins.

Introduction to the Site

Introduction to the Site

The Fernald Environmental Management Project (FEMP), formerly the Feed Materials Production Center (FMPC), a uranium metals processing facility, is today the focus of extensive environmental restoration activities. Owned by the U.S. Department of Energy (DOE), the site and surrounding areas are closely observed for contamination, and remedial techniques are then developed accordingly.

This ASER is presented as a summary of 1991 environmental monitoring results. It also includes a brief summary of waste management and remediation activities at the site. In accordance with DOE Order 5400.1, the information in the 1991 ASER is updated through December 31, 1991, with the exception of Chapter Three, Environmental Compliance Summary. The compliance chapter is updated through April 1, 1992. To provide a perspective of the material presented in the report, Chapter One contains the following introductory sections:

- ***The FEMP Mission: Changing from Production to Restoration*** – a historical overview of the site and its former operations, including the evolution of the Environmental Monitoring Program;
- ***Local Geography*** – an introduction to the physical, ecological, and human characteristics of the area;
- ***Exposure Pathways to People*** – 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 FEMP must comply to protect the local environment.

The FEMP Mission: Changing from Production to Restoration

Today's mission at the FEMP is to achieve environmental compliance and restoration, whereas in previous years, the site's primary mission was to produce uranium metal.

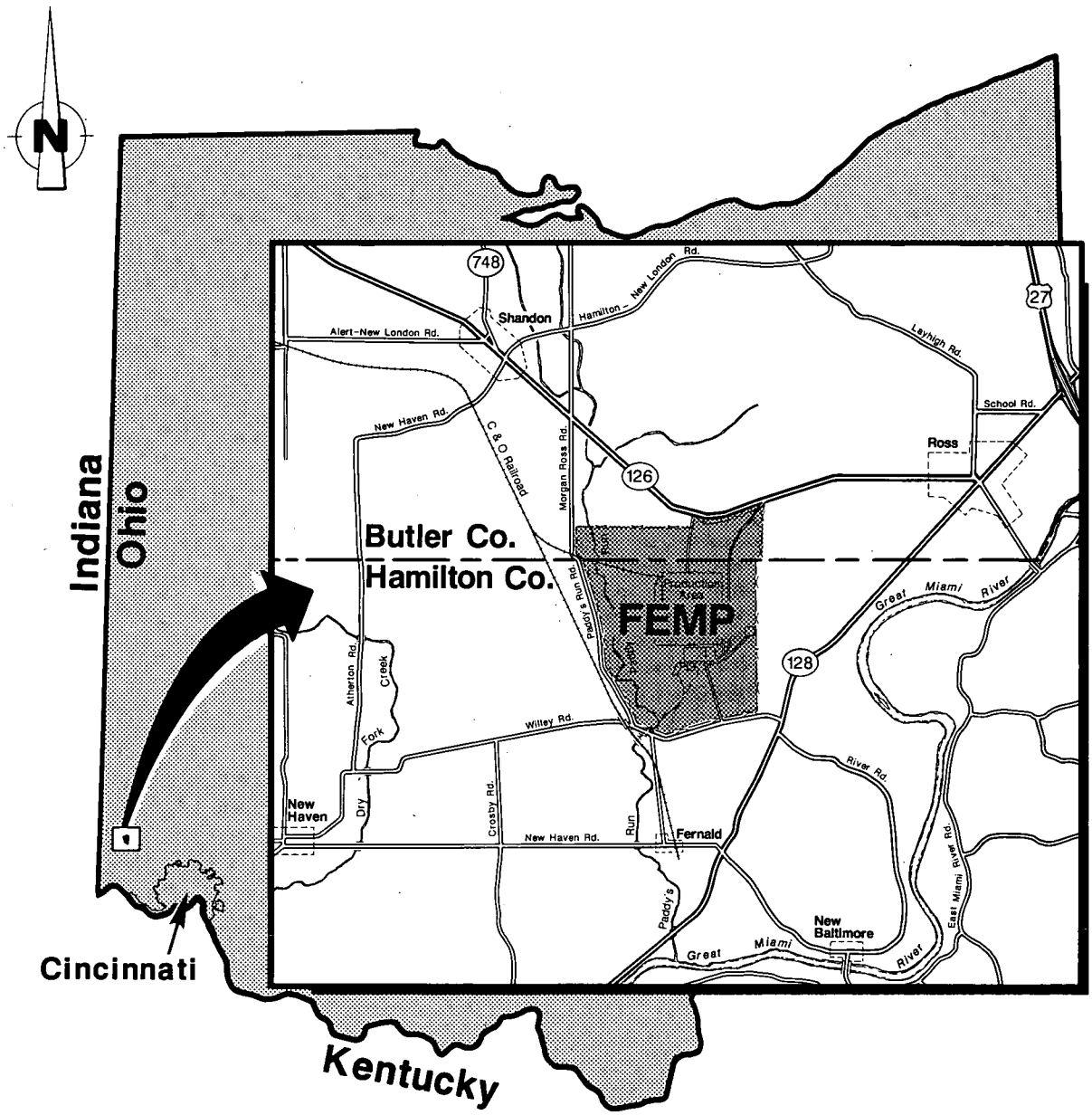
Shortly after the end of World War II, the United States recognized a need for new facilities to produce uranium metal in support of defense activities. Existing facilities, developed for the war effort, were neither economical to operate nor able to meet increasing demands. The Atomic Energy Commission (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 (Figure 1). This facility was sited just north of Fernald, Ohio, a small farming community. Ground was broken on May 16, 1951, and the first uranium derby was produced at the site's Pilot Plant on October 11, 1951. The major portion of construction was completed by 1954.

In general, the relative importance and corresponding funding of the site's 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 during the 1950s and 1960s. During the late 1970s, funding for site production and supporting organizations, including environmental monitoring, was significantly reduced and the site nearly closed. The closing was averted in the early 1980s when the United States increased Defense spending, and production at the facility accelerated. At that time, a restructuring effort began in anticipation of continued operations. 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 of the site.

Production was suspended in July 1989. In October 1990, the Department of Energy 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 production and submitted a closure plan to Congress, which became effective in June 1991. Finally, in August 1991, the site was renamed the Fernald Environmental Management Project in accordance with the new mission.

Figure 1: FEMP and Vicinity



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

1588

Handling and Storing Radioactive and Hazardous Materials

Although the FEMP 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 1991 include:

Radioactive

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

Hazardous

- Heavy Metals,
- Hydrochloric acid,
- Laboratory chemicals,
- Methanol,
- Nitric acid,
- Process waste, and
- Sulfuric acid.

The FEMP is renovating and adding buildings to store hazardous waste, repackaging some materials into new drums, and removing materials no longer needed since production has ended. For example, two new warehouses originally built to store uranium products have been converted to meet the requirements for hazardous waste storage. Also, thorium previously stored in a deteriorating above-ground silo, in bins, and in drums on an outdoor pad was repackaged in new drums and stored in a warehouse. The FEMP has significantly reduced its inventory of chemicals once used for production by selling and disposing of them at designated waste disposal facilities.

An Overview of Production Operation

Although production at the Fernald site ended in 1989, a brief overview of the production process will provide the reader with a perspective on the ongoing Environmental Monitoring Program and other environmental investigations. The major steps in the former production process are highlighted in Figure 2 on page 8. A variety of materials were used in the process, including many that were received from other DOE sites. In fact, materials

> ***Depleted and Enriched Uranium***
> *Most of the uranium processed in recent years at the site was depleted in the uranium–235 isotope; that is, it contained a smaller percentage of uranium–235 than does naturally occurring uranium — less than 0.71%. (Isotopes are discussed in Chapter Two, Fundamentals of Radiation and Health Hazards.) For many years, much of the uranium processed was slightly enriched — 0.71% to 2% uranium–235.*

such as floor sweepings, dust collector residues, and production residues were recycled in order to recover as much uranium as possible.

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 on page 9). The main product of this operation was uranium metal called a *derby*.

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

Purpose of the Environmental Monitoring Program

The FEMP investigates the effects that years of operation had on the environment, and 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, site production processes, which involved both radioactive and nonradioactive materials, resulted in air and liquid discharges 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 is designed to:

- Ensure that the FEMP will detect any unusual release of materials as quickly as possible so that corrective actions can be taken,
- 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,

Figure 2: Former Site Production Process

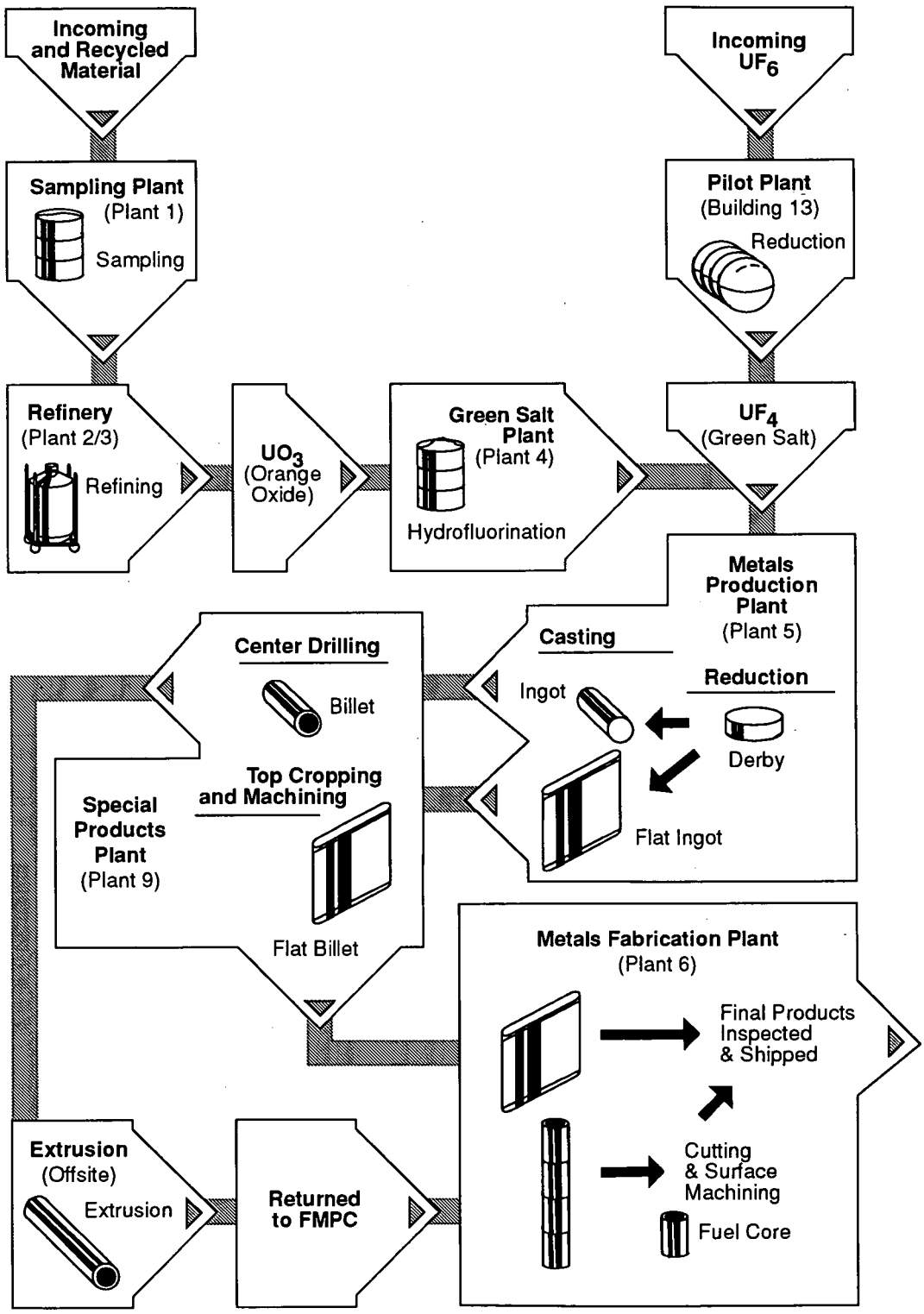
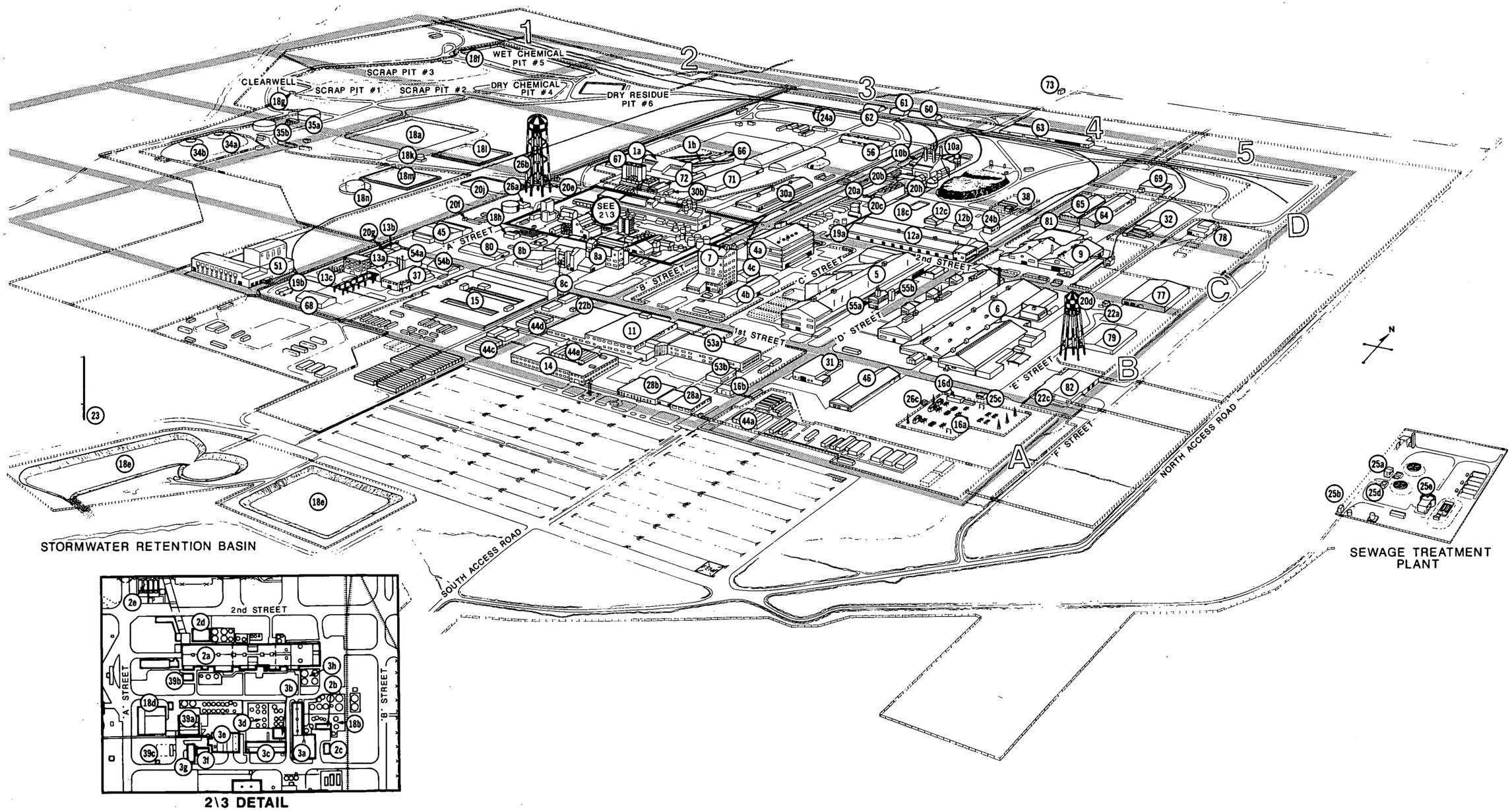


Figure 3: FEMP Site Perspective



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

- 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.

This ASER required by DOE Order 5400.1[1] serves several purposes:

- It focuses on the results of the ongoing FEMP Environmental Monitoring Program,
- It reports summary data of the sampling conducted to determine if the site complies with DOE, U.S. Environmental Protection Agency (USEPA), and Ohio EPA (OEPA) requirements, and
- It provides general information on the major waste management and environmental restoration activities during 1991.

This report, formerly called the Environmental Monitoring Report (EMR) and the Annual Environmental Report (AER), has been published for the site since 1960.

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, FEMP 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 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 hardened over time to become predominantly shale with alternating thin layers of limestone, strata known universally as the Cincinnatian Series. The shale is the relatively impermeable bedrock underlying the FEMP 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 melted, they filled the trough with sand and gravel sediments.[2]

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

The Great Miami River and its tributaries have eroded significant portions of the overburden and left *terrace remnants* which stand higher than surrounding bottom lands of the river valley. The FEMP site lies on top of one of these terrace remnants, about 177 meters (580 feet) above sea level. The FEMP property rises to 213 meters (698 feet) at the northern boundary of the site and slopes downward to 168 meters (551 feet) at Paddy's 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 FEMP, is about 165 meters (540 feet), while the land rises gently to about 183 meters (600 feet) west of the site. Figure 4 presents a cross-section of the FEMP area.

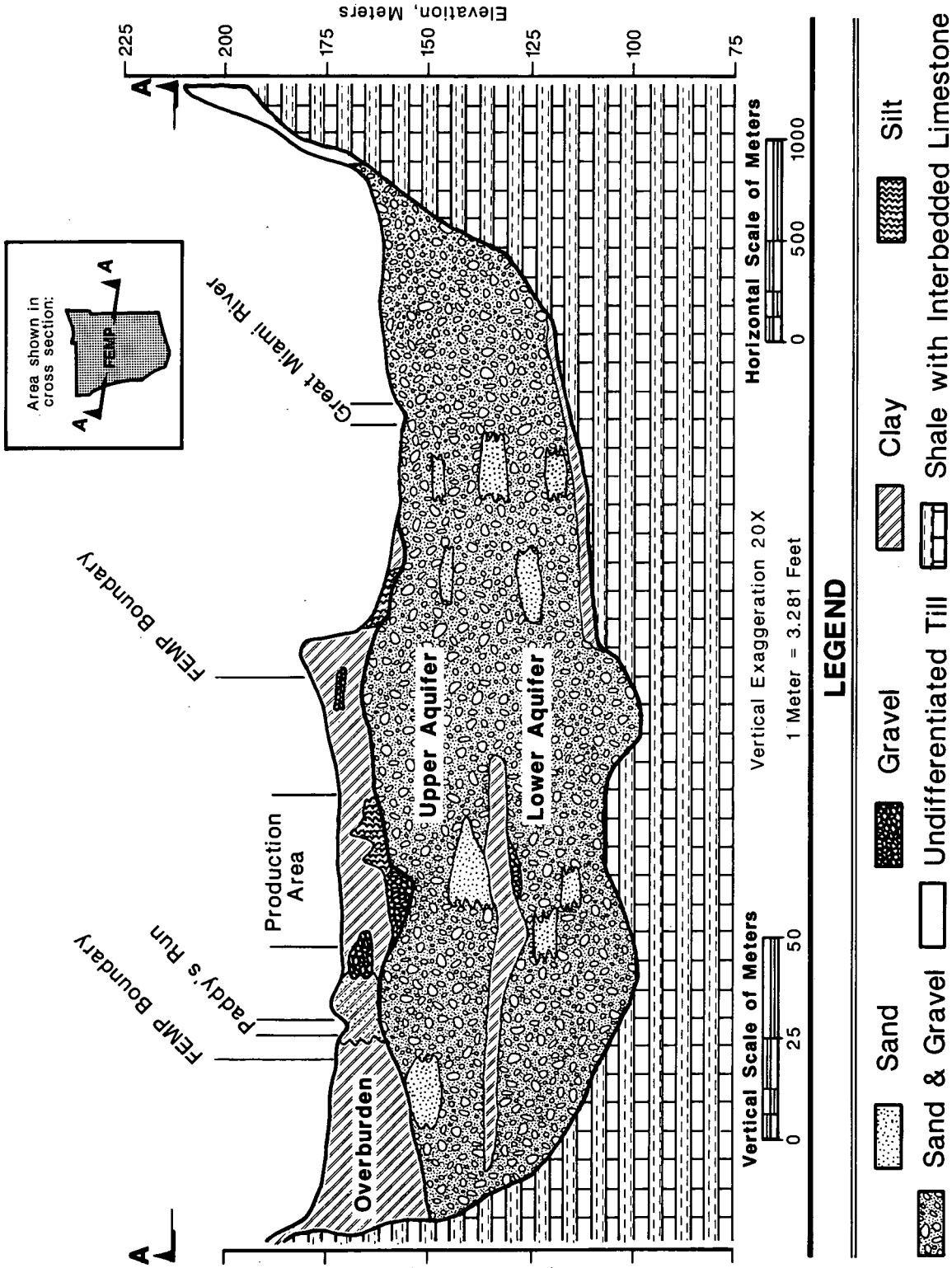
Lithology

Lithology is the study, classification, and mapping of rocks and rock formations. This science is vital in determining the location, flow, and direction of groundwater. The shale underlying the FEMP forms the floor and valley walls of the New Haven Trough and is generally between 18 and 60 meters (60 to 200 feet) below the ground surface. The elevation of the bedrock surface varies from 100 meters (330 feet) above sea level south of the production area to 122 meters (400 feet) just north of the FEMP.[3]

Sand and gravel filling the New Haven Trough is up to 60 meters (200 feet) thick. This relatively porous material makes up the Great Miami Aquifer. About 30 to 38 meters (100 to 125 feet) below the surface of the FEMP, the sand and gravel is divided by a greenish-black silty clay layer, about 3 to 6 meters (10 to 20 feet) thick.[3,4] Data collected as part of the ongoing RI/FS suggest that the clay layer extends from west of Paddy's 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 to 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.[3,4,5] The silty clay overburden continues north and east of the site, where it rests upon the shale bedrock. However, in the lower reaches of Paddy's Run and the outfall ditch, the clay has eroded, exposing the underlying sand and gravel and giving the aquifer direct contact with surface runoff.

Figure 4: Cross-Section of the New Haven Trough, Looking North



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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 FEMP occurs in the glacial overburden as perched water, in a sand and gravel aquifer and, to a much lesser extent, in the underlying bedrock. Perched water occurs when water sinking through the earth from the surface is trapped above very dense clay. Some of this perched water may slowly seep through the clay, but most remains trapped. At the FEMP, it 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. Water in the overburden does not move as easily as water in the sand and gravel aquifer below since it occurs mostly in isolated pockets.[6]

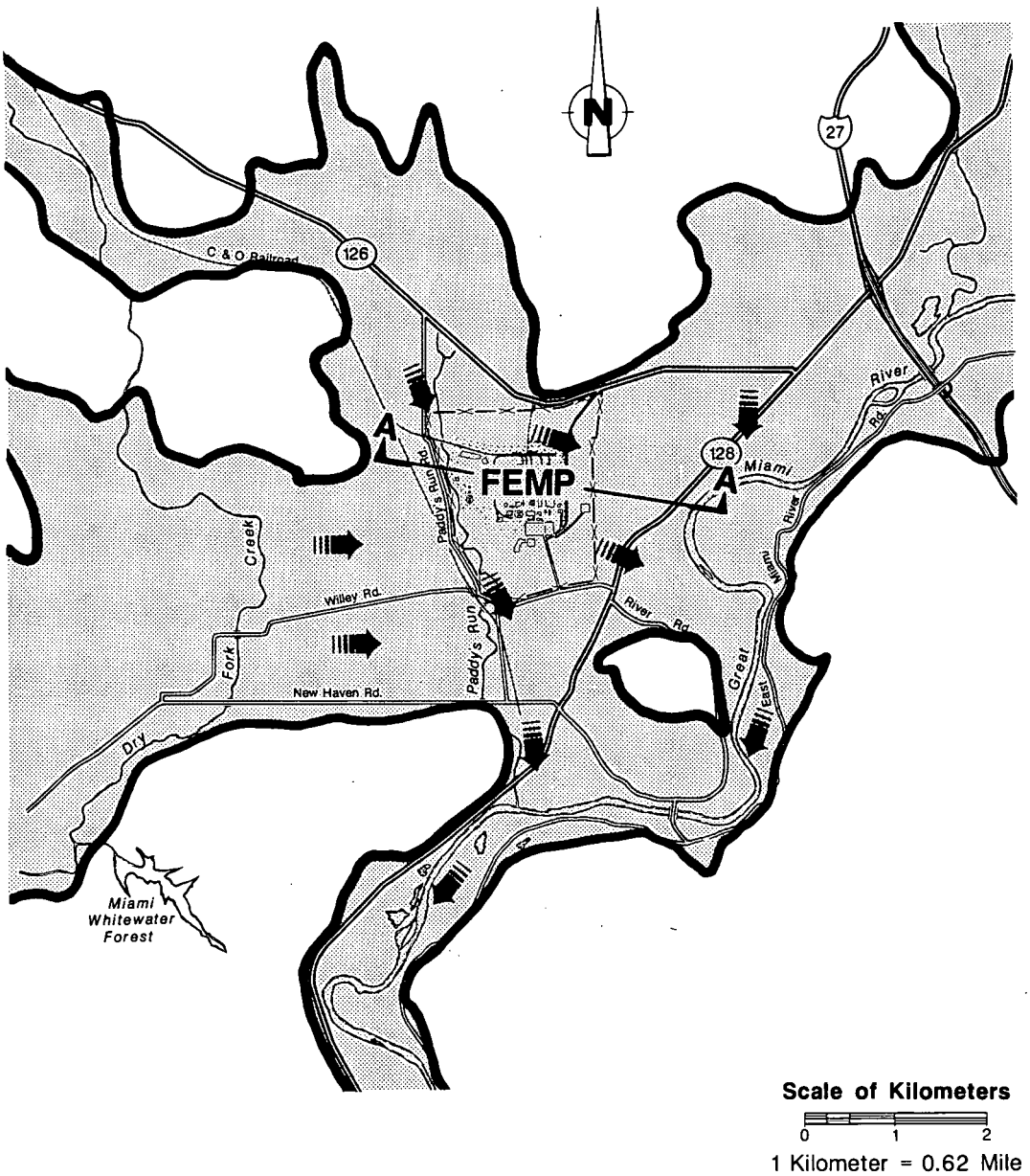
Water sinking through the glacial overburden quickly collects in the sand and gravel aquifer, saturating it. Most water is prevented from sinking further by the nearly impermeable rock floor. The top of the aquifer is about 25 meters (82 feet) beneath the FEMP, and the aquifer is between 38 to 53 meters (125 to 175 feet) thick. As shown in Figure 5, 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 to the south. These groundwater flow data are used to track and forecast the movement of contaminants which 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 site is part of the Great Miami River drainage basin, although above the floodplain (Figure 6). Natural drainage from the FEMP to the Great Miami River is primarily via Paddy's Run, a small creek which begins north of the FEMP and flows southward along the western edge of the site. 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, Paddy's Run empties into the Great Miami River.

Figure 5: Buried Valley Aquifer Underlying the FEMP and Vicinity



Scale of Kilometers

0 1 2

1 Kilometer = 0.62 Mile

LEGEND

Buried Valley Aquifer

General Direction of Groundwater Flow

Plant Perimeter

Location of Cross-Section Shown in Figure 4

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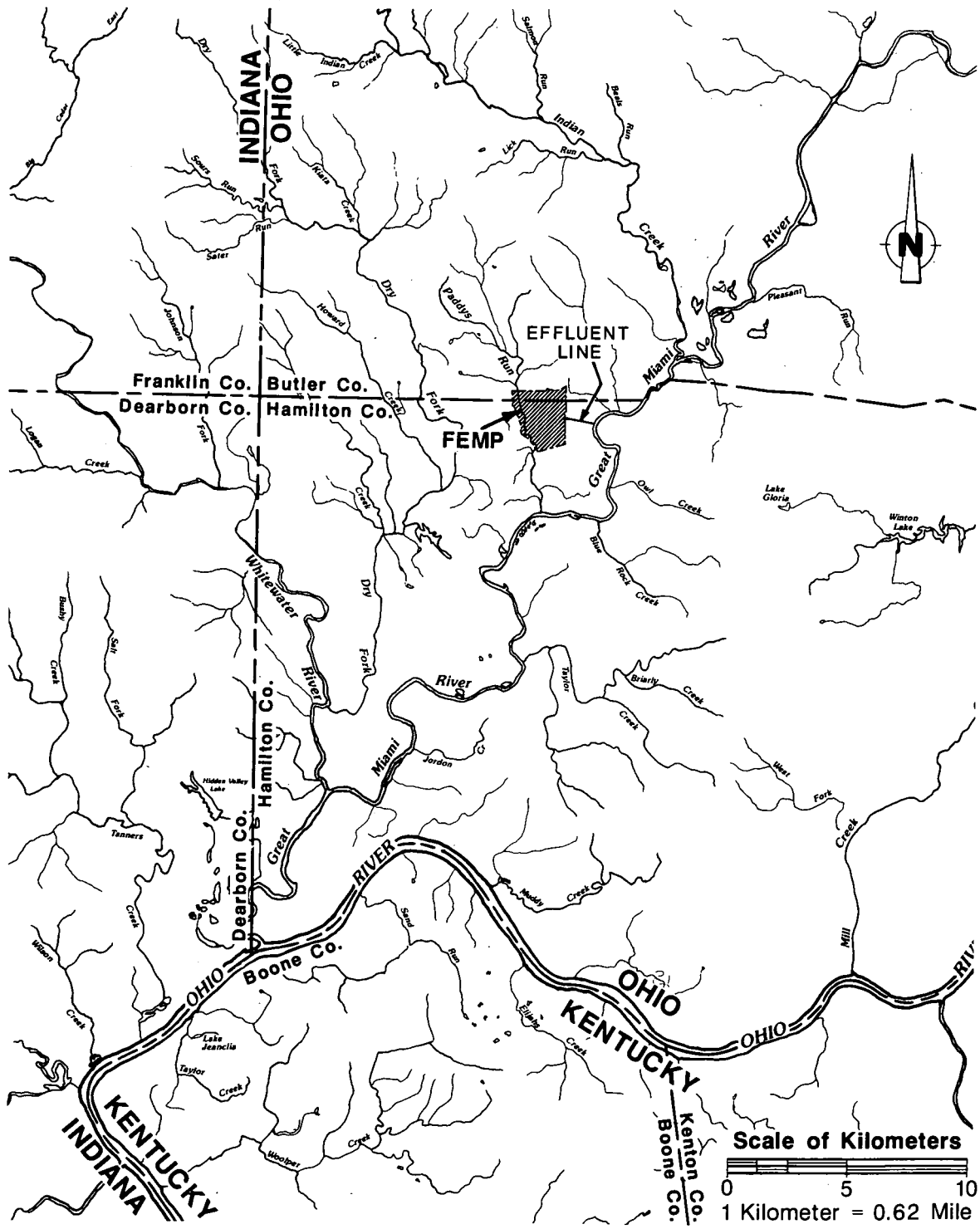
Figure 6: Great Miami River Drainage Basin



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In addition to natural drainage through Paddy's Run, most FEMP stormwater runoff is collected, treated, and discharged to the Great Miami River through an effluent pipeline. The river, about 1 km (0.6 miles) east and south of the FEMP, runs in a southerly direction and flows into the Ohio River about 39 km (24 miles) downstream of the FEMP. Although turbulence makes the Great Miami River unsafe for swimming, some people do fish there. The river is not a source of public drinking water between the FEMP and the Ohio River.

The average river flow rate for 1991 was 91 cubic meters per second (cms) (3,200 cubic feet per second [cfs]), measured daily about 16 km (10 river miles) upstream of the effluent discharge. Because the water picks up speed as it moves downstream, the average flow rate just downstream of the effluent discharge increased to 96 cms (3,400 cfs). Flow rate also fluctuates throughout the year. In 1991, the maximum rate was 1,300 cms (46,000 cfs) in January, following above-average annual precipitation in December 1990; the minimum flow was 9.4 cms (330 cfs) in November, following a dry autumn.[7]

Meteorology

The FEMP's meteorological monitoring system was installed in August 1986. The meteorological tower is 60 meters (200 feet) tall, with monitoring equipment at both the 10–meter (33–feet) and 60–meter (200 feet) heights. The tower instruments measure wind speed and direction, ambient air temperature, dew point temperature, barometric pressure, and precipitation. These data are listed in Table 1. (All tables can be found in Appendix A.)

The meteorological instruments at the FEMP are inspected and re-calibrated regularly to ensure they are functioning properly. The system does not operate during these routine maintenance periods but not for a length of time that significantly impacts the data obtained. In 1991, the FEMP provided additional training to site personnel to minimize downtime as much as possible; as a result, data recovery improved to 93%. During system downtimes, the FEMP obtains meteorological data from the Greater Cincinnati International Airport, located about 27 km (17 miles) south of the site.

The meteorological data gathered at the FEMP site are primarily used to evaluate climatic conditions at the site. The Environmental Monitoring Program uses atmospheric models to determine how airborne effluents mix and disperse; these models, in turn, are used to evaluate the impact of site activities on the surrounding environment, in accordance with DOE requirements.

Airborne pollutants are subject to whatever weather conditions exist. 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 references for collecting environmental samples and locating monitoring stations. For example, the FEMP added two air monitoring stations in 1986 in the predominant wind direction to evaluate concentrations of pollutants in air as distance from the site increases.

Figures 7 and 8 are annual wind roses, which illustrate the average wind speed and general direction measured at the 10–meter (33–feet) and 60–meter (200–feet) levels in 1991. The average wind speed measured at a height of 10 meters (33 feet) was 6.6 km per hour (4.1 mph); at 60 meters (200 feet), wind speeds averaged 11 km per hour (6.9 mph). The wind direction was predominantly toward the northeast, blowing from the southwest sector 12% of the time at the 10–meter (33–feet) level and from the south-southwest sector 12.5% of the time at the 60–meter (200–feet) level.

The total precipitation measured for the area in 1991 was 97 cm (38 inches), which is slightly less than the average precipitation of 104 cm (41 inches) for 1960 through 1990, and considerably less than the 146 cm (58 inches) recorded in 1990. Figure 9 shows 1991 total precipitation in relation to the annual precipitation amounts recorded since 1981.

Figure 7: 1991 Wind Rose Data, 10 Meter Height

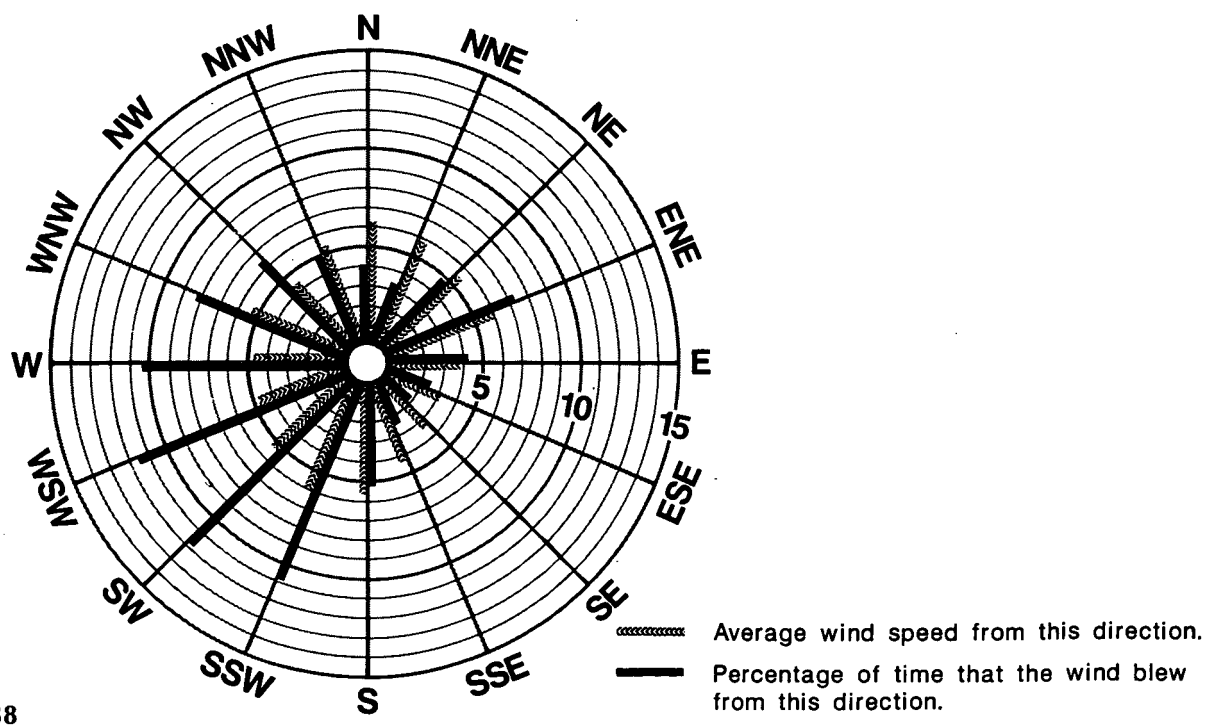

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Figure 8: 1991 Wind Rose Data, 60 Meter Height

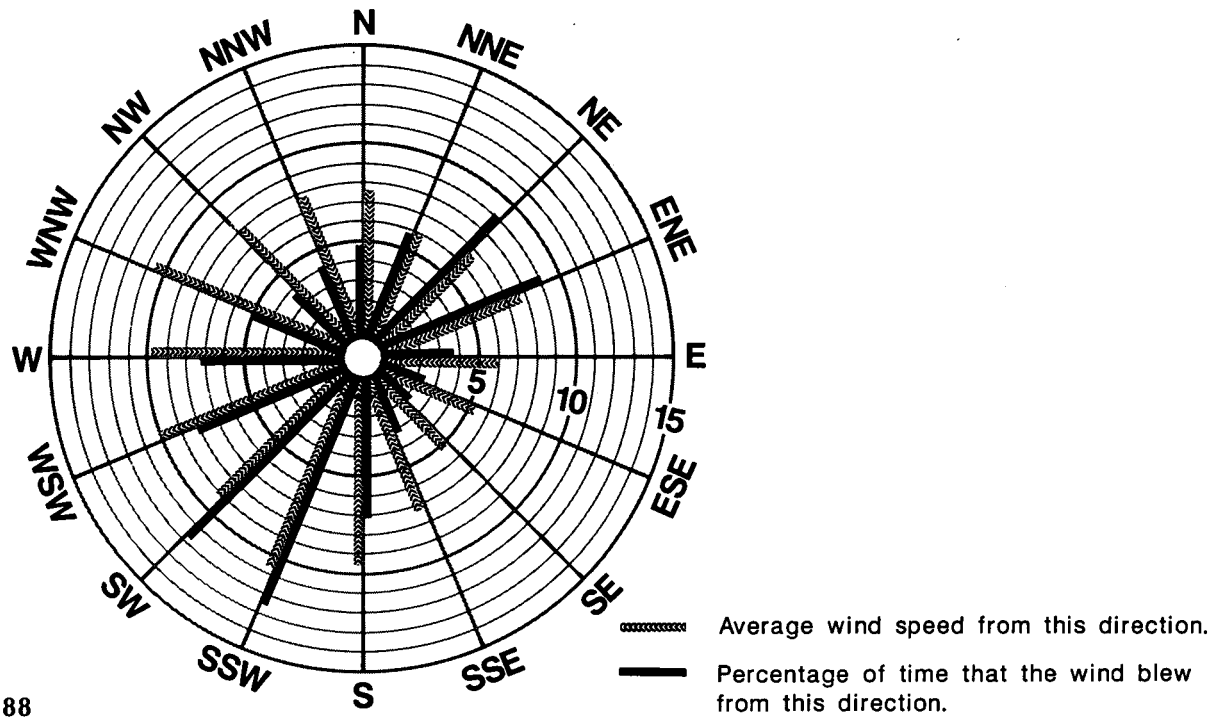

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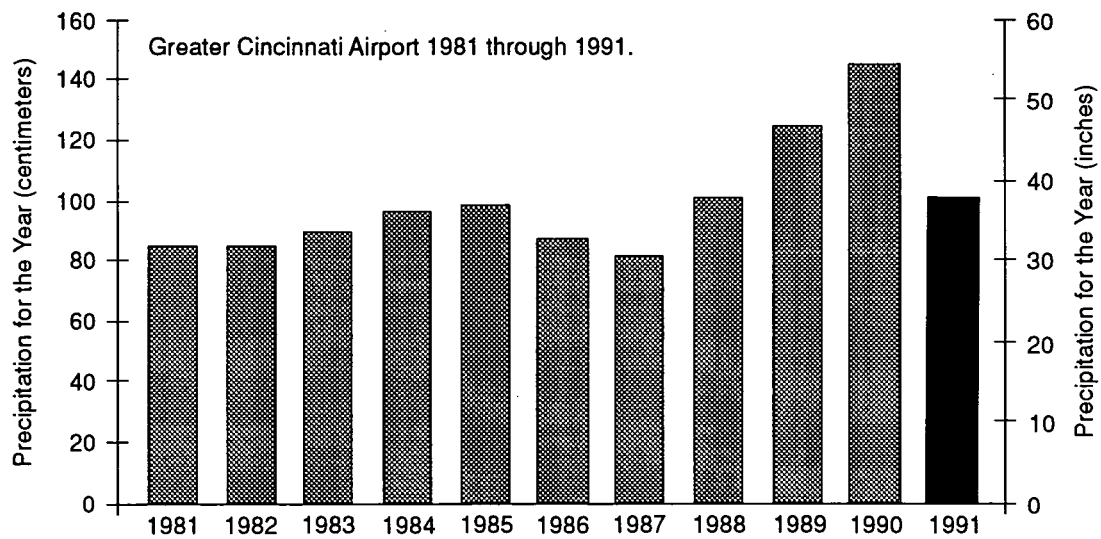
Figure 9: Annual Precipitation Data, 1981 – 1991



Biology

Representative of the regional climate, the area's natural vegetation is a broad-leafed deciduous forest, dominated by beech and maple hardwoods. Some of these naturally wooded areas still exist north of the site and in the Paddy's Run watershed to the west. Several acres immediately north of the production area were planted with white and Austrian pines as part of a 1973 environmental improvement project. Short pasture grasses and brush cover the remainder of the site. Also, local dairy farmers lease FEMP pastures for their herds to graze, consistent with the property's former agricultural uses.

Special Studies since the Biological/Ecological Site Characterization Study

Since the 1986 characterization study, several studies have continued to evaluate whether or not individual species have been affected by site operations. Individual species studied are the periodical cicada, the American robin, and the spring peeper treefrog.

Periodical Cicada *– Specimens of the periodical cicada, which remain burrowed underground for 17 years before their emergence to mate, were collected and sampled to determine if the genetic structure was affected by soil contaminants. A report published in May 1991 concluded that there was no significant difference between on- and offsite cicadas.*

American Robin *– The baseline study reported that American robin nestlings observed onsite were slightly smaller than normal size. This suppressed growth was also observed in 1990, and poor diet quality was suggested as a possible cause. The study was continued in 1991 and included testing of earthworms and soil, but the suppressed growth was no longer noted in the onsite robins.*

Spring Peeper Treefrog *– The baseline characterization reported an inactive group of genes (called a* null allele*) in onsite treefrogs. Further research indicates that this gene pattern is found at locations other than the FEMP. The* null allele *is found in populations which more closely correspond to the southern reaches of ancient glaciers.*

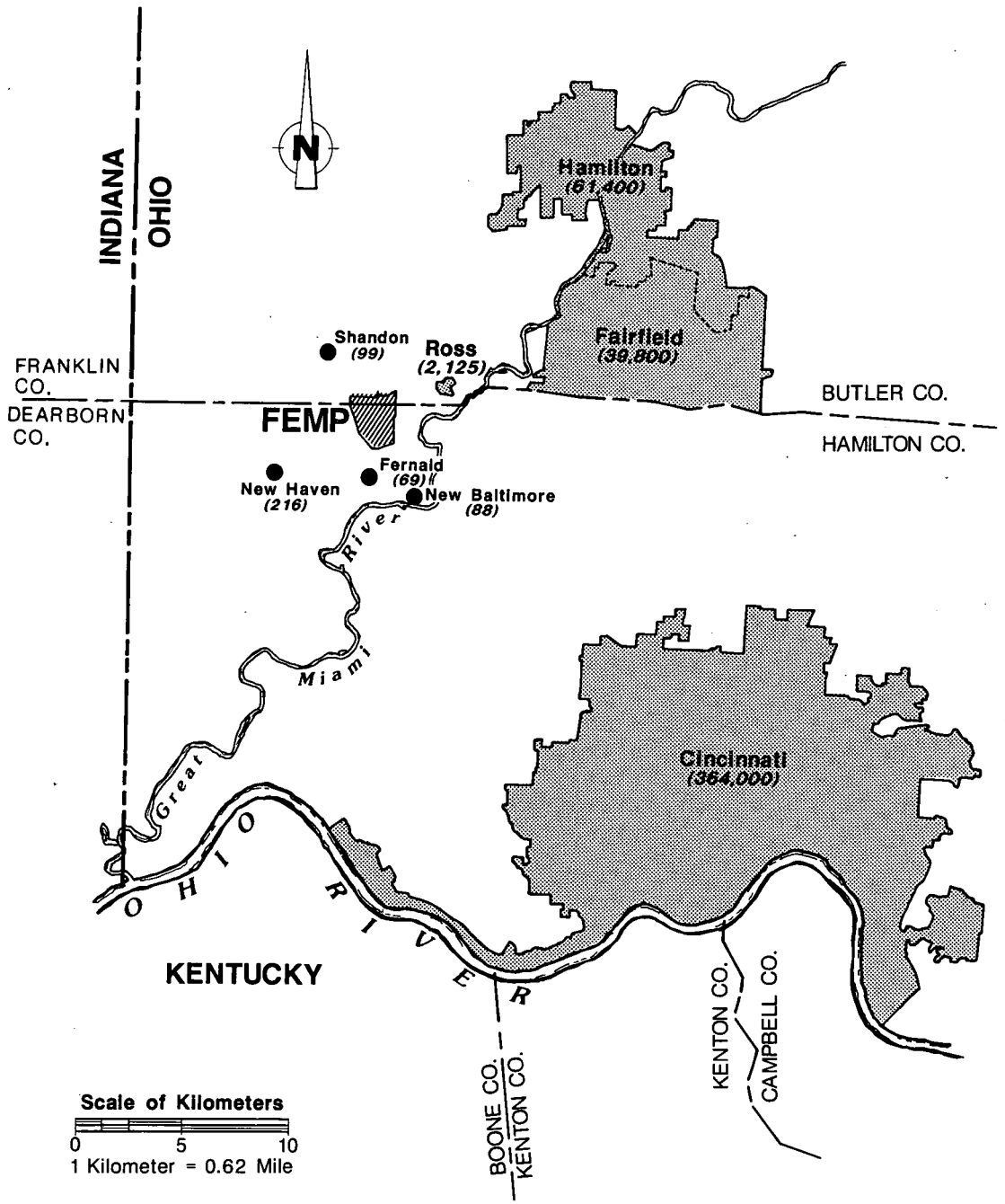
The wide variety of plants provides abundant cover for deer, eastern cottontails, woodchucks, and pheasants; bobwhite quail and assorted waterfowl have also been observed onsite. Song sparrows, blue jays, cardinals, and robins nest in the pine plantations, while Paddy's Run is home to several species of small fish, including minnows, darters, and shiners.

In 1986, zoologists from Miami University (Oxford, Ohio) began a comprehensive ecological study of the site. They studied plants and animals to determine if any species were being stressed by site activities. Based on statistical analyses, the study concluded that these activities did not appear to impact the natural habitat differently from the ecological impact of any other local industrial site. Their report, published in 1990, also concluded that no plants or animals found onsite were on the federal endangered species list.

Demography and Land Use

Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the FEMP (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)

Figure 10: Major Communities in Southwestern Ohio



LEGEND

● Population in parentheses estimated in 1989

▒ Population in parentheses from 1990 U.S. Census Figures

1588

to the northeast.[2] There is an estimated population of over 13,000 within 8 km (5 miles) of the FEMP, and an estimated 2.6 million within 80 km (50 miles). Table 19 is an estimate of the 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. A water company is located 2 km (1.3 miles) upstream of the FEMP effluent discharge to the river; presently, this company pumps about 76,000 m^3 (20 million gallons) of groundwater per day, for sale primarily to Greater Cincinnati industries.

Exposure Pathways to People

To protect this 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 delivery of 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 released from a production stack settles on a field or a plant and is absorbed into the soil. A plant may also 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 is 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.

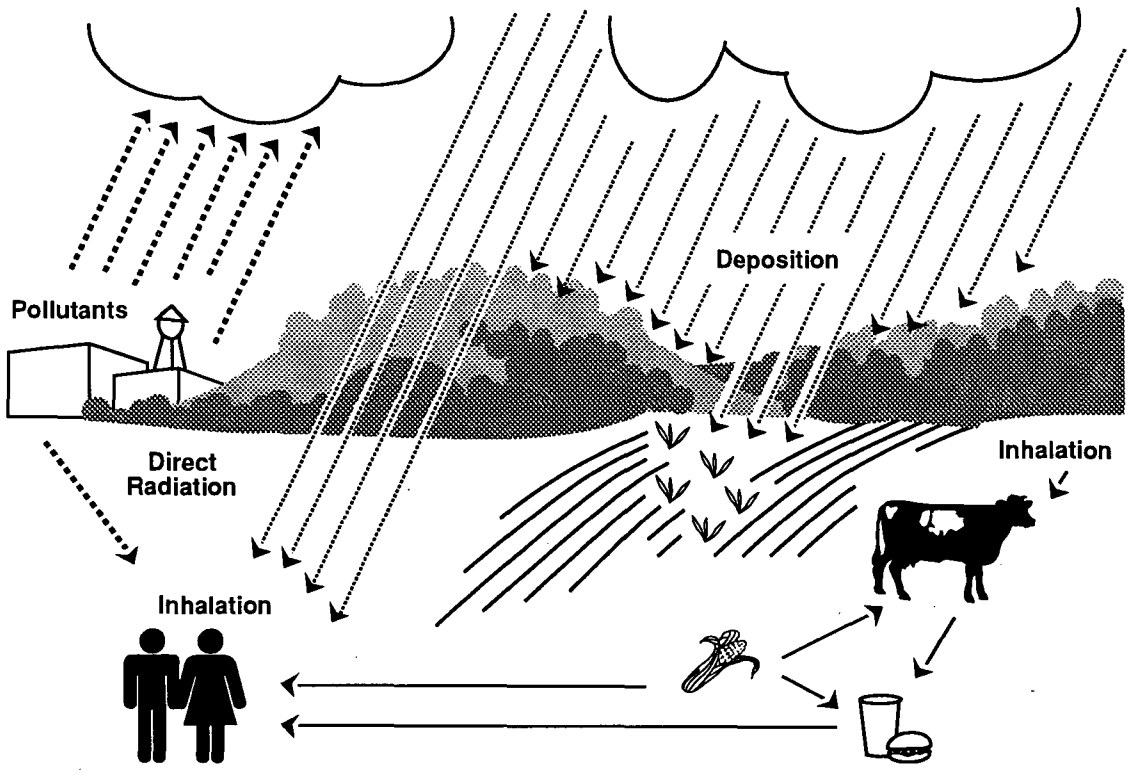
Although both radioactive and nonradioactive materials can reach people through the same pathways, the pathway scenarios presented here and throughout the ASER will focus on radioactive contamination since this is of primary concern at the FEMP. Much of this report, as well as the Environmental Monitoring Program, focuses on radioactive contamination. Uranium is the major radioactive pollutant at the FEMP; however, some of the uranium processed was recycled from nuclear reactors and contains trace concentrations of fission products (such as strontium–90 and cesium–137) and *transuranics* (such as neptunium–237, plutonium–239, and plutonium–240). These nuclides are radioactive, and the FEMP monitors for them in air and liquid discharges to the environment. These trace radionuclides 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 FEMP 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. A radionuclide in the air or liquid pathway delivers its dose after inhalation or ingestion. However, direct radiation dose is the result of gamma radiation reaching nearby residents. (Direct radiation dose is discussed further in Chapter Seven.) The following sections describe how materials from the FEMP may follow the air and liquid pathways and briefly describe environmental monitoring procedures.

Air Pathway

The air pathway includes all the airborne pollutants that may be carried from the FEMP through emissions. Direct radiation is included with the air pathway (see Figure 11 on page 24). 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 are breathed in, 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.

Figure 11: General Air Pathways to People

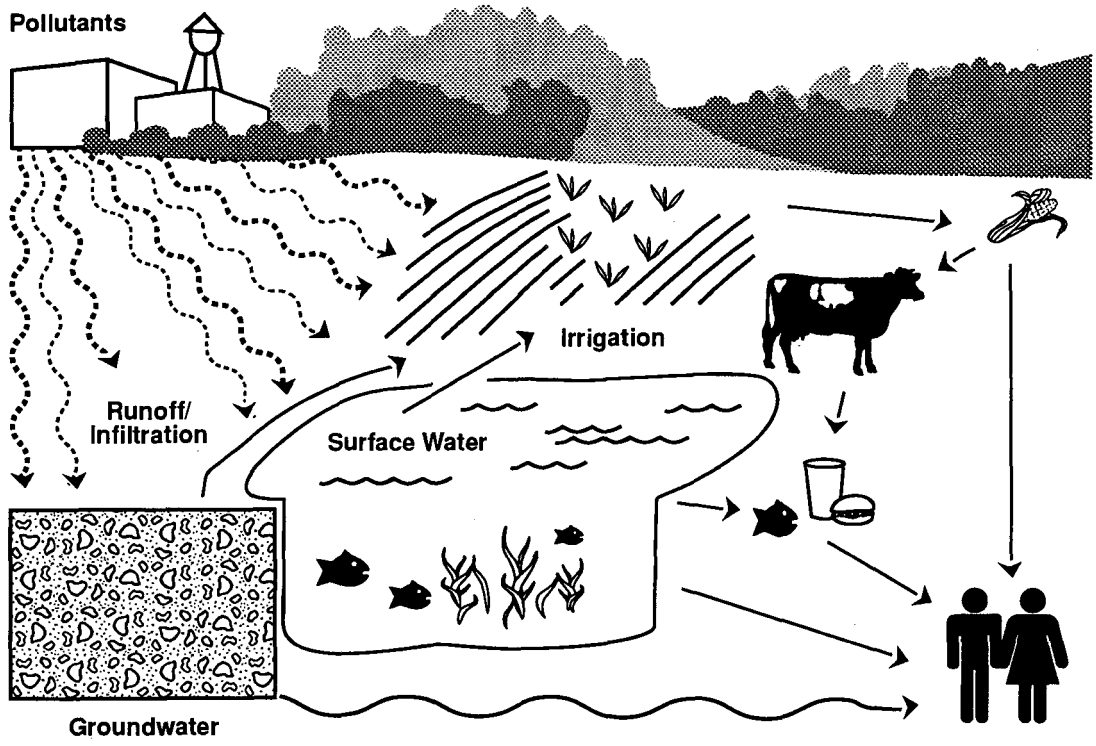


For the environmental scientist, the first step in monitoring the air pathway is to measure the concentration of the pollutants at the point of release, after they have gone through treatments and filtering. This provides preliminary information on how many pollutants are released and how they will behave in the environment. It is also possible to estimate the concentration of contaminants in the air once the emissions pass through the stack.

Liquid Pathway

The liquid pathway includes all releases from the FEMP that could carry waterborne pollutants (Figure 12), such as the effluent discharge line to the Great Miami River, the overflow spillway from the Stormwater Retention Basin, uncontrolled stormwater runoff, and groundwater. Just as with the air pathway, 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.

Figure 12: General Liquid Pathways to People



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

Groundwater is an important component of the liquid pathway because it is the source of water for homes and farms in the FEMP area. Extensive sampling of the wells on the FEMP site and in the surrounding area provides information about the aquifer. By sampling the aquifer in many locations and at varying depths, the FEMP 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 their data analysis, FEMP personnel compare the data to established standards and guidelines whenever possible. These standards and guidelines have been established by numerous national and international scientific and government groups, including National Council on Radiation Protection and Measurements (NCRP), International Commission on Radiological Protection (ICRP), USEPA, OEPA, and DOE.

These organizations 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.

The DOE adopts standards recommended by the various groups of experts and publishes them in DOE orders, thereby establishing the recommendations as limits to be met by the 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.[8,9] 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 the 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 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 background radiation (discussed in Chapter Two). Underlying all rules and requirements is the philosophy of keeping exposures As Low As Reasonably Achievable (ALARA). Therefore, the 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 philosophy of the ALARA process, DOE is subject to several pathway and source-specific limits defined in regulations developed by other federal agencies. 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 from a plant) cannot contribute

more than a 10 mrem effective dose in one year to a member of the public. Again, doses from radon–222 and its decay products are covered separately.[10] For drinking water, DOE operations cannot contribute more than 4 mrem effective dose in one year to a member of the public.[11]

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 FEMP follows these standards and guidelines in its daily operations, and must report monitoring results on a regular basis to DOE, USEPA, and OEPA. Examples of these reports include:

- Annual Radionuclide Air Emissions Report to DOE and USEPA,
- National Pollutant Discharge Elimination System Monthly Discharge (NPDES) Monitoring Report to OEPA,
- Effluent Information System/Onsite Discharge Information System to DOE,
- Monthly Consent Agreement Report to USEPA,
- SARA 313 Report to USEPA and OEPA, and
- Quarterly Report of Radionuclide Discharges to USEPA.

Throughout this report, the FEMP compares the results of its monitoring program to specific standards for various pollutants. Where several agencies propose different standards for a substance in the environment, the FEMP always uses the most stringent standard for comparison. However, there are some pollutants for which standards and DCGs have not yet been established. Furthermore, there are instances where standards do not exist for specific media, such as uranium in soil, grass, produce, or fish. Where no standards or guidelines are available, other points of reference are presented in order to help the reader assess the impact of FEMP operations. For example, results are compared with background data from areas unaffected by the FEMP activities. Results from 1991 are also compared with results of previous years to look for possible trends.

Next, Chapter Two provides an explanation of radiation, radioactivity, and other health hazards pertinent to the FEMP.

Fundamentals of Radiation and Health Hazards

2

2

Fundamentals of Radiation and Health Hazards

Since radioactive materials and hazardous chemicals are stored at the FEMP, 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,
- "Hazardous" definitions,
- Laws regulating health hazards, and
- Types of health threats.

If you are already familiar with the concepts and terms used in the study of radiation and other health hazards, you may wish to proceed directly to the next chapter on the Environmental Compliance Summary.

The Atom

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

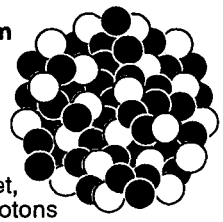
- The nucleus, and
- The electrons orbiting the nucleus.

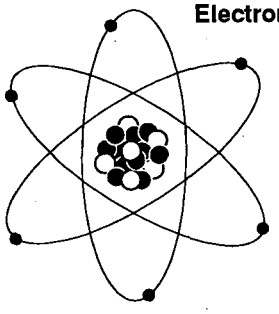
The nucleus is made up of protons, which are positively charged, and neutrons, which have no charge. Protons and neutrons are similar in size, and both are considerably larger than electrons (about 1,800 times more massive). Therefore, the weight and mass of the atom is principally concentrated in the 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 (blue). 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.



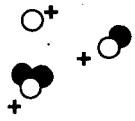


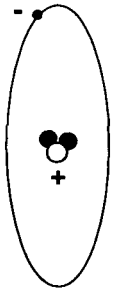
Electrons Orbiting the Nucleus

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. This energy 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 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 a specific atom contains can vary since they have no charge and don't 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 FEMP contains 146 neutrons to go with the 92 protons present in every uranium nucleus; therefore, the mass number is 238 (146 neutrons + 92 protons = 238). Uranium–234 has 142 neutrons + 92 protons, uranium–235 has 143 neutrons + 92 protons, and uranium–236 has 144 neutrons + 92 protons. All isotopes of uranium are radioactive. 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 radioactivity:

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

It should be noted, however, that not all radioactive substances emit all three types of radiation. Some homeowners have expressed concern about receiving radiation from gamma rays due to the presence of uranium–238 in well water. However, uranium–238 emits alpha particles, not gamma rays. The differences between alpha 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 FEMP 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 has seemed an inconsistency and cause for 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 the cell structure as if it were a different chemical. 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.

There is also a chemical toxicity associated with uranium, independent of its associated radiation hazards. Studies indicate that uranium is toxic to the kidney cells in high short-term concentrations (30,000 pCi/L) or lower long-term concentrations (3,000 pCi/L).

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 a common example in nature and here at the FEMP. (The uranium and thorium decay chains are presented on the following 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. Much of the uranium and thorium at the FEMP 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 at the FEMP. 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 seconds	alpha, gamma
Thallium–210	1.3 minutes	beta, gamma
Lead–210	22 years	beta, gamma
Bismuth–210	5.0 day	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 seconds	alpha
Lead–212	10.6 hours	beta, gamma
Bismuth–212	60.5 minutes	alpha, beta, gamma
Polonium–212	0.000000304 seconds	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 (one to eight centimeters 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 FEMP that decay by emitting alpha particles include thorium–228, –230, and –232.

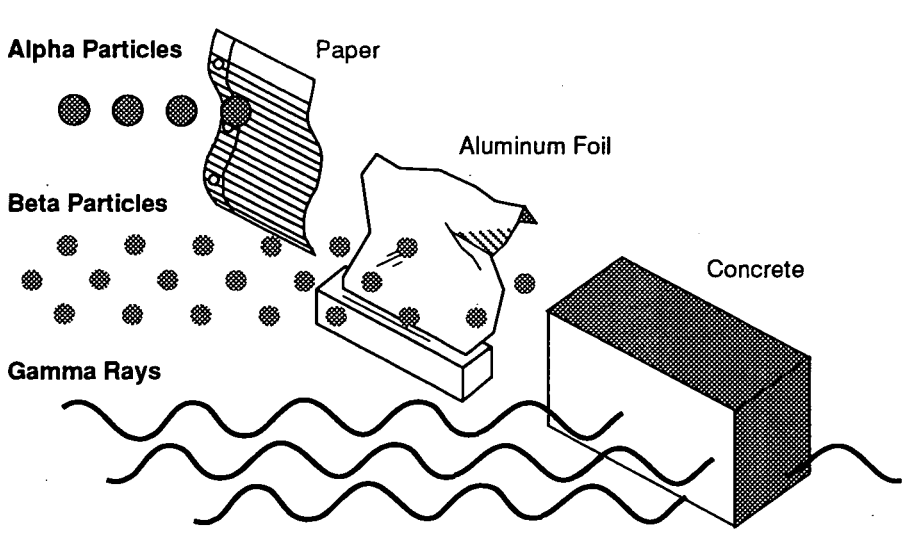
Beta Particles

Beta particles are electrons and 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 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 depending on their energy, can

Figure 14: Types of Ionizing Radiation



penetrate substantial distances into solid materials such as concrete or steel. Gamma rays are often released during radioactive decay along with alpha and beta particles. Some of the materials stored in the K–65 silos at the FEMP 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 to this report.

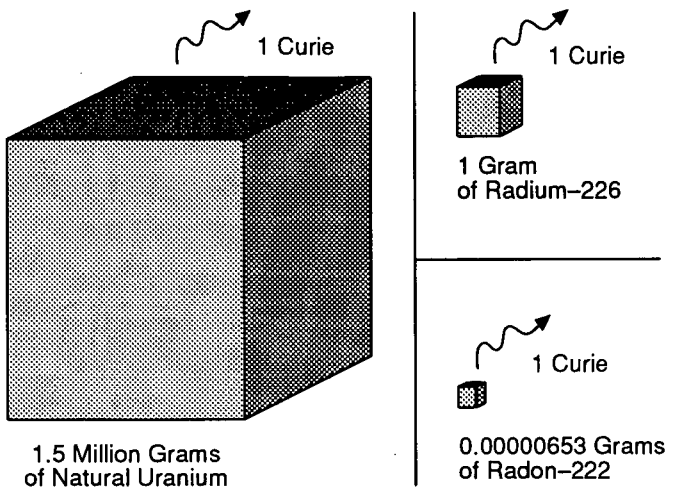
Activity

Activity is the number of nuclei in a material that decay per unit of time. An amount of radioactive material which 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 (μCi), 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, is 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 on page 36).

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

Figure 15: Comparison of Disintegration Rate



• Not Drawn to Scale

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 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 FEMP is so small, millirem (mrem) is often used instead of rem. One mrem is equal to 1/1000 of a rem.

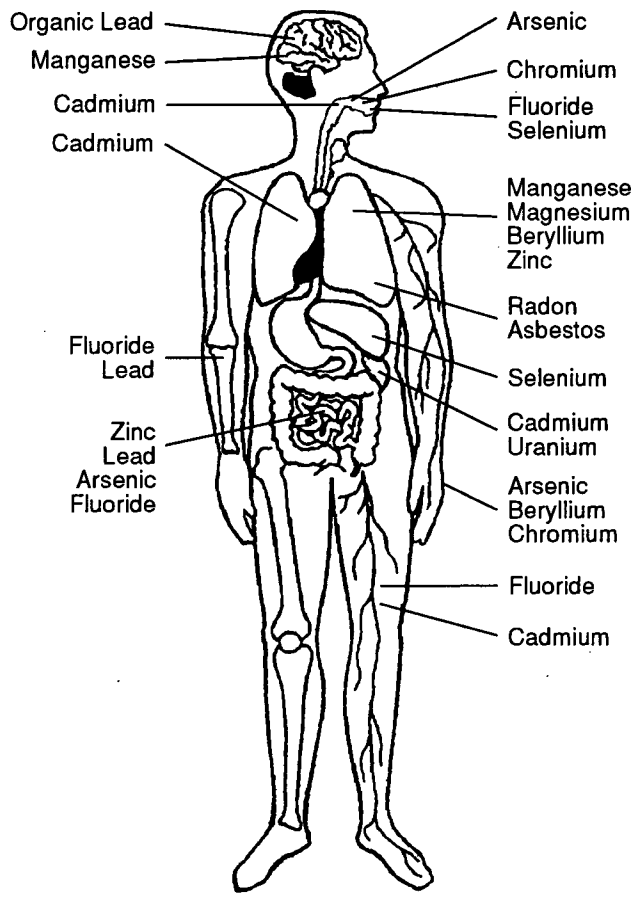
In this report, we use the term dose frequently. Unless specified differently, that term will be used in place of the term dose equivalent.

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 chosen 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 at the FEMP, the critical organs have been identified as the lung, kidney, and bone surface (endosteum). Figure 16 shows which organs are most affected by various substances found at the FEMP.

The effective dose expresses how much of a health risk radiation doses pose to individuals. To determine the effective dose, scientists first estimate each organ dose. Then, since some organs are more sensitive to radiation than others, the organs are given different weighting factors, 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.

Figure 16: Organs Affected by Substances Found at the FEMP



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.[12] The DOE 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.[10]

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.

Weighting Factor
"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.

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*

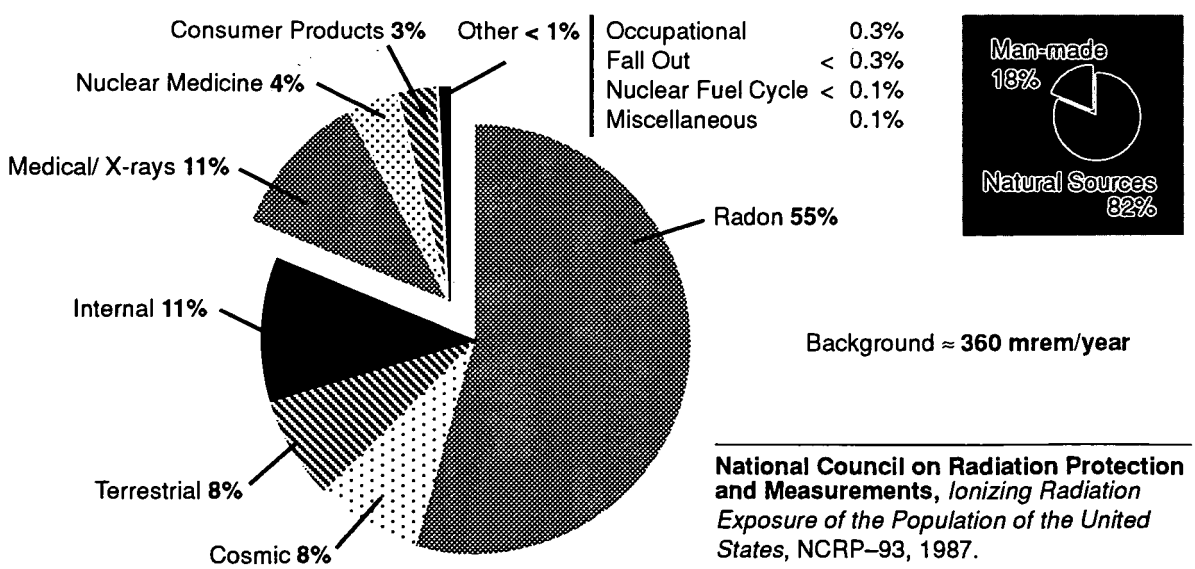
The whole body dose is the amount of radiation an individual receives when the entire body is irradiated evenly by penetrating (gamma) radiation. Most radionuclides present at the FEMP do not contribute toward a whole body dose because they concentrate more in some organs than others and do not emit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

Exposure to Background Radiation

The dose terms defined in the preceding paragraphs apply to more than just the radiation we may be exposed to from facilities like the FEMP. We are constantly exposed to other background and man-made sources of radiation. This 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.[13] In the United States, a person's average annual exposure to background radiation is 360 mrem.[12] The DOE guidelines (as well as other radiological guidelines) apply to exposures we receive in addition to background radiation and medical procedures.

As the 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.[9] (Radon is discussed further in Chapter Eight.)

Figure 17: Exposure to Background Radiation



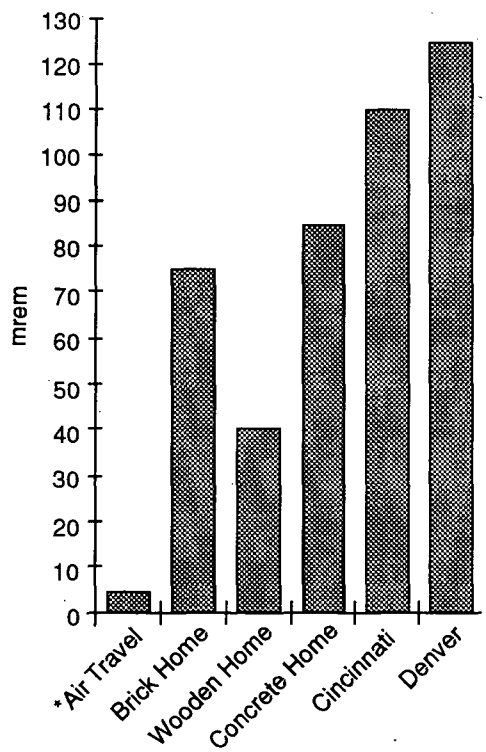
National Council on Radiation Protection and Measurements, *Ionizing Radiation Exposure of the Population of the United States,* NCRP–93, 1987.

Background radiation dose will vary in different parts of the country. For example, living in the Cincinnati area will produce an exposure level of approximately 110 mrem, while the dose received annually from living in Denver is approximately 125 mrem. This difference can be attributed to soil composition and distance above sea level. Another factor which affects annual 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 larger 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.[14] In comparison, the dose received at the FEMP fenceline from an entire year is about 9 mrem.

One way to measure how much radiation we are exposed to is to complete a personal radiation dose counter, like the one on page 40.

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

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



* One round-trip from Cincinnati to London or the equivalent

Personal Background Radiation Dose Counter*

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 watch an average of 4 hours of TV a day in 1991, 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.

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 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, scientists are still not able to determine with certainty how much cancer may have been caused by low-level radiation.

Those exposed to high levels of radiation are at greater immediate 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.[15] From these very high doses and their affects, scientists try to predict the effects and risks from low levels of radiation.

Significant clinical symptoms of radiation probably won't be seen in individuals who have been exposed to less than 100 rem.[16] (The FEMP dose to the maximally exposed individual from all pathways, except radon, was about 9 mrem — or 0.009 rem — in 1991.) 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 it exists, vary significantly. As mentioned above, some scientists believe it could be as high as 10 rem.[15] Others insist there is no threshold level below which radiation exposure is safe.[17] 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.[13]

Genetic Effects

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

Human cells normally contain 46 chromosomes — 23 transmitted from the mother and 23 from the father. These 46 chromosomes contain about 10,000 genes which are passed on to the next generation and 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 the number and structure. A cell can rejoin the ends of a broken chromosome, but if there are two breaks close enough together in space and time, the broken ends from one break may join incorrectly with those from another. This can cause translocations, inversions, rings, and other types of structural rearrangement.[13] 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 body of the offspring and are passed on to following generations. If they meet similar genes when reproducing, they would then become present in the characteristics of the offspring.[15]

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.[18, 19]

Health Hazards at the FEMP

There are other health hazards associated with the FEMP aside from radiation and its effects. 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.

Hazardous Definitions

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 synonymous and are easily confused.

A ***hazardous chemical*** is defined as 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*** is defined as 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. The Hazardous Materials Table, with more than 16,000 entries, 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 (TSCA).

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, or disposed of, or otherwise managed. The four characteristics of hazardous waste are ignitability, corrosivity, reactivity, and toxicity. All RCRA Subtitle C hazardous wastes are also CERCLA hazardous substances.[20]

Laws Regulating Health Hazards

Some of the laws that regulate health hazards are:

- CERCLA,
- RCRA,
- Toxic Substances Control Act, and
- The Clean Air Act.

CERCLA defines hazardous substances and has its own reporting and response requirements when a hazardous substance release to the environment exceeds a threshold quantity. ***RCRA***, as discussed above, defines and regulates hazardous waste.

Section 7 of the ***Toxic Substances Control Act*** (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 immanently hazardous chemical substances or mixtures, but USEPA currently regulates PCBs, fully halogenated chlorofluoroalkanes, asbestos, and hexavalent chromium under Section 6 of TSCA.

Under the ***Clean Air Act***, National Emission Standards for Hazardous Air Pollutants (NESHAP) are established. 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 FEMP. They should all be addressed and understood by both area residents and onsite workers so they may be avoided whenever possible. Carcinogens, corrosives, explosives, flammables, irritants, and poisons/toxins all have the potential to do harm.

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

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 burns to exposed skin or injury resulting from impact of debris.

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

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

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

Summary of Radiation and Health Hazards

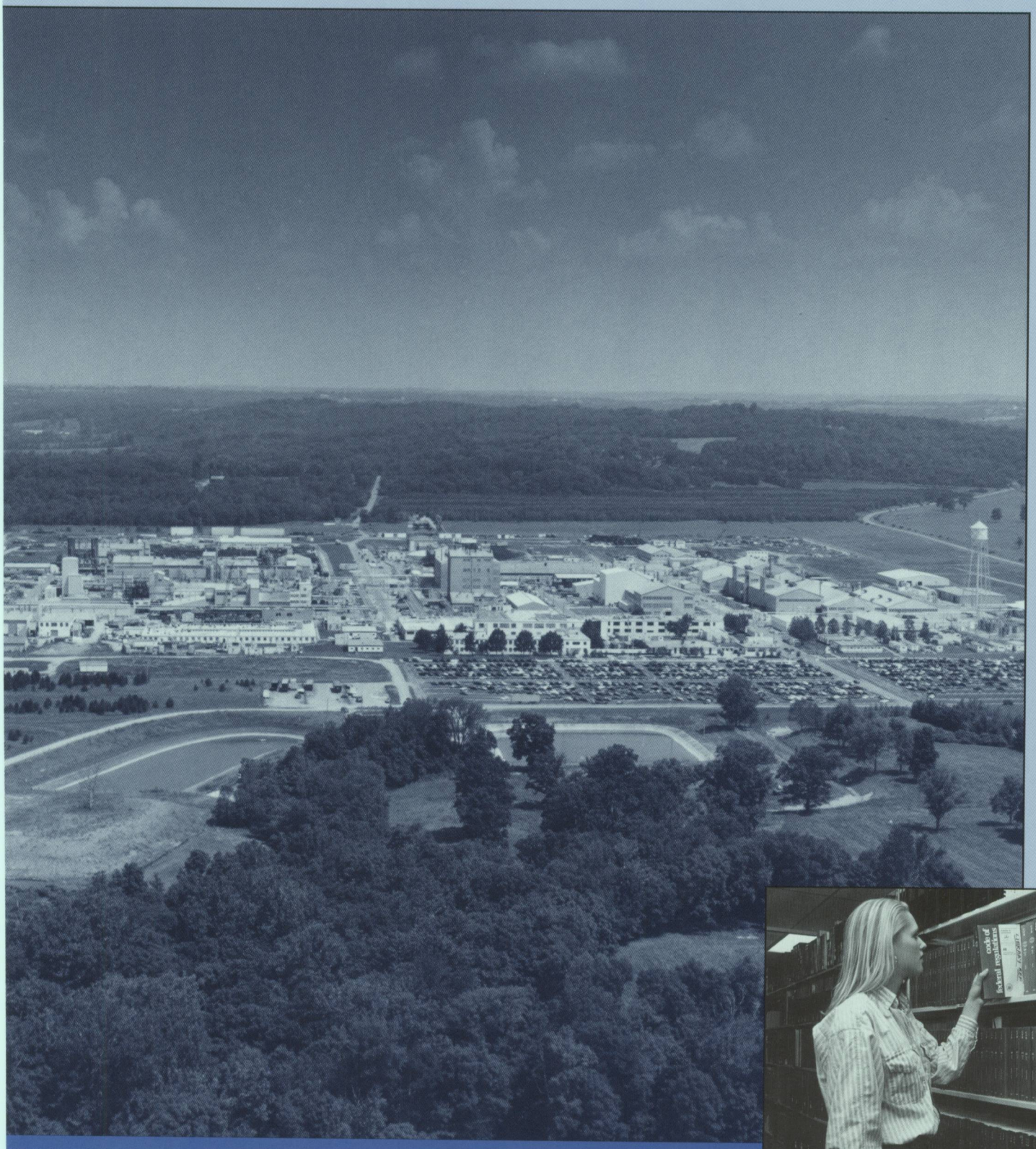
Atoms have two basic parts: the nucleus, which is a mass of protons and neutrons, and the electrons. Since ordinary matter is electrically neutral, there must be an equal number of positively charged protons and negatively charged electrons in the atom. When the nucleus of an atom spontaneously decays by "throwing off" a particle or additional energy, we refer to this as radioactivity. Therefore, radiation refers to the energy that is released from this decay in the form of alpha particles, beta particles, or gamma rays. We use the term Curie as a measure of the activity of a radioactive substance and the term rem to express the amount of dose a person receives when exposed to radiation. Dose is defined in four different ways: organ dose, effective dose, committed effective dose, and whole body dose.

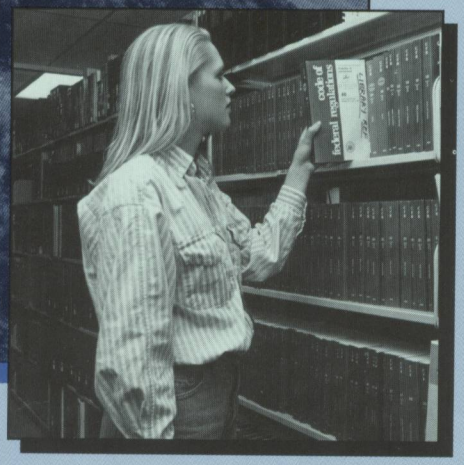
These terms apply to more than just the radiation associated with facilities like the FEMP. We are constantly being exposed to low levels of radiation produced by everyday things such as the earth, a television set, or the sun. This is called background radiation. The effects of the radiation that we are exposed to can be categorized into two types: somatic and genetic. Those people exposed to very high levels of radiation undoubtedly face a greater immediate risk of illness, cancer, or death, but scientists are unable to determine whether an increase in low-level radiation increases the number of radiation effects.

Also, many substances are located at the FEMP which may pose health threats to both onsite workers and area residents. It is extremely important, then, to understand the differences among the various substances and how they are regulated under CERCLA, RCRA, TSCA, and the Clean Air Act. Aside from radiation, some other health hazards of concern to the FEMP are carcinogens, corrosives, explosives, flammable materials, irritants, poisons, and toxins.

The FEMP environmental monitoring data are presented in chapters Four, Five, and Six, and the Radon Monitoring Program is discussed in Chapter Eight. Along with this information are descriptions of the methods used to gather data. Using this information and a basic understanding of radiation, we can proceed to Chapter Seven for a discussion of the estimated radiation doses to which the people near the FEMP might be exposed and how these results were calculated.

Compliance



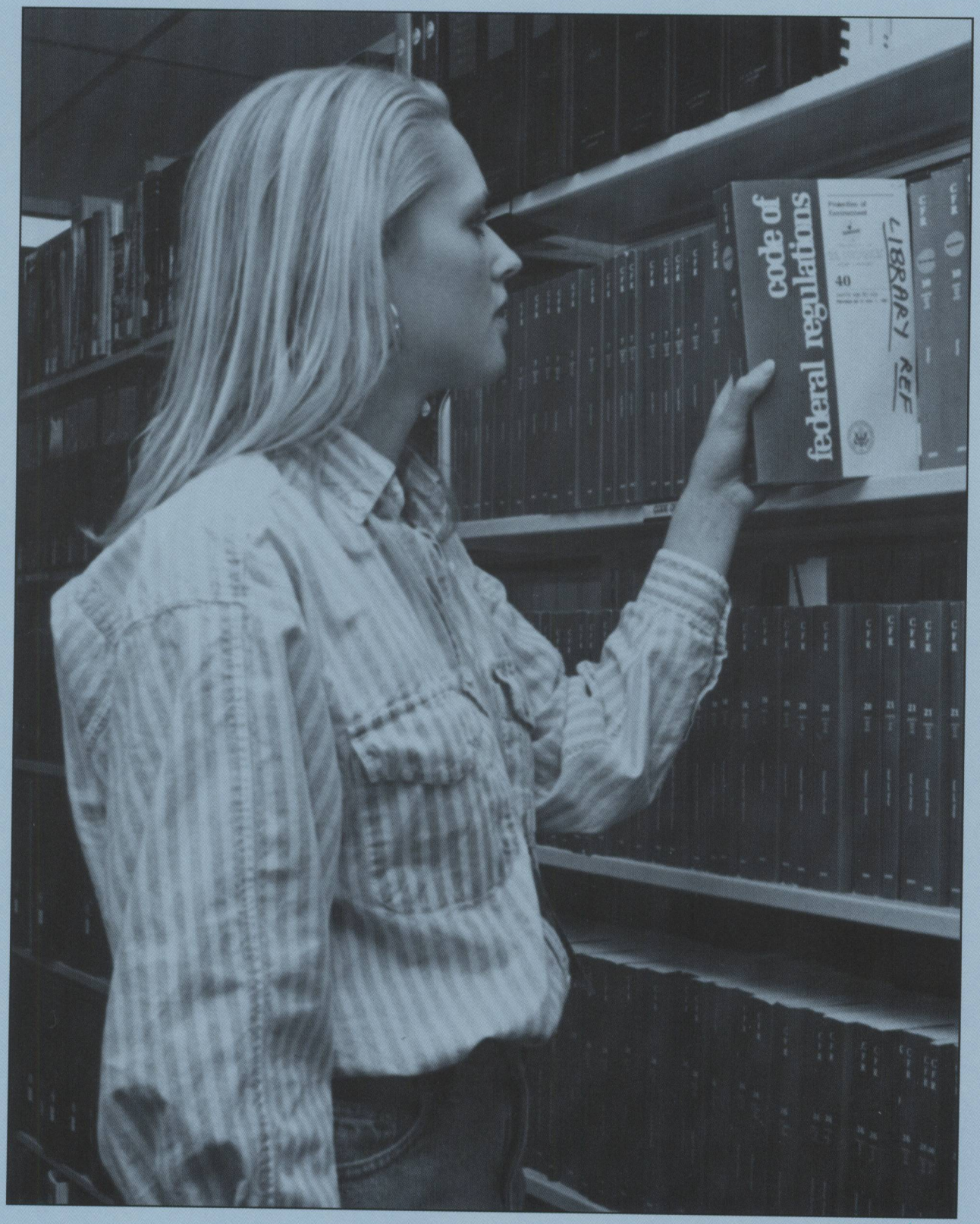


Compliance

As part of the DOE, the FEMP has to meet the standards established by state and federal regulations. These and other standards are enforced primarily by the USEPA Region V, but the OEPA also has some enforcement responsibilities delegated to them. The FEMP must comply with many regulations, including:

- Comprehensive Environmental Response, Compensation, and Liability Act;
- Resource Conservation and Recovery Act;
- Clean Air Act;
- Clean Water Act;
- Safe Drinking Water Act;
- Toxic Substances Control Act;
- Solid Waste Act;
- National Environmental Policy Act;
- Federal Insecticide, Fungicide, and Rodenticide Act;
- National Historic Preservation Act;
- Executive Order 11988, "Protection of Wetlands;" and
- Executive Order 11990, "Floodplain Management."

Environmental Compliance Summary



Environmental Compliance Summary

The FEMP 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,
- Guidelines imposed by DOE orders and directives, and
- Site-specific requirements imposed through agreements with regulatory agencies.

As these requirements are initiated by several different sources, enforcement likewise falls under several federal, state, and local agencies. OEPA is the primary agency that issues permits, reviews compliance reports, inspects facilities and operations, and oversees compliance with applicable regulations. USEPA Region V governs the CERCLA process with the cooperation and active participation of OEPA. In addition, USEPA develops, publishes, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by Congress. The FEMP also has a number of Federal Facility Compliance Agreements with USEPA Region V. In these cases, the Ohio regulations must meet or exceed USEPA requirements. DOE Headquarters issues directives to its field offices and conducts compliance audits. In addition, the FEMP conducts internal audits.

The FEMP's progress toward achieving full compliance with all environmental regulations is summarized in this chapter. It is divided into three sections — Compliance Status, Current Issues and Accomplishments, and Environmental Permits. This summary covers the period from January 1, 1991, to April 1, 1992, as required by DOE reporting requirements.

Compliance Status

CERCLA

In 1986, DOE and USEPA entered into a Federal Facility Compliance Agreement (FFCA), in which DOE agreed to comply with various federal and state pollution control regulations, including those under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The FFCA addresses the remediation as well as compliance with environmental laws and regulations.

The FEMP is on the National Priorities List (NPL) of sites requiring environmental cleanup under CERCLA. Consistent with the requirements of Section 120 of CERCLA, a Consent Agreement was signed by DOE and USEPA in April 1990 and became effective June 29, 1990. This 1990 Consent Agreement amended the CERCLA portion of the 1986 FFCA. The 1990 Consent Agreement defined five "Operable Units" at the FEMP and the surrounding contaminated area. The site is divided into operable units to more effectively manage the ongoing CERCLA investigations. These operable units, which are further described in Chapter Eleven of this report, are as follows:

- **Operable Unit 1** – Waste Pit Area,
- **Operable Unit 2** – Other Waste Units,
- **Operable Unit 3** – Former Production Area,
- **Operable Unit 4** – Silos 1–4, and
- **Operable Unit 5** – Environmental Media.

In general, the operable units address specific areas or facilities at the site and were defined based on their location or the potential for similar technologies to be used in the ultimate cleanup.

Under the 1986 FFCA, DOE began a RI/FS at the site. Through this RI/FS, DOE is investigating existing and potential environmental impacts associated with facility operations and will select final remedial action alternatives to address identified environmental concerns. Separate reports and decision documents that summarize the results of the RI/FS process are being prepared for each operable unit.

Due to potential delays, it became necessary to re-evaluate the Agreement driving these activities. Consequently, in September 1991, an Amended Consent Agreement was signed by DOE and USEPA. This Amended Consent Agreement:

- Established new schedules for the completion of the ongoing RI/FS;
- Identified 14 new *removal actions*, tasks undertaken to abate immediate threats to the environment and health; and

- Established a Sitewide Operable Unit (encompassing operable units 1 through 5) to ensure that actions taken under the individual operable units are protective of human health and the environment on a sitewide basis.

SARA

The Superfund Amendments and Reauthorization Act of 1986 (SARA) was written to clarify and expand CERCLA ("Superfund") requirements. Included in these amendments were more detailed guidelines for reporting on hazardous substances as outlined below.

The SARA Title III, Section 312 report was completed and submitted by the March 1, 1992, deadline. This report lists the amount and location of hazardous substances stored or used in amounts greater than the minimum reporting threshold. A computerized chemical tracking system is being installed which will provide better information on all chemicals used and stored at the site.

The SARA Title III, Section 313 Toxic Chemical Release Inventory Report was to be completed and submitted by July 1, 1992. This report is required for any toxic chemical that is manufactured, processed, or otherwise used at a facility in quantities greater than a minimum reporting threshold. For 1991, a report was completed for Hydrochloric Acid, Methanol, and Sulfuric Acid which were processed and/or otherwise used at the FEMP. (See Appendix B for a summary of these releases.) The Toxic Chemical Release Inventory Report also lists routine and accidental releases, as well as information about the activities, uses, and waste for each reported toxic chemical. The 1991 report also included source reduction and recycling information as required by the Pollution Prevention Act of 1990.

For any release, SARA Title III, Section 304 requires immediate notifications to local Emergency Planning Commissions and State Emergency Response Commissions. All releases are evaluated to ensure that proper notifications are made in accordance with SARA. In addition to SARA, releases are also evaluated for notification under CERCLA Section 103, RCRA, TSCA, the Clean Air Act, the Clean Water Act, Department of Transportation requirements, Ohio environmental laws and regulations, and the Ohio Fire Code. Depending on the requirement, notifications may also be made to the National Response Center, OEPA, USEPA, the Ohio State Fire Marshal, or a local fire official.

During 1991, it was FEMP policy to evaluate weight discrepancies discovered during overpacking operations and to report those that exceeded a Reportable Quantity (RQ) as potential releases. The following is a summary of reported releases.

From January 1, 1991, to April 1, 1992, a total of 15 events were reported as releases to the environment. Eleven of these "releases" were in regard to drum weight discrepancies, that is, a drum containing a measured amount of waste indicated an unexplained weight loss upon being reweighed. Although no spilled material was observed at the drum location, and in all likelihood the discrepancies were due to evaporation or errors in weighing, the possibility exists that some materials may have leaked out of the drums stored on open pads. These 11 drum weight discrepancies resulted in reported potential releases of:

- 9.1 kg (20 pounds) of dust collector residue containing cadmium;
- 69 kg (150 pounds) of sump cake containing arsenic, cadmium, and lead;
- 0.9 kg (2 pounds) of lead-contaminated grit blast;
- 260 kg (570 pounds) of sump cake containing benzene;
- 1,000 kg (2,200 pounds) of incinerator cinders containing spent solvents;
- 220 kg (490 pounds) of filter cake (dried processing sludge) containing tetrachloroethane and trichloroethane;
- 90 kg (200 pounds) of oily sludges characterized as ignitable hazardous waste;
- 34 kg (75 pounds) of trash containing arsenic, lead, selenium, benzene, and spent solvents (over two releases); and
- 30 kg (65 pounds) of spent solvents containing benzene (over two releases).

In a February 1991 event, 1,200 kg (2,700 pounds) of metal oxide from cold raffinate dropped from the Plant 1 Ore Silos onto the underlying pad. This was reported as a release, even though all materials were recovered and properly packaged.

In October 1991, the water level in the pilot plant sump was observed to have gone down, and subsequent measurements showed a potential loss of 37 kg (81 pounds) of liquid containing cadmium, chromium, selenium, and thorium–232. However, laboratory analysis of the sump mixture indicated that these chemicals were present only in trace amounts. An investigation on what caused the water level to drop is underway, and a removal action is being planned to empty the sump tank.

In January 1992, coal in a storage bin at the Boiler Plant spontaneously ignited and burned for 26 hours. Although only coal was involved in the fire, a release to the atmosphere of 60 kg (130 pounds) of sulfur dioxide was reported.

In March 1992, seven uranium ingots were dropped onto a plant driveway as they were being moved within the former production area. The weight

of these ingots, 2,050 kg (4,500 pounds), was reported as a release to the environment (according to the USEPA definition), even though the material and its residues were removed immediately.

RCRA

Past operations and ongoing cleanup activities generate both hazardous wastes and mixed wastes (containing hazardous and radioactive components). As a management practice, some wastes are accumulated at locations throughout the facility known as "satellite accumulation areas" before being moved to designated RCRA storage facilities.

There are a limited number of facilities in the nation that can treat or dispose of mixed waste, and a final disposal site for all FEMP mixed waste is not yet available. Therefore, most of the mixed waste remains onsite. However, in 1987, when regulations were less stringent, the FEMP shipped 790 drums of TSCA regulated waste to the K–25 incinerator at Oak Ridge. This mixed waste was finally incinerated in 1991 when that facility received its operating permit.

In addition to being regulated by state and federal legislation, RCRA waste is handled according to the 1988 Consent Decree between the State of Ohio and DOE. In 1990, negotiations between the State of Ohio, DOE, and WEMCO resulted in the Proposed Amended Consent Decree (PACD). This agreed-to (but still unsigned at the time of this printing) document outlines many requirements, including:

- Hazardous waste characterizations,
- A Drum Management Plan,
- Closure plans for Underground Storage Tank 5 and Waste Pit 5,
- A timetable for submitting the revised Part A and Part B permit applications, and
- A report of all known hazardous waste management units.

According to the PACD, the characterization program is to be completed by October 1992. This characterization program encompasses both process knowledge and sampling and analysis requirements, including:

- Process knowledge determinations for 1,800 drums of suspect materials in RCRA storage,
- Initial process knowledge determinations for the 8,000 drums of material not affected by the Hazardous Waste or Solid Waste Management Unit (HWMU or SWMU respectively) review,
- Initial process knowledge determinations for the 8,000 drums of material affected by the HWMU/SWMU review, and
- A Waste Determination Plan, approved by OEPA, which identifies the approach the site will take in conducting the characterization program.

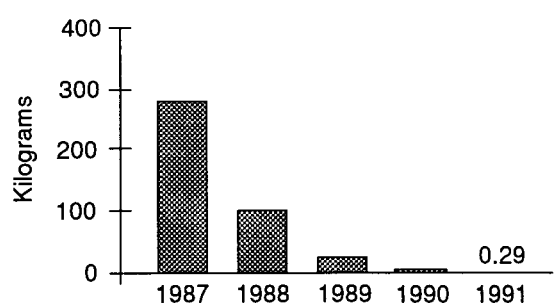
The first three sets of determinations bulleted previously have already been completed. In addition, hazardous waste characterizations are being completed as scheduled. Quarterly reports have been submitted to OEPA, as specified by the PACD, since January 1991.

Clean Air Act

In Ohio, authority to enforce requirements of the Clean Air Act has been delegated by the USEPA to the OEPA, except for the enforcement of the National Emission Standards for Hazardous Air Pollutants (NESHAP) for radionuclides and radon. Because most of the air emission sources have the potential to emit both radioactive and nonradioactive particulates, operation of most sources requires the approval of OEPA.

As the FEMP is a former uranium processing plant, uranium is the radioactive particulate of most concern in monitoring airborne emissions. The FEMP estimated airborne uranium emissions for 1991 totalled 0.29 kg (0.64 pounds). This is a 91% reduction from 3.3 kg (7.2 pounds) estimated in 1990. Airborne uranium emissions have been steadily dropping since processing operations were discontinued in 1989 (Figure 19).

Figure 19: Total Kilograms of Uranium to Air, 1987 – 1991



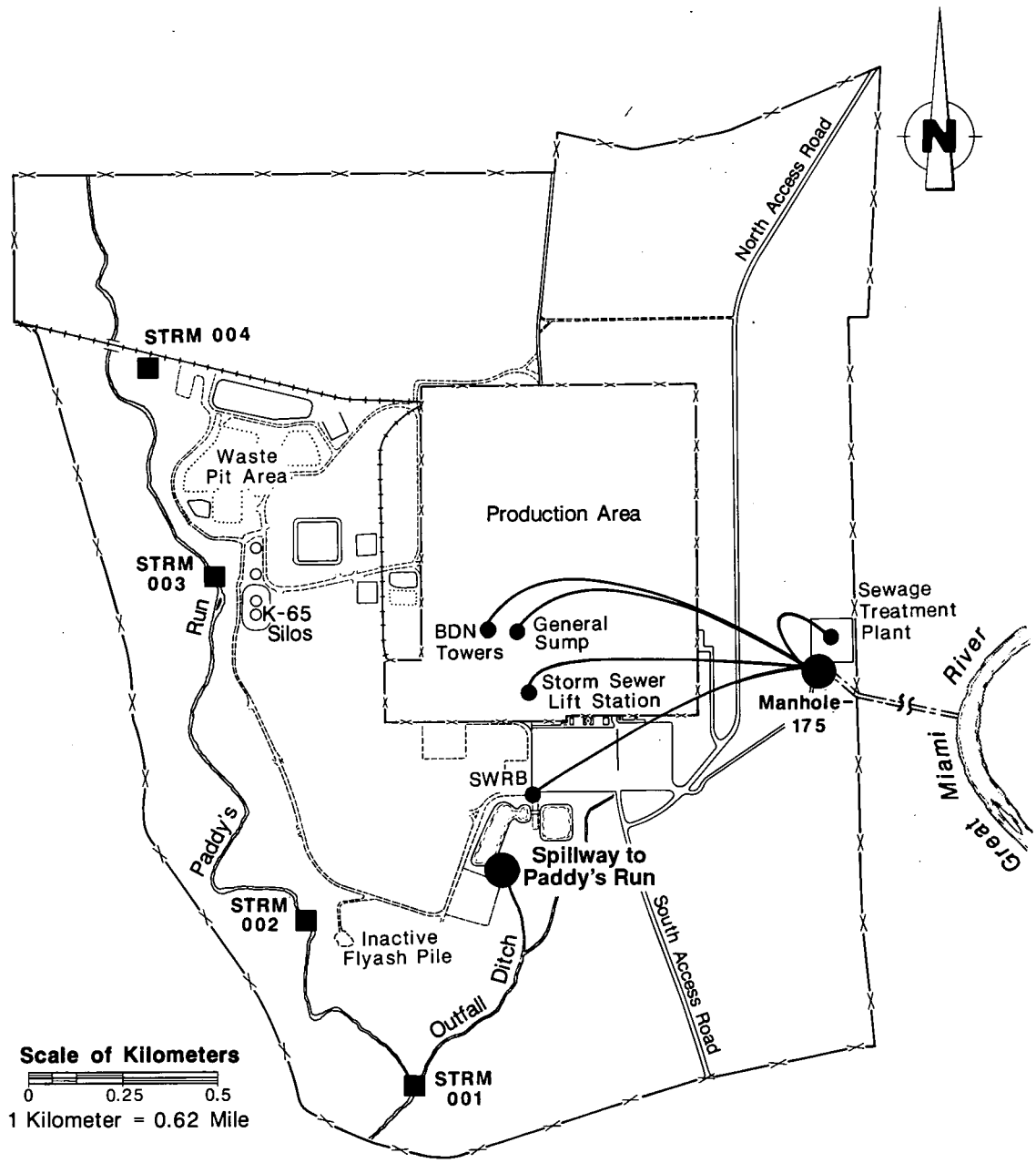
During 1991, the State of Ohio regulation limiting sulfur dioxide emissions was revised to reduce the allowable SO_2 emission level from the FEMP's coal-fired burners from 4.4 kgs (2.0 pounds) SO_2/MMbtu heat input to 2.9 kgs (1.33 pounds) SO_2/MMbtu heat input to be effective in 1993. In response, the FEMP began purchasing a low sulfur coal in 1991 and has been in compliance with the reduced limit ever since.

Clean Water Act

National Pollutant Discharge Elimination System (NPDES) Effluent Regulation

Under the Clean Water Act, the FEMP is governed by an NPDES permit issued by the State of Ohio and must control the discharge of nonradiological pollutants to Ohio waters. The permit specifies discharge and sampling locations, sampling and reporting schedules, and discharge limitations. The current permit specifies seven regulated monitoring locations — two are external discharges directly to Ohio waters and five are internal effluent streams which lead to one of the external discharges (see Figure 20).

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

1588

Monitoring from the Clearwell in the waste pit area to Manhole–175 was discontinued in 1990; the Clearwell now pumps directly to the Biodenitrification Surge Lagoon (BSL).

During 1991, the FEMP was compliant with the NPDES permit requirements 99.7% of the time. Of the 6,219 samples pulled from the effluent lines, there were only 18 noncompliances. All noncompliances were at internal monitoring points as follows:

- Three noncompliances for pH at the Storm Water Retention Basin (SWRB) and at the General Sump;
- One noncompliance for nickel at the General Sump, presumably from the coal pile;
- One noncompliance for Five-Day Biochemical Oxygen Demand (BOD,5) at the Biodenitrification Facility (BDN); and
- 13 noncompliances for fluoride at the BDN.

In July 1991, OEPA discontinued requirements for fluoride analyses at the BDN, since concentrations at the discharge to the Great Miami River were within permit limits.

NPDES Stormwater Regulation

In November 1990, new NPDES rules were established by USEPA to monitor industrial stormwater discharges. Under these new rules, any industrial site which discharges stormwater to public waters through a pipe, ditch, channel, or other *point source* was required to apply for an NPDES stormwater permit by November 18, 1991. Subsequently, USEPA extended the deadline for stormwater permit applications to October 1, 1992. As part of this ongoing application process, the FEMP has mapped onsite runoff patterns and determined that flow is generally to the west and south. Four NPDES stormwater monitoring locations have been marked where this stormwater flows into Paddy's Run. As shown in Figure 20 on page 55, these monitoring locations are:

- **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 perimeter property, excluding the waste management facilities; and
- **STRM 004** – Collecting runoff from the northern perimeter property.

Stormwater runoff from the Production Area is already collected through the internal outfalls and discharged through Manhole–175 to the Great Miami River, while the waste pit runoff is planned to be controlled by the Waste Pit Area Stormwater Runoff Control Removal Action. (See "Ongoing Removal Actions" beginning on page 62 of this chapter.)

Safe Drinking Water Act

New Safe Drinking Water Act monitoring regulations put forth between 1986 and 1991 will require more extensive monitoring of the FEMP drinking water system beginning in July 1993. In response to these new regulations, 1991 SDWA activities focused on determination of which pollutants the FEMP must monitor for in 1993.

Toxic Substances Control Act

PCB Material – The FEMP ships non-contaminated polychlorinated biphenyl (PCB) materials to commercial facilities for disposal, while it stores radioactively contaminated PCB materials from past operations and maintenance activities. There were no PCB shipments in 1991, but one 1992 shipment was made to a facility in Deer Park, Texas.

The radioactively contaminated PCB materials are stored in Building 81 in compliance with TSCA requirements. A document log and annual PCB report is completed by July 1 of each year. Fourteen drums of solid PCB waste and 30 drums of liquid PCB waste (all "mixed") remain onsite due to the lack of treatment and disposal facilities.

Asbestos – In order to identify the location of asbestos-containing materials, a site survey was begun in February 1991, and it was to be completed in December 1991. Locations of all asbestos-containing material were recorded on site diagrams. The material was assessed for its hazard potential, and work orders were written and implemented to repair or remove damaged asbestos.

To control the asbestos identified as hazardous by the site survey, a special "Asbestos Team" was assembled, trained, and equipped for abatement purposes. The team encapsulated over 3,050 linear meters (10,000 linear feet) of damaged pipe insulation and removed more than 610 linear meters (2,000 linear feet) that was beyond repair. Using the data from the site survey, all piping insulation was labeled as either "Danger – Asbestos" or "Asbestos Free."

An Asbestos Operations and Maintenance Work Practice Manual was developed and issued to instruct the Asbestos Team on proper abatement methods and to ensure regulatory compliance.

A Transite Fiber Migration Study was initiated in October 1991. The purpose of this study was to determine if asbestos fibers were being released from the transite panels that are used for most roofs and exterior walls of buildings.

Ohio Solid Waste Act

This 1988 act and its subsequent revisions regulate infectious waste. The FEMP is considered a small generator under Ohio law because the medical department generates less than 23 kg (50 pounds) of infectious waste — such as hypodermic needles — per month. Therefore, generator registration with the State is not required. All infectious wastes generated in the medical department are transported to a licensed treatment facility, Therm-Tec Destruction Service of Ohio, for incineration. An annual surveillance is conducted 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

The majority of pesticide and herbicide applications are done by subcontractors according to state and federal requirements. Applications are made for pest control in food areas as well as for general control along railroad tracks. Actions have been taken to ensure that historical information is available on the identification and location of chemicals used at the site.

National Environmental Policy Act

National Environmental Policy Act (NEPA) activities continue to focus on the integration of NEPA with CERCLA. A total of seven removal actions were deemed to be Categorical Exclusions (CXs) and were approved as such. An additional six CXs were prepared but not approved as of April 1, 1992. Two Findings of No Significant Impact (FONSIs) were also approved for the K–65 silos and Waste Pit Area Stormwater Runoff Control Removal Actions.

Other NEPA activities in 1991 included the preparation of an Environmental Impact Statement (EIS) and Environmental Assessments (EAs) as follows:

- Preparation of a RI/FS–EIS for OU2; the initial draft is expected to be completed in April 1992;
- Preparation of an EA for the remediation activities at the RMI Titanium Company (this site was subcontracted to extrude uranium billets produced at the FEMP);
- Withdrawal of the Renovation EIS in December 1991; and
- Public Interactive Workshops for the Programmatic EIS (for the DOE complex) in March 1992.

Endangered Species Act

The Endangered Species Act requires the protection of any endangered species found at the site. In addition, USEPA ecological guidelines direct

CERCLA sites to identify any threatened species present at the site. Critical habitats that may support any threatened or endangered species must be recognized as well. The baseline ecological survey conducted by Miami University (Oxford, Ohio) in 1986 and 1987 found no federal or state endangered species at the FEMP. However, the Miami University study, as well as other studies, have identified suitable habitats at the FEMP for the following endangered animals.

The Indiana bat (*Myotis sodalis*) is a federal- and state-listed endangered species. While none have been seen at the FEMP, some areas within the property along Paddy's Run are considered good habitat for the Indiana bat. There is a breeding colony on nearby Banlick Creek, a tributary to the Great Miami River near Ross, Ohio.

The cave salamander (*Eurycea lucifuga*) is on Ohio's endangered species list and has been found in several locations close to the FEMP. There are areas along Paddy's Run which are suitable habitat for the cave salamander, but none have been sighted.

Executive Order 11988, "Protection of Wetlands"

This executive order is a directive requiring federal agencies to institute programs to identify and protect *wetlands*. A study of the FEMP site conducted in 1990 delineated wetlands onsite, most of which were manmade. Since restoration activities have the potential to alter or influence these wetland areas, all restoration projects and activities are reviewed for their potential impact. Removal actions for operable units 1 and 2 may have an impact on wetlands, and the designs will include mitigation.

Executive Order 11990, "Floodplain Management"

This Executive Order instructs federal agencies to avoid construction in river floodplains. Even though activities included in the South Plume Removal Action have been identified to be within the 100–year floodplain of the Great Miami River, floodplain assessments have determined that there is no practicable alternative to the proposed removal action.

National Historic Preservation Act

Pursuant to the National Historic Preservation Act, construction activities are required to take into account the impact on any local historic or cultural resources. Consultation and coordination with federal and state preservation agencies is required when cultural resources are in danger of being disturbed.

Previous contact with the State Historic Preservation Officer (SHPO) had established that the 1,050–acre site had already been sufficiently disturbed so

that there would be no requirement to consult the SHPO for new actions onsite. However, a survey and consultation for land disturbance activity outside the fence, such as the South Groundwater Contamination Plume Removal Action, is needed. The U. S. Army Corps of Engineers is conducting an archeological survey to verify that the South Plume projects will not adversely affect cultural resources. Their report is in the final stage and no known resources have been identified.

For activities that involve minimal land disturbance, such as installation of monitoring wells and hydropunching, the FEMP is seeking an exemption from consultation. This will be contingent on the FEMP's commitments to use only small trucks, to conduct activities only during dry weather, and to minimize land disturbance.

Current Accomplishments and Issues

This section presents significant compliance-related accomplishments and issues for 1991 and through the first quarter of 1992.

CERCLA

In the course of a RI/FS effort, conditions are occasionally identified that call for immediate action in order to address releases or potential releases of hazardous substances. These actions, called removal actions, are coordinated with USEPA and OEPA.

Completed Removal Actions

Through March 31, 1992, the FEMP had identified 27 removal actions. One of these, Exposed Materials at Pit 6, was completed in 1990. Six more removal actions were completed during this January 1, 1991, to March 31, 1992, reporting period. They are discussed in further detail below.

K–65 Silos – In November 1991, a 12–inch layer of bentonite clay was applied to the surface of the waste material contained in silos 1 and 2. This was done to reduce the amount of radon gas being emitted into the atmosphere through the silo domes. Surface mapping was done to ensure that the clay covered all the valleys, cracks, and peaks of the wastes' surface within the silos. In addition, a monitor within the silos continues to measure the humidity of the bentonite to ensure that it does not dry out and crack. With completion of this removal action, radon emissions to the environment were reduced approximately 99%.

K–65 Decant Sump – This removal action was completed in April 1991 when approximately 30,280 liters (8,000 gallons) of contaminated water were pumped out of the K–65 decant sump tank. During the 1950s, this tank was used to store liquid that was drained from the K–65 silos after the solid material had settled. Removal of the water from the underground sump tank reduces the potential for leakage of contaminated water into the surrounding soils. The extracted water is being stored onsite in above-ground tanks near Plant 2/3. Samples of the liquid removed from the sump tank are being analyzed and characterized to determine proper treatment and final disposition. In addition, samples were recovered in June 1991 from a layer of sludge located at the base of the interior of the decant sump tank. These samples are currently being analyzed at an offsite laboratory.

Inactive Flyash Pile Controls – Completed in December 1991, this removal action consisted of installing a chain barrier and posting signs around an area of contaminated surface soil to prevent unauthorized access. The contaminated areas included the Inactive Flyash Pile, used until 1968, and the South Field, which holds approximately 95,600 m^3 (125,000 cubic yards) of rubble and debris.

Active Flyash Pile Controls – The need to minimize fugitive dust emissions and stormwater runoff from the Active Flyash Pile was recognized by the initiation of this removal action. The use of measures to address ongoing wind and rain erosion were approved by USEPA in March 1992, and they are expected to be completed in June 1992.

Waste Pit 5 Experimental Treatment Facility (ETF) – This removal action, consisting of the removal, containment, and onsite storage of both the waste materials within the abandoned ETF and the structure itself, was completed ahead of schedule in March 1992. Vegetation and soils in the vicinity of the ETF were sampled and analyzed to determine whether or not contaminants were present. Soils found to be contaminated will be addressed in future removal actions or as part of the final remedial action.

Expedited Silo 3 Dust Collector Removal – This removal action dismantled the Silo 3 dust collector and hopper and provided for sealing the openings in the silo dome vent pipe and sampling ports. Initiated in December 1991, this expedited removal action was completed on January 8, 1992.

Ongoing Removal Actions

Of the 20 removal actions in progress, 16 are still in the planning stages as they await work plan approval. Four removal actions, however, are already underway to alleviate immediate threats to the environment. These four removal actions are discussed below; a list of those still being planned is also provided.

Contaminated Water Under FEMP Buildings – Some of the groundwater trapped beneath former production buildings is contaminated with uranium and VOCs. As a result, the removal action was designed to minimize the potential for this contaminated groundwater to work its way into the underlying aquifer. Pumping of contaminated water from underneath Plant 6 was initiated in July 1991, from underneath Plant 9 in August 1991, and from underneath Plant 2/3 and Plant 8 in October 1991. A centralized VOC treatment facility was constructed and became operational in Plant 8 in 1991.

Waste Pit Area Stormwater Runoff Control – After analysis had shown that releases had contaminated the surface soils, the glacial overburden, and the groundwater beneath the waste pits, this removal action was initiated. A runoff control collection system is being installed to separate the contaminated runoff from the uncontaminated stormwater runoff. The contaminated water will be treated in the existing wastewater treatment facilities.

South Groundwater Contamination Plume – A plume of groundwater extending south of the FEMP has been identified as containing elevated concentrations of uranium. In response to the identification of this plume, the South Groundwater Contamination Plume Removal Action was initiated. The goals of this removal action are:

- To limit access and exposure to this water,
- To protect the groundwater environment, and
- To control further southerly migration of the plume.

Because of its magnitude, the removal action has been divided into five parts. In ***part one***, the FEMP will supply an alternate water source to two local industrial plants whose well water showed concentration of uranium greater than 22 pCi/L, the DOE guideline. Construction of this alternate source was scheduled for the spring of 1992. In ***part two***, the FEMP will install recovery wells in the South Plume area. Groundwater will be pumped from these wells and piped back to the site for monitoring and discharge to the Great Miami River. Part two construction is scheduled for July 1992. In ***part three*** of the removal action, the FEMP will compensate for discharging contaminated water into the river from this and other removal actions by installing an advanced wastewater treatment system to treat existing higher concentration wastewater streams from site operations. This will ensure that

the total amount of uranium discharged to the river will not increase because uranium levels equal to or greater than that of the recovered South Plume groundwater will be removed from the site wastewater. Construction on this treatment system began in February 1992. ***Part four*** includes the ongoing private well and FEMP well sampling programs within the existing Groundwater Monitoring Program (see Chapter Six). Finally, ***part five*** will call for groundwater modeling and geochemical investigations. These actions have not yet begun.

The revised work plans for parts one, two, and three were all submitted to USEPA in December 1991. The work plan for part five was approved by both USEPA and OEPA in June 1991. (Part four, as mentioned above, consists of two already-established monitoring programs and requires no additional work plans through the RI/FS.)

Plant 1 Pad Continuing Release – This removal action was initiated in order to protect surface soils and groundwater from hazardous materials stored next to Plant 1. The Plant 1 pad has been used since 1952 to store hazardous substances, including uranium and thorium and has a current inventory of approximately 45,000 drums. The removal action is designed to control runoff, provide covered storage structures, and improve the surface of the existing pad surface. Interim runoff control measures began in 1991.

The following removal actions are in the very early stages and will continue to be developed and worked on through the remaining three quarters of 1992:

- Control Exposed Material in Pit 5,
- Removal of Waste Inventories,
- Safe Shutdown,
- Plant 1 Ore Silos,
- Contaminated Soils Adjacent to Sewage Treatment Plant Incinerator,
- Scrap Metal Pile,
- Improved Storage of Soil and Debris,
- Collection of Uncontrolled Production Area Runoff,
- Plant 7 Dismantling,
- Stabilization of Uranyl Nitrate Inventories,
- Waste Pit Area Containment Improvement,
- Inactive Flyash Pile,
- Removal of the Pilot Plant Sump,
- Cleanup of Nitric Acid Tank Car and Surrounding Area,
- Asbestos Removals, and
- Management of Contaminated Structures.

RCRA

The PACD requires that all Hazardous Waste Management Units (HWMUs) at the site be identified. As a result, the FEMP is investigating burners, incinerators, furnaces, stills, process equipment, tank units, dust collectors, and other potential waste containment units to determine if they are HWMUs or SWMUs. During 1991 and the first quarter of 1992, a total of 51 HWMUs were recognized and individual schedules established for bringing the units into compliance.

Other RCRA actions include conducting quarterly surveillances to verify adherence of site activities to regulatory and quality site procedures. The Deviation Corrective Action Report is used to track progress in improving procedures.

The RCRA Annual Report was sent to the OEPA on February 28, 1992. This report included the following:

- Facility Hazardous Waste Report;
- Generator Hazardous Waste Report;
- Waste Minimization Report;
- Groundwater Monitoring Annual Report; and
- Waste Treatment, Disposal, and Recycling Process Systems Report.

The Waste Determination Plan submitted in 1990 established Material Evaluation Forms as a consistent method to characterize waste. These forms include information on waste generation, process knowledge determinations, proper labeling, and storage requirements.

Thorium Management

A Thorium Management Strategy and schedule of accomplishments were developed as part of the PACD to provide a plan to complete RCRA determinations of thorium materials and to improve the storage of thorium materials at the FEMP. The Thorium Management Strategy was initiated as part of the PACD 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.

On July 28, 1991, the FEMP completed the overpacking and relocation of 35 thorium containers characterized as mixed waste to a RCRA warehouse. Also completed were the necessary overpacking, relocation, and RCRA evaluation actions for all but 16 of 192 containers which require further characterization

as specified in the PACD. The characterization of the 16 remaining containers is scheduled to be complete in June 1992.

RCRA Closures

During 1991 and the first quarter of 1992, six RCRA closures were underway. The status of each of these closures is charted below:

Closure Plan	Submitted to OEPA	Field Work	Certification
Trane Incinerator	July 1990	Awaiting OEPA approval	—
Underground Storage Tank 5	October 1990	Awaiting OEPA approval	—
Storage Pad North of Plant 6	December 1990	Completed	Scheduled May 1992
Tanks T–5 and T–6	September 1991	Underway	Scheduled July 1992
Waste Pit 5	September 1991	Awaiting OEPA approval	—
Equipment Storage Area	March 1992	Awaiting OEPA approval	—

Land Disposal Restricted Waste

The FEMP currently stores mixed waste subject to the RCRA Land Disposal Restrictions (LDR). This LDR waste is being stored due to the lack of treatment and disposal facilities for mixed waste in accordance with USEPA policy. DOE is pursuing a one-year case-by-case extension from USEPA to continue to allow storage after May 1992.

Clean Air Act

Clean Air Act activities for the past year have concentrated on applying for state permits and reviewing these permits to determine regulatory compliance. Permits for equipment that is not expected to operate are being deleted. Support was also given to CERCLA projects, specifically through the identification of Applicable or Relevant and Appropriate Requirements (ARARs) and the determination of appropriate Best Available Technology (BAT) for remediation.

A sitewide survey has been conducted to identify all potential air pollution sources that are required to have permits to operate. The majority of the sources being identified are minor and are of such type that, by industry practice, have not had permits in the past. Nonetheless, permit applications continue to be submitted to OEPA in accordance with regulations.

Radon Sources

NESHAP regulations under 40 CFR 61, Subpart Q, specify a radon–222 flux standard of 20 pCi/m^2 per second. In response to these regulations, a commitment has been made to USEPA that radon sources will achieve compliance with the flux standard upon final remediation under CERCLA. An additional

commitment was to provide USEPA with estimates of radon–222 emissions from all sources which potentially have emissions in excess of the standard under the Federal Facility Agreement (FFA) for Control and Abatement of Radon–222 Emissions, signed November 19, 1991.

The results of measuring flux from waste pits 1, 2, and 3 show that the average level for each of the three pits was less than 10 pCi/m^2 per second. Negotiations with USEPA are underway regarding flux measurements for the Clearwell and for pits 4 and 5, all of which have already been identified as minor potential emission sources.

Safe Drinking Water Act

During 1991, OEPA certified FEMP Water Treatment Plant personnel to conduct drinking water analyses for pH, alkalinity, stability, hardness, phosphate, and chlorine. Four consecutive quarters of monitoring for VOCs in the FEMP's three production wells and distribution system were completed in September 1991.

Toxic Substances Control Act

The FEMP continues to manage the storage and shipment of PCBs. In February 1991, an exception report was filed for PCB waste that had been shipped to a commercial disposal facility in Arkansas in October 1990. The report was filed because the PCB items had been removed from service for more than nine months before they were shipped. Shipment of the PCBs was delayed due to a DOE moratorium on all offsite shipping because of an infraction at another DOE site.

In November 1991, USEPA issued a Notice of Noncompliance for storage of PCB containers in excess of one year. In response to this notice, the FEMP outlined the status and disposal options for the 68 drums of PCBs and PCB items in its inventory as follows:

- Twenty-eight drums of PCB items were shipped to a commercial disposal facility in Texas in January 1992;
- Thirty drums were radioactively-mixed PCB liquids, and disposal at the Oak Ridge TSCA incinerator was proposed; and
- Ten drums were radioactively-mixed PCB solids, for which there are currently no disposal options.

In February 1992, USEPA requested that the FEMP report the status of the PCB wastes remaining onsite on a semi-annual basis. The first of these reports is scheduled to be submitted by July 1, 1992.

The asbestos site survey was completed in February 1992. The results were used to commence the repair/removal of asbestos presenting the greatest hazard. The Transite Migration Study is progressing and preliminary results indicate that fibers were being released from roofing. Follow-up analysis is underway.

NEPA

NEPA coordination at the site is being revised to oversee activities more efficiently. Administrative activities in 1991 and the first quarter of 1992 include:

- Issuance of DOE site office NEPA procedures,
- Appointment of a NEPA Compliance Officer,
- Formation of the Management Quality Committee,
- Delegation of Section D Determination Authority by DOE Headquarters,
- Revision of the NEPA site documents and training program to ensure integration with the Project Management Procedures (PMPs) that are presently being revised and to further foster the integration of NEPA requirements with all types of activities at the FEMP, and
- Upgrade of the NEPA database to permit sitewide access.

Environment, Safety, and Health Assessments

The concept of Environment, Safety, and Health (ES&H) Assessments, also known as Tiger Team Assessments, was developed to evaluate compliance of all DOE facilities. To determine the actions taken in response to previous ES&H Assessment findings, the Secretary of Energy ordered that small, focused Progress Assessments be performed. The ES&H Assessment at the FEMP was conducted from October 15 through October 25, 1991, and it was the pilot assessment for this new program. Seven key findings were cited representing potential compliance issues related to federal and state regulations or DOE Orders:

- Failure to ensure effective management control and accountability of the ES&H Programs;
- Failure to develop self-assessment programs that ensure sustainable ES&H Program compliance;
- Unclear and outdated policy and procedure documents;
- Failure to formalize RCRA, CERCLA, and NEPA integration activities;
- Lack of a comprehensive program to achieve and maintain compliance with U.S. Occupational Safety and Health Administration (OSHA) standards;
- Ineffective identification and correction of the root causes of significant ES&H deficiencies; and

- Inefficient provision of ES&H guidance through the DOE directive system.

A draft Action Plan containing 57 response actions to these findings was submitted to DOE Headquarters on March 26, 1992, for review. Comments will be incorporated into another draft for review and approval.

Environmental Permits

The following is a summary of the environmental permits applied for and received between January 1, 1991, and March 31, 1992.

Air Permit Applications

Under the Ohio Administrative Code, the FEMP must obtain permits to install and operate equipment that is a source of emissions to the atmosphere. During 1991, the FEMP submitted five Permit to Install (PTI) and 25 Permit to Operate (PTO) applications to the OEPA; six PTOs were also withdrawn by the FEMP. During the same time, 29 PTOs were received, and 202 were on hand by December 31, 1991.

Water Permit Applications

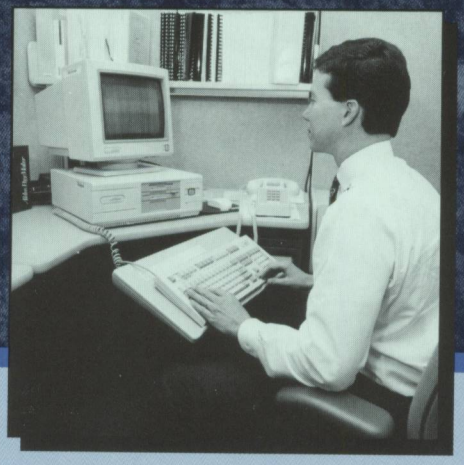
Only one water permit was received during this time period. In March 1992, the FEMP received an OEPA Wastewater PTI for the Manhole 34 Spill Control Project. Wastewater discharges are governed by an NPDES Permit revision issued in the summer of 1991.

The effluent system is currently operating under the NPDES permit issued in February 1990. This permit was modified in July 1991 to delete the effluent limitation and monitoring requirement for fluoride at Outfall 605. In response to new NPDES regulations concerning stormwater discharge (see page 54 of this chapter), preparation began in July 1991 for a stormwater permit application. It is being revised for submission to OEPA by October 1992.

RCRA Permits

Under the PACD, the FEMP submitted the RCRA Part A Permit Application in June 1991 and in October 1991. The RCRA Part B Permit Application was also submitted in October 1991. The permit is currently undergoing technical review by OEPA. Comments had not been received by the end of the first quarter of 1992. Part A was revised in March 1992 to add/renew additional waste streams and a HWMU; Part B is currently under review.

Environmental Monitoring



Environmental Monitoring

The FEMP continually strives to gain a detailed understanding of the effects of past production, current cleanup, and ongoing storage operations on the surrounding environment. Consequently, the FEMP collects samples of air, water, soil, and other media to measure the amounts of various radioactive and nonradioactive materials that leave the site. The results of these measurements serve several purposes:

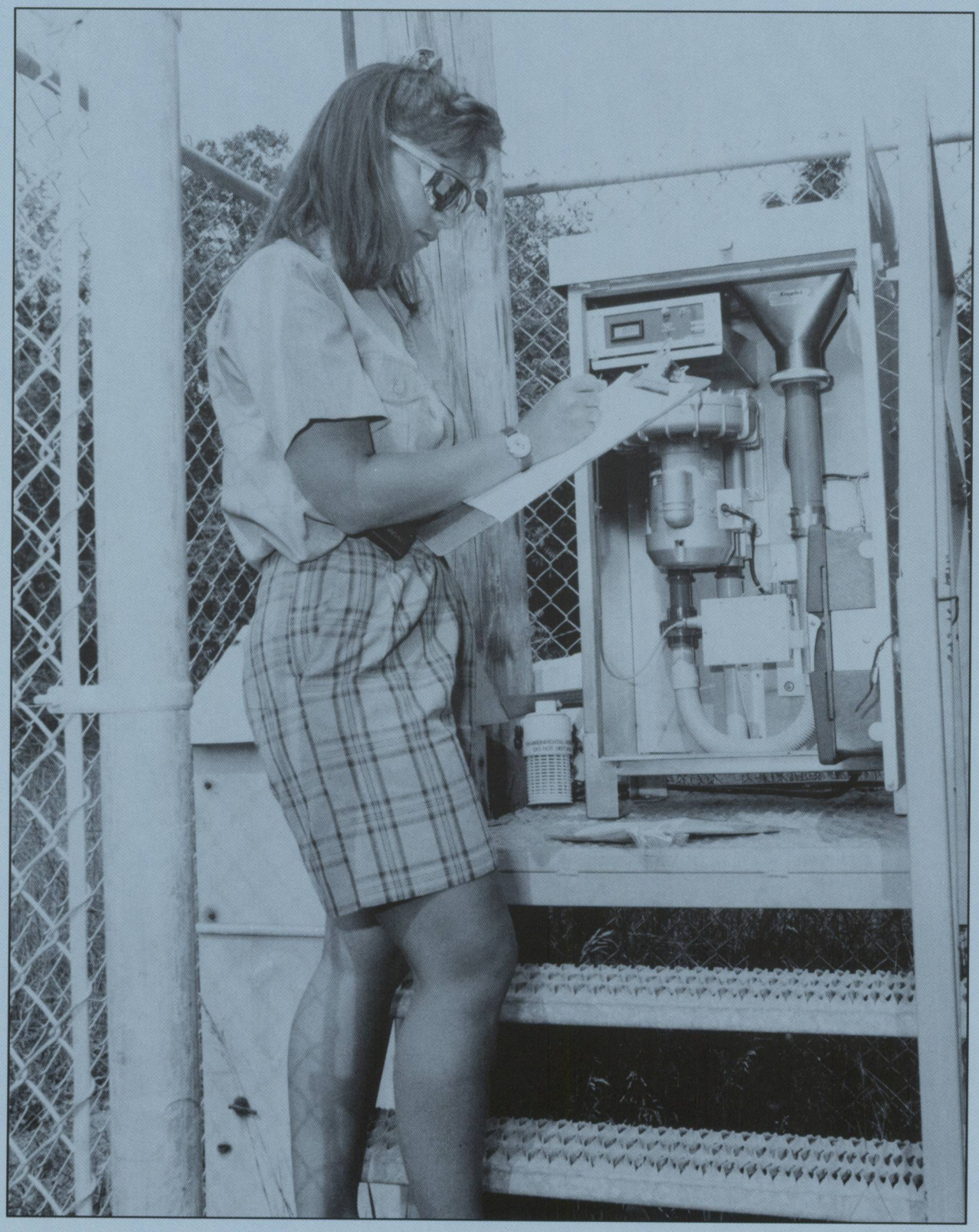
- To determine if the FEMP complies with applicable environmental standards and guidelines,
- To assess the site's impact on the environment, and
- To estimate radiation doses to the people living in the surrounding area.

The air and liquid pathways allow radioactive and nonradioactive materials to leave the FEMP and are, therefore, monitored. Radon is monitored as a separate component of the air pathway because it is regulated separately. Since many people live and work in the area surrounding the FEMP, the Environmental Monitoring Program formulates an estimated radiation dose.

Units of Measure
The guidelines presented in DOE Order 5400.1 for the content and format of the ASER state that radiological data be presented in Curies and not Becquerels, the Systeme International unit for radiological data. To simplify the discussion in the text, data will be presented in Curies (generally picocuries). Picocuries can be converted into Becquerels by multiplying the measurement by 0.037.

As part of the Environmental Monitoring Program, the FEMP developed comprehensive procedures that contain detailed instructions to ensure that reliable data are obtained. The FEMP's QA measures are achieved through a system of planned audits, surveillances, and inspections.

Air Pathway Monitoring



Air Pathway Monitoring

This chapter focuses on the air pathway and its components that may become contaminated as a result of FEMP airborne emissions. Results from the sampling of air, soil, grass, produce, and milk are therefore included and discussed in this chapter. The nonradioactive boiler plant emissions are also reported. Throughout the chapter, 1991 results are compared to data from the past four years. Although it is part of the air pathway, the Radon Monitoring Program and results are described in Chapter Eight in order to improve the presentation of information and regulations which are unique to radon.

The air pathway includes all the airborne pollutants that may be carried from the FEMP as a particulate or gas. 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 are breathed in, 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.

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 provides preliminary information on how much pollutant is released and how it will behave in the environment. Since production ended in 1989, there are only a few stacks and vents that continue to emit at the FEMP. However, monitoring of emissions continues through the use of air monitoring stations located onsite, on the site fenceline, and at several locations in nearby communities. During 1991, the FEMP operated 16 air monitoring stations 24 hours a day, seven days a week as part of the Air Monitoring Program.

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 references for collecting environmental samples and locating monitoring stations.

DOE Order 5400.5 establishes guidelines for concentrations of radionuclides in air emissions. These concentrations, referred to as Derived Concentration Guidelines (DCGs), are initial screening levels.

The intent is that the DCGs enable site personnel to review emissions and effluent data and determine if there is a need for further investigation and corrective actions.

The FEMP must report monitoring results on a regular basis to DOE, USEPA, and OEPA. Examples of these reports include:

- Annual Radionuclide Air Emissions Report to DOE and USEPA,
- Effluent Information System/Onsite Discharge Information System to DOE,
- Monthly Consent Agreement Report to USEPA,
- SARA 313 Report to USEPA and OEPA, and
- Quarterly Report of Radionuclide Discharges to USEPA.

Results in Brief: 1991 Air Pathway

The FEMP continued its extensive monitoring of the air pathway during 1991. In general, the data from this monitoring program were either consistent with or lower than last year's results. Each component of the air pathway is discussed in detail in this chapter; the results are summarized below.

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 1991 were estimated to be 0.29 kg (0.0006 pounds).*

Soil *– Some onsite and nearby offsite soil samples continue to indicate elevated uranium concentrations due to deposition of airborne particles from past operations. One offsite sampling location, northeast of the site, had a total uranium concentration of 14 pCi/g, which is above the background level of about 4.4 pCi/g for this area of Ohio.*[21]

Grass *– 1991 uranium concentrations were higher than 1990 data at most locations. The increase is attributed to different analysis techniques used by offsite laboratories. There is no evidence that the increase is due to higher airborne emissions.*

Produce *– Uranium concentrations were consistent with previous years' data. There were no significant differences in uranium concentrations between produce grown near the plant and produce grown at distant locations from the plant.*

Milk *– Analysis of milk samples by offsite laboratories continued to experience quality assurance problems. While one laboratory's analyses of the January through May samples were acceptable, a second laboratory's analyses of June through December samples were considered invalid because of poor QA performance by this offsite laboratory. A third laboratory analyzed duplicate samples from June through December using a more accurate analysis technique which indicated that uranium concentrations in milk from the dairy next to the FEMP and at the background dairy (37 km [23 miles] from the FEMP) were below laboratory detection levels or similar at both locations.*

Boiler plant *– All emissions were well below permit limits.*

Monitoring for Radioactive Pollutants

As discussed in Chapter One, a potential mechanism of radiation exposure to the public from the FEMP is through the air pathway. This includes emissions from specific point sources (such as plant stacks), as well as dust from large open areas like the waste pit area. The suspension of production in 1989 essentially eliminated production emissions. However, some waste materials were re-packaged and moved during 1991 as part of the remediation effort, and this processing resulted in extremely minor emissions. Now that production has ended, the largest sources of airborne contamination are the boiler plant cooling tower mists, which have low levels of uranium contamination, and *fugitive dust* from the waste pit area or 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 FEMP as a result of the ongoing remediation work. Sources of fugitive dust at the FEMP include dust generated as contaminated material is moved or repackaged, small amounts of soil carried away by the wind during the excavation of a trench, wind erosion of waste pit materials which are not covered by water, and soil erosion during dry, windy weather.

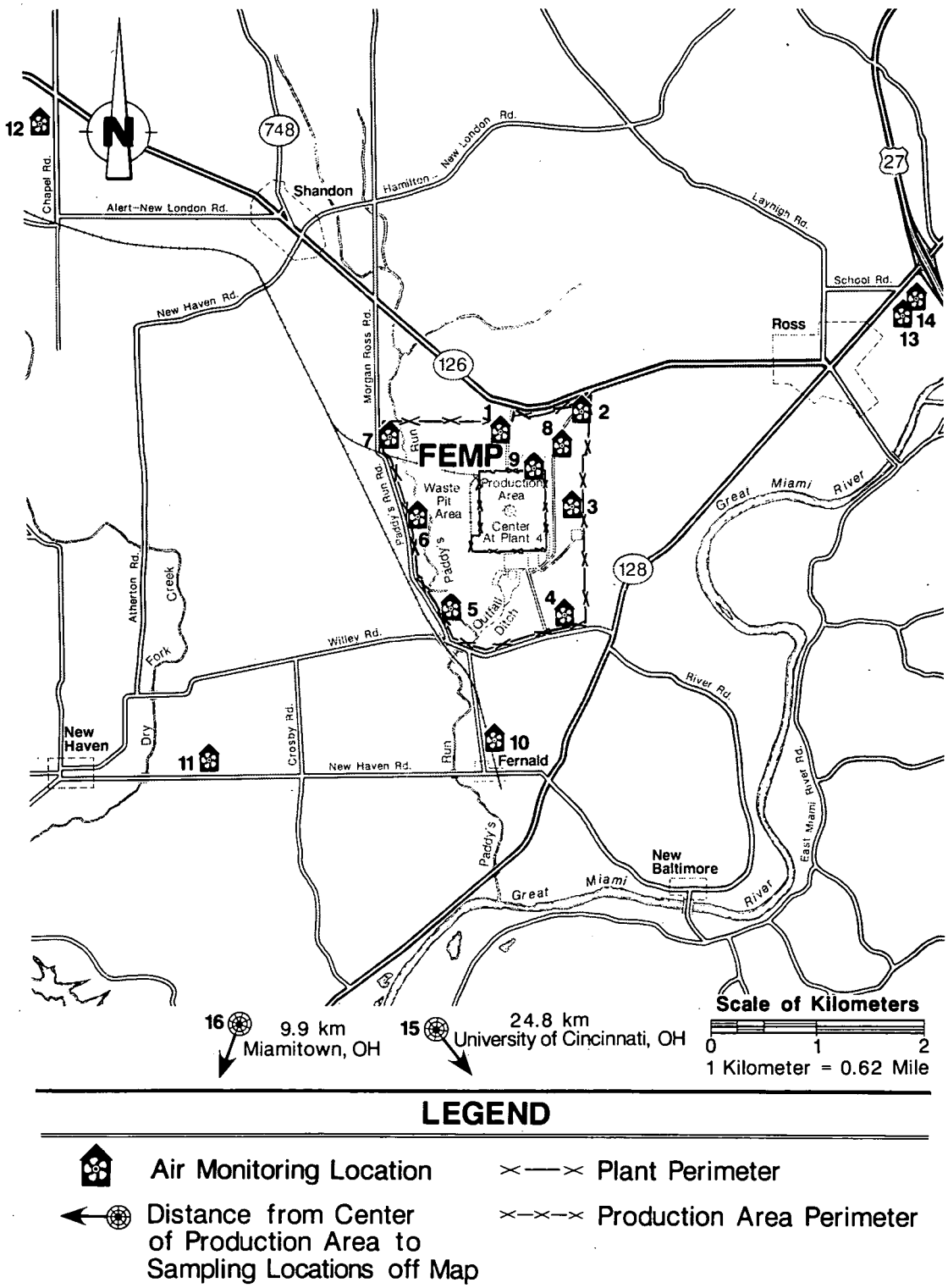
The FEMP continues to monitor the primary components of the air pathway by sampling air, soil, grass, produce, and milk. This enables scientists to evaluate the effects of the cleanup efforts at the site, as well as fulfill the site's obligations toward ongoing environmental surveillance and dose estimation. The following sections describe the air pathway sampling programs.

Air Sampling for Radioactive Particulates

In order to obtain accurate information about the amounts of uranium and other radionuclides in the air, the FEMP operates 16 continuous, high-volume air monitoring stations (AMS). The locations for the AMSs, as shown in Figure 21, were selected for several reasons:

- AMS 1 through 7 provide data at the FEMP fenceline because this is where the public has closest access to the site and guidelines for offsite exposure take effect;
- AMS 8 and 9 are in the prevailing wind direction at the FEMP. 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 FEMP operations would be found;
- AMS 10 through 14 are located at schools and industries near the FEMP and provide additional monitoring of FEMP emissions at these points;
- AMS 15 and 16 were installed in 1989 to obtain additional background data — AMS 15 is located near the University of Cincinnati in Corryville, Ohio; AMS 16 is located in Miamitown, Ohio.

Figure 21: Air Monitoring Locations



1588

At each AMS, air is drawn through a 20 cm by 25 cm (8 inch by 10 inch) filter at a rate of about 1.3 m^3/min (about 45 ft^3/min). Technicians account for any changes in flow rate over the sampling period by inspecting charts that continuously record flow data.

The filters from the air monitoring stations are collected and analyzed at weekly intervals. At the laboratory, technicians store the filters for at least three days following collection to allow naturally occurring, short-lived radionuclides (such as radon daughters) to decay. (This holding period does not affect the amount of uranium on the filters.) After the holding period, the filters are heated to 550°C (1,022°F) to remove organic matter. Finally, these filters are dissolved in acid, and the resulting solutions are analyzed for uranium. A portion of each of these solutions is retained each week to prepare a yearly composite which is then analyzed for trace concentrations of radionuclides such as isotopes of radium, neptunium, plutonium, and thorium.

The average concentrations of uranium at the seven fenceline AMSs (AMS 1 through 7) were all less than 1% of the DOE guideline. Table 2 lists 1991 data for uranium concentrations. Figure 22 compares uranium concentrations at the air monitoring stations for 1987 through 1991.

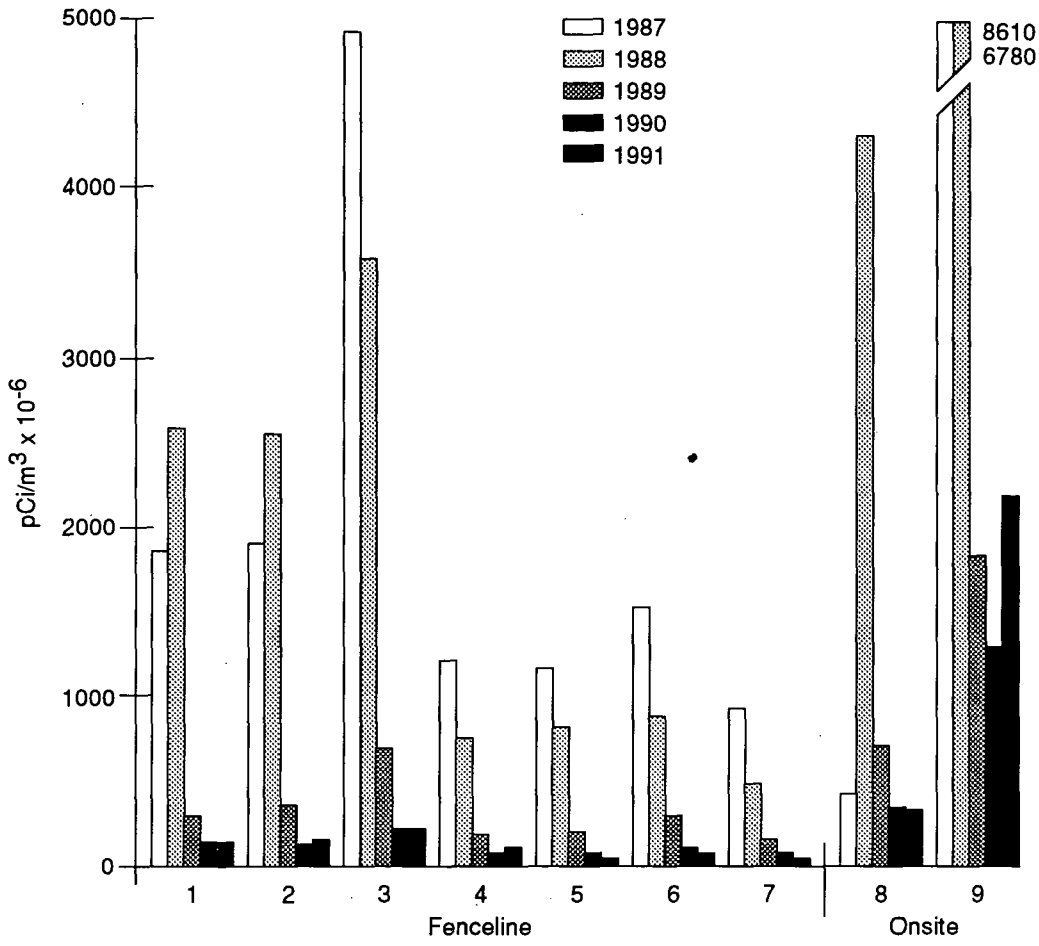
The data on the concentrations of trace radionuclides in 1991 were not available for inclusion in this report; however, the four-year trend indicates that the number of trace radionuclides detectable at all AMSs continues to decrease. Concentrations of thorium–232, measured at the AMSs, for 1987 through 1990 are presented in Figure 23 on page 78. The 1991 data for thorium–232 and the trace radionuclides are not available at this time and will be included in the 1992 ASER.

Soil Sampling for Uranium

The FEMP takes annual soil samples at the air monitoring stations and offsite locations to determine if soil uranium concentrations in the area are changing (see Figure 24 on page 79). Any uranium found in the soil may be naturally occurring, added by fertilizers, or a result of FEMP operations. There is a wide variability in the amount of uranium naturally present in rocks and soils (see Figure 25 on page 80). 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.[21] 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.

Because of the variability in the amount of uranium and minerals naturally present in rock and soil, it is not possible to establish a single value for the background level of uranium and other minerals for an area, such as near the

Figure 22: Average Uranium Concentrations in Air, 1987 – 1991

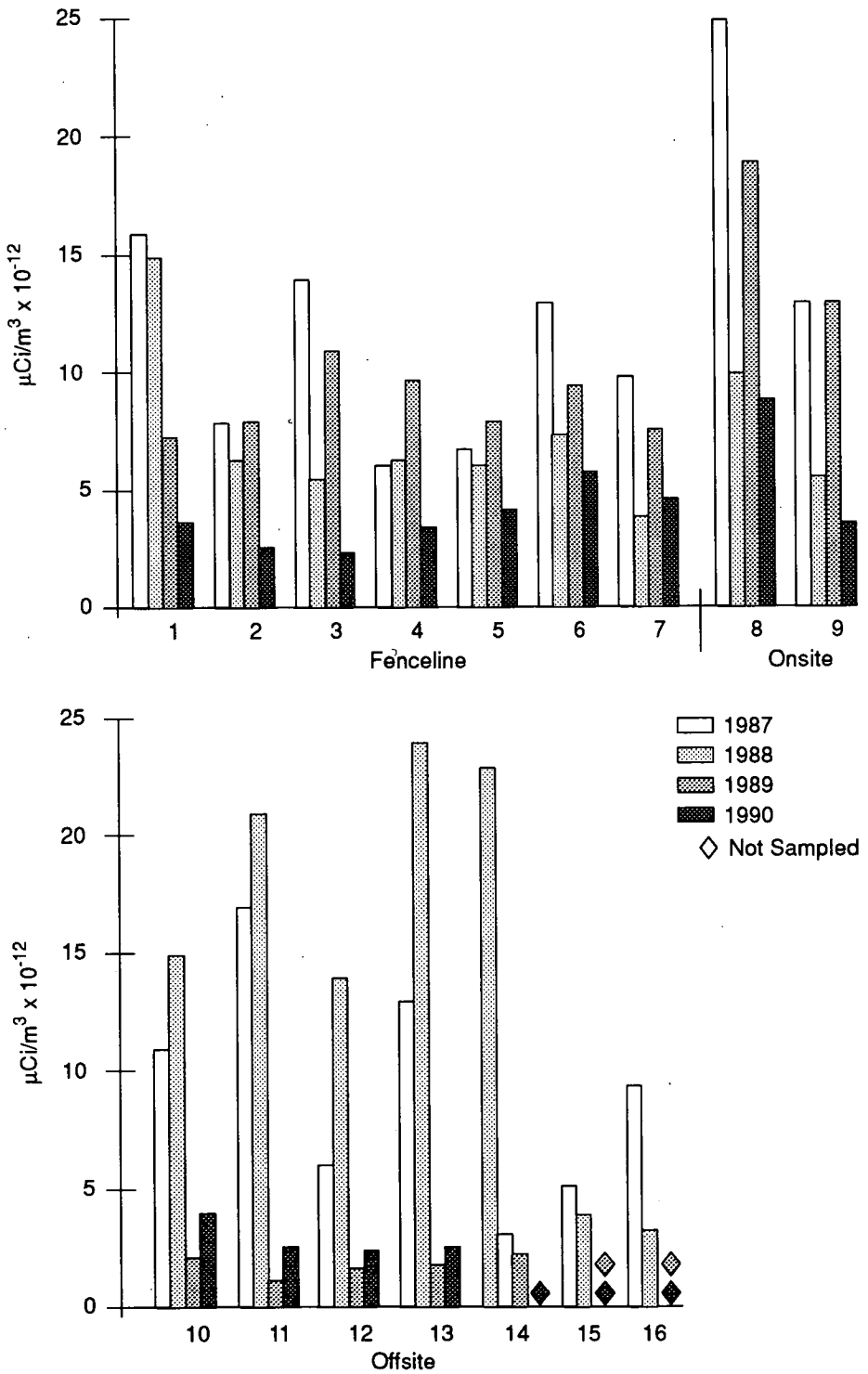


FEMP. No DOE or USEPA guidelines or standards have been established for uranium in soil. However, to assist sites like the FEMP in their cleanup efforts, the DOE and USEPA have agreed that an acceptable level at which to begin cleanup activities for uranium in soil is 35 pCi/g or greater, based on potential dose. [22]

To better evaluate the significance of the uranium concentration in soil samples collected for the Environmental Monitoring Program, the FEMP is funding a study to determine the amount of uranium naturally present in soil near the site. Soil samples have been collected and are currently being analyzed for uranium content. Results from this study are expected to be available in the 1992 ASER.

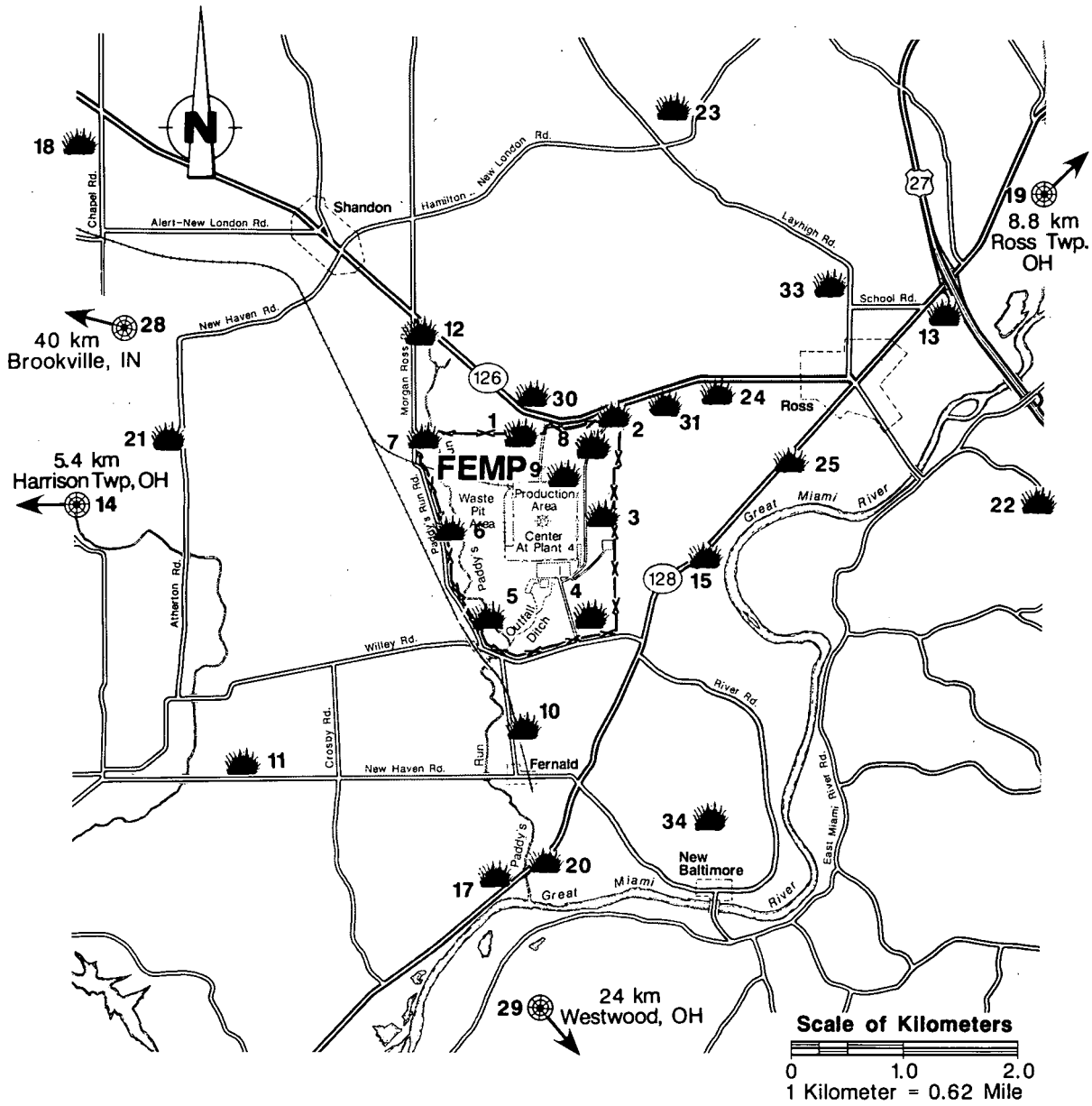
As part of the FEMP soil sampling program, technicians collect cores of soil from undisturbed plots at two depths, 0–5 cm (0–2 inches) and 5–10 cm (2–4 inches). Care is taken to exclude grass from the soil samples. Results

Figure 23: Average Thorium – 232 Concentration in Air, 1987 – 1990



105

Figure 24: Soil and Grass Sampling Locations



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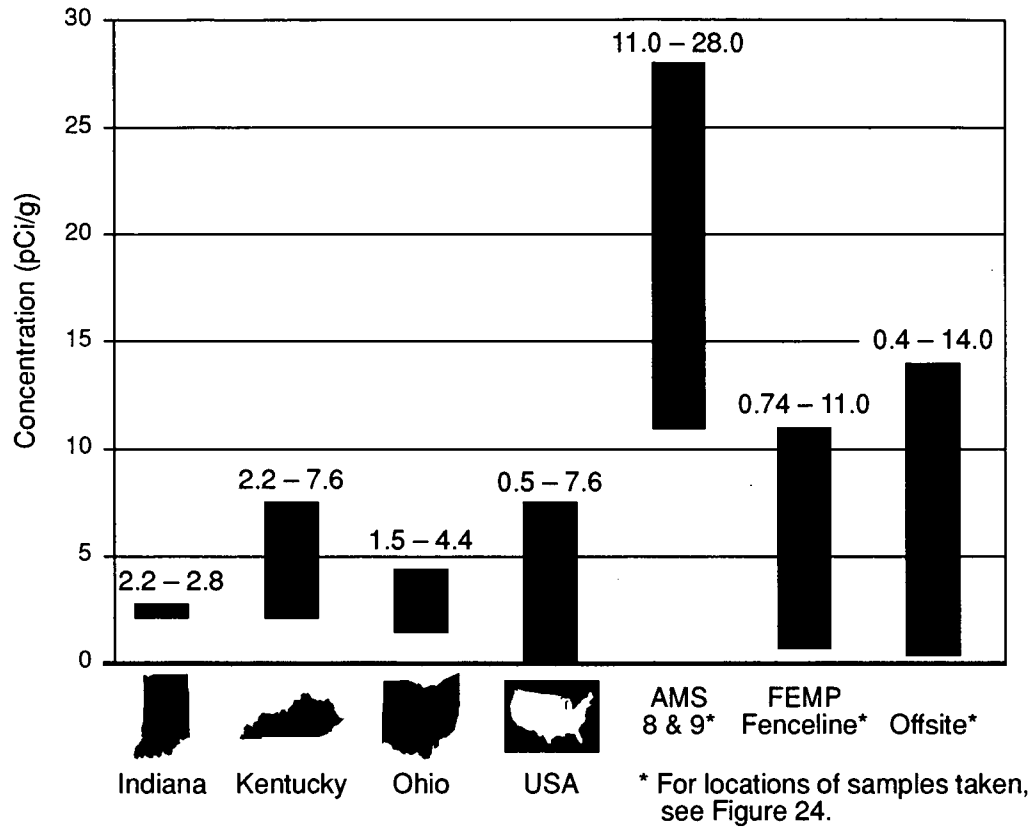
- Sampling Location
- Distance from Center of Production Area to Sampling Locations off Map
- Plant Perimeter
- Production Area Perimeter

1588

Figure 25: Range of Total Uranium Occurring in Surface Soils



from the 0–5 cm (0–2 inches) depth show that uranium concentration in the soil samples taken at two onsite locations ranged from 11 to 28 pCi/g dry weight, while samples collected along the fenceline ranged between 0.7 and 11 pCi/g dry weight at the 0–5 cm (0–2 inches) depth (see Table 3). The higher concentrations in onsite soil are indicative of the soil contamination known to exist, particularly in the northeastern quadrant of the site. The uranium concentration in offsite samples ranged from 0.4 pCi/g dry weight at sample location 10, to 14 pCi/g at sample location 30, which is directly north of the FEMP. Higher than background concentrations at this location northeast of the site have been reported in past annual reports and are probably the product of airborne emissions and deposition during the period of uranium production at the FEMP.

Results from the 5–10 cm (2–4 inches) depth for onsite and fenceline locations generally show higher uranium concentrations than the 0–5 cm (0–2 inches) depth samples. The reason for this observed distribution of uranium in soil is not understood. Data from previous years do not consistently show higher uranium concentrations at the 5–10 (2–4 inches) cm depth.

107

Grass Sampling for Uranium

Samples of grass were collected at the same locations as soil. 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.

In addition to soil sample results, Table 3 reports the following uranium concentrations in onsite, fenceline, and offsite grass samples:

- Onsite results ranged from 0.16 to 0.17 pCi/g dry weight,
- Fenceline results ranged from 0.041 to 0.28 pCi/g dry weight, and
- Offsite results ranged from 0.020 to 0.68 pCi/g dry weight.

Standards have not been established for uranium in grass; however, the data for 1991 show that fenceline concentrations lie within the range of concentrations measured at offsite locations. Although concentrations are higher than the results reported in 1990, the increases are attributed to differences in the analysis techniques used by offsite laboratories. There is no evidence from the AMS data to indicate that increased deposition of uranium occurred, nor is there evidence that uranium concentrations in soil have increased. The onsite results are within the ranges observed at the fenceline and offsite locations and also within the range of concentrations (0.041 to 0.48 pCi/g dry weight) measured in 1990.

For soil: 1 µg uranium/g = 1 ppm = 0.68 pCi/g; 1 pCi uranium/g = 1.48 ppm

Produce Sampling for Uranium

As mentioned in Chapter One, the FEMP is surrounded by farmland. Home-grown sweet corn and tomatoes are two of the major crops sold from roadside stands within three miles of the FEMP. Beets, potatoes, apples, lettuce, pumpkins, cucumbers, and peppers are among the other fruits and vegetables grown and sold near the plant. The FEMP samples produce each year to determine if uranium concentrations in produce grown near the FEMP (0–5 km or 0–3 miles) are higher than concentrations in produce grown distant from the FEMP (11–42 km or 7–26 miles) and are, therefore, a pathway of exposure from FEMP emissions. The sample results are then used to estimate the potential dose to people from this component of the air pathway (see Chapter Seven).

With air emissions reduced to very low levels, the possibility of uranium contamination in produce, that is caused by 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 FEMP airborne emissions.

Environmental monitoring personnel sampled produce (and soil, where possible) from 17 farms and gardens within 5 km (3 miles) of the center of the site. To determine background uranium concentrations, the FEMP also collected samples from five farms located between 11 km (7 miles) and 42 km (26 miles) from the site (Figure 26).

The results of the produce and soil sampling program are reported in Table 4. In general, uranium concentrations varied greatly for each type of produce. Concentrations in produce sampled near the FEMP are similar to concentrations found distant from the site; there is no measurable difference between the uranium concentrations of produce grown near the FEMP and the uranium concentrations of produce grown distant from the FEMP.

The soil in which the produce is grown is also sampled. This sampling is conducted to allow for comparisons of uranium concentrations found in soil with the concentrations found in produce. To date, no strong correlation between uranium concentrations in soil and produce have been established. Uranium concentrations in the soil taken along with produce ranged from 0.74 to 3.9 pCi/g and were similar to the results of the routine soil sampling program discussed above. Chapter Seven presents information on the potential dose from eating produce grown near the FEMP. This dose was very small and differed little from the potential dose from eating produce grown at background locations.

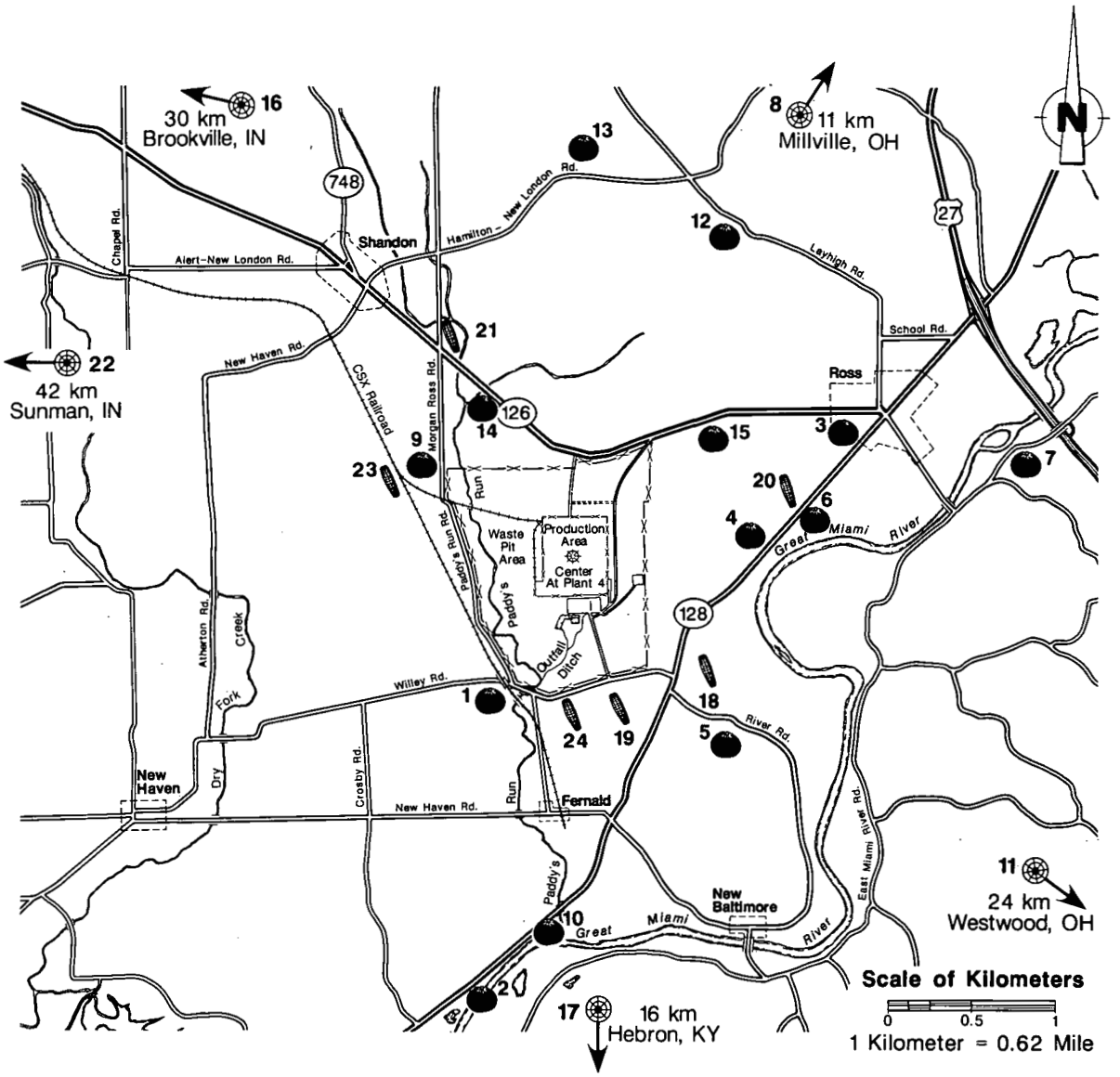
Milk Sampling for Radionuclides

Even though uranium is not normally concentrated in cows' milk, the FEMP examines this component of the air pathway in response to public concerns about the dairy farm located next to the FEMP site. In 1991, the FEMP sampled 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 FEMP. Data are reported in Table 5.

Analysis of the air-to-grass-to-cow-to-milk pathway is important for several reasons:

- A single cow can graze a relatively large surface area every day,
- A commercial herd grazes on land leased from the FEMP and land immediately adjacent to the FEMP,
- Milk is rapidly transferred from producer to customer, and
- Milk is an important staple in the American diet.

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

1588

Milk results from January through May 1991 reflect an increased sensitivity in laboratory analysis, which is now below the previously reported minimum detection limit of 0.68 pCi/L. In general, the limited amount of data reported with increased sensitivity do not indicate any difference between the uranium concentrations in milk from the local and control dairies for this set of samples.

In June 1991, the FEMP began using a different offsite lab to perform uranium analysis of milk samples. As part of the contract with the offsite lab, analysis of spiked milk samples was required. *Spiked samples* are routinely used in confirming the quality of analytical laboratory results. A sample will be spiked with a specific amount of uranium and then submitted to the lab (without the spike value provided) to determine how accurately the analysis is performed. The spiked sample results sampled from June through December indicate the offsite laboratory over-estimated the uranium concentration in the sample by three to four times. As a result of this poor performance, the results from the offsite laboratory are considered invalid. Reported results of the June through December samples erroneously indicated that uranium concentrations in the milk had suddenly jumped to higher levels at both dairies. This is inconsistent with earlier 1991 data and previous years' data.

As part of the investigation into the poor quality assurance results from the offsite laboratory, a detailed evaluation of the analysis technique used by the laboratory, kinetic phosphorescence, was performed. The evaluation concluded that the chemistry of milk (the various minerals and chemical components of milk) creates a *positive interference* in the kinetic phosphorescence analysis. A positive interference produces a result which indicates uranium is present in the sample, when in fact the sample contains little or no uranium. In order to avoid the problem of positive interference, the FEMP has selected a different analysis technique, alpha spectroscopy, for all future analysis of uranium in milk.

Duplicate milk samples from June through December were sent to a different offsite laboratory for analysis. Analysis of duplicate samples using the alpha spectroscopy method indicated that uranium–238 concentrations in milk were near or below the levels found in milk during January through May. Furthermore, the results are in agreement with previous years' results. The quality assurance results from the duplicate samples indicated the accuracy in the analysis of spiked samples was acceptable.

Monitoring for Nonradioactive Pollutants

Estimates of emissions from the FEMP Boiler Plant are required by the OEPA in order to operate such facilities and to demonstrate compliance with statutes such as the Clean Air Act. The FEMP estimated the amount of nonradioactive pollutants including sulfur dioxide (SO_2), nitrogen oxides (NOx), 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.

In order to estimate SO_2 emissions, the FEMP regularly assays the sulfur content of the coal. Using this assay information and the total amount of coal burned, the amount of SO_2 emissions can be calculated. For 1991, SO_2 emissions were calculated to be 410,000 kg (900,000 pounds).[27] This was well below the allowable limit of 1.6 million kg (3.5 million pounds) calculated from information in the Permit to Operate issued by the OEPA.

The NO_x and CO emissions are estimated using USEPA-developed emission factors which utilize data on the combustion characteristics of the Boiler Plant and the grade of coal burned. Nitrous oxide emissions for 1991 were estimated to be 154,000 kg (340,000 pounds). To date, the State of Ohio has not set NO_x limits for FEMP industrial processes. Carbon monoxide emissions were estimated to be 55,000 kg (120,000 pounds) in 1991.

1990 SWOAPCA Air Emissions

The OEPA maintains an inventory system for actual air emissions from major point sources; the inventory is reported by Southwestern Ohio Air Pollution Control Agency (SWOAPCA). The most recent data tabulated by SWOAPCA are from 1990, while the FEMP data reflect 1991 emissions (in kg).

	Hamilton Co.	*Butler Co.*	*Combined Counties*	*FEMP*
Particulates	*2,390,000*	*2,251,000*	*4,641,000*	*16,410*
SO_2	*103,470,000*	*9,188,200*	*112,658,000*	*408,800*
NO_X	*25,895,000*	*4,303,000*	*30,198,000*	*154,000*
CO	*2,045,000*	*19,684,000*	*21,729,000*	*55,000*

Electrostatic precipitators control particulate emissions from the Boiler Plant. These emissions were estimated to be 16,410 kg (36,100 pounds) for 1991. This estimate was based on emission factors developed from stack testing in 1988. The opacity of the emissions from the two FEMP coal-fired boilers were continuously monitored by instruments designed for that purpose. During 1991, the boilers operated 12,048 hours and 120,480 measurements were made and recorded at six-minute intervals. Only 23 (0.02%) of these measurements failed to meet the opacity standard of 20%, as a six-minute average. Results of all 1991 opacity measurements exceeding

20% were reported to Southwestern Ohio Air Pollution Control Agency (SWOAPCA), a local regulatory agency which monitors air quality and industrial emissions.

Summary of Air Pathway Monitoring Results for 1991

Airborne uranium emissions for 1991 were the lowest in the history of the site. And, in general, air pathway monitoring results were lower or consistent with results from 1990. Some onsite and nearby offsite soil samples continue to indicate some deposition of airborne particles from past operations. While produce and grass samples indicated no measurable contributions via the air pathway in 1991, problems with obtaining reliable data for the milk sampling program continued.

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 deposited from the air can be transported into surface water such as Paddy's Run. Eventually, these contaminants may affect groundwater quality as well. The next two chapters describe the FEMP's monitoring program for the liquid pathway beginning with Effluent and Surface Water Monitoring in Chapter Five.

Liquid Pathway: Effluent and Surface Water Monitoring

5

Liquid Pathway: Effluent and Surface Water Monitoring

Because radionuclides and chemicals may be present in its regulated liquid effluents and uncontrolled stormwater runoff, the FEMP investigates the effects of past and current operations on a second major pathway — the liquid pathway. Since contaminants can leave the site through the components of the liquid pathway, this chapter discusses sampling methodologies and results used to evaluate the FEMP's effluents and to determine any impacts from the FEMP on the Great Miami River and Paddy's Run. Groundwater, another major component of the liquid pathway, is discussed in the next chapter.

Results in Brief: 1991 Liquid Pathway: Effluent and Surface Water

Even though production has ended, the FEMP continued to closely monitor the liquid pathway during 1991. Indeed, remedial activities intensified as cleanup activities increased. For example, projects to reduce radionuclide concentrations in the effluent and to increase the area of controlled stormwater runoff progressed. Each component of the liquid pathway is discussed in detail in this chapter; the results are summarized below.

Effluent *– About 663 kg (1,462 pounds) of uranium was discharged to the Great Miami River during 1991; this was a slight reduction compared to 1990.*

Surface water *– The liquid effluent discharged to the river resulted in a slight increase in downriver uranium concentration from the upriver location. However, the downriver concentrations were lower than in 1990 and less than 1.0% of the DOE guideline. The uranium concentration in Paddy's Run continued to show effects of stormwater runoff from the site, although the average uranium concentration at the nearest offsite sampling location was also less than in 1990 and below 1.0% of the DOE guideline.*

Sediments *– Radionuclide concentrations in the Great Miami River and Paddy's Run sediments for 1991 were consistent with previous years' data and did not indicate a build-up of radioactive pollutants in the sediment.*

Fish *– Uranium concentrations were no greater in fish caught downstream of the FEMP effluent line than in those caught upstream, and the fish appeared healthy.*

NPDES *– The site complied with the discharge limits 99.7% of the time during 1991. Out of the yearly total of 6,219 NPDES samples taken, only 18 were not in compliance.*

Surface water quality *– Concentrations of fluoride, nitrate-nitrogen, and pH values in the river showed little or no effect from FEMP operations.*

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. Like the air pathway, the liquid pathway can carry both radioactive and nonradioactive contaminants offsite. Figure 27 on page 90 shows the relationship of the FEMP's effluents to the local surface water systems. A discussion of the river and creek surface water sampling program follows. The FEMP conducts these programs because radionuclides in the regulated liquid effluent discharge and in stormwater runoff may be a source of radioactive exposure to the public.

Effluent Sampling for Radionuclides

The FEMP's liquid effluents originated from five sources:

- Process wastewater,
- Sanitary sewage,
- Controlled stormwater runoff,
- Wastewater from the water treatment plant, and
- Uncontrolled stormwater runoff.

Figure 28 on page 91 illustrates the flow of the effluents and where they are treated before they are discharged to the river.

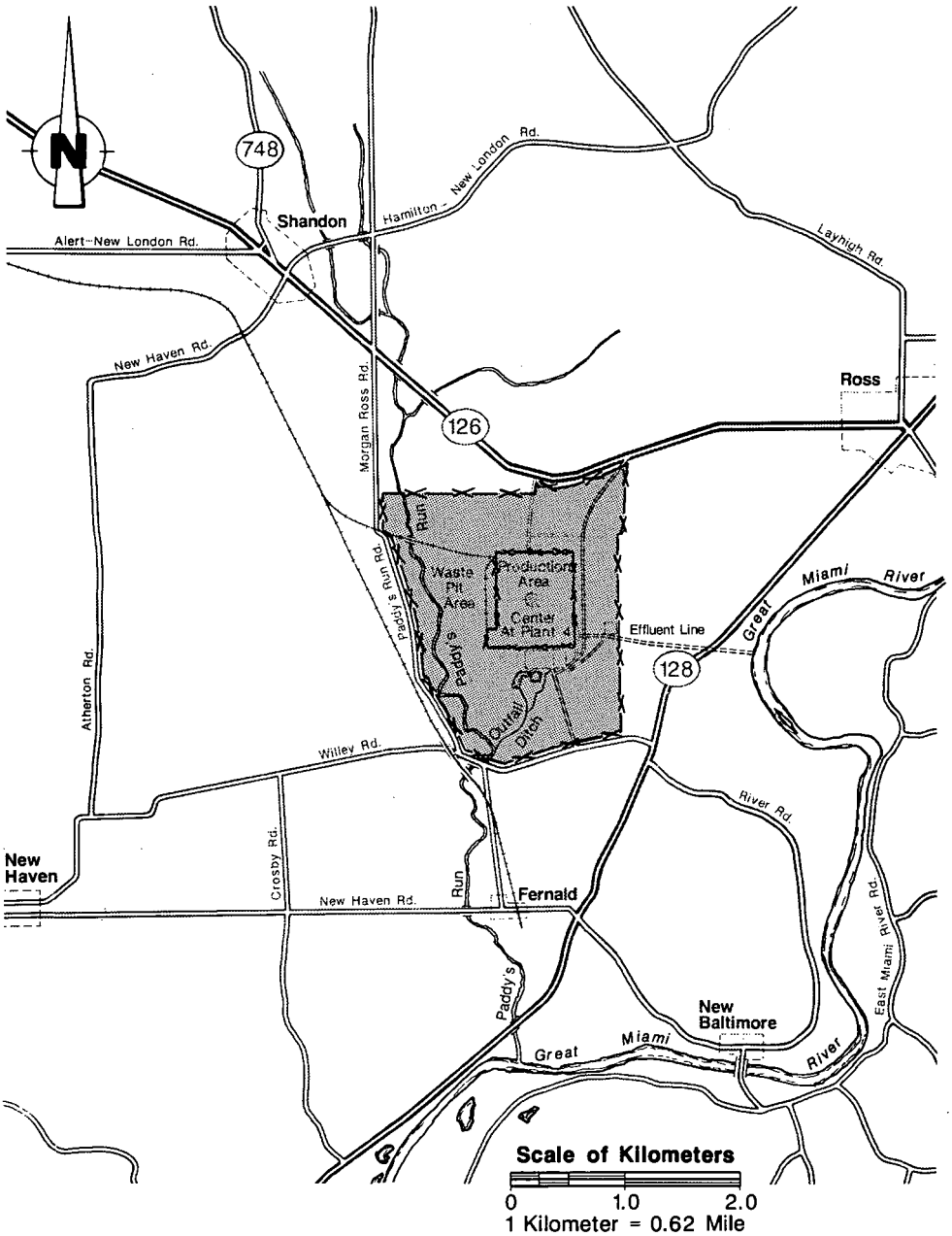
Sources of Effluent During 1991

The first source of liquid effluent is ***process wastewater*** and ***controlled stormwater runoff from the waste pit area.*** Process wastewater is collected from controlled storage areas in the former production area to reduce radioactive and chemical contaminants. It then is sent to the contaminated side of the General Sump for treatment and on to the Biodenitrification Surge Lagoon (BSL). Stormwater runoff that is controlled in the wastepit area is collected in the clearwell and then pumped to the BSL. At the BSL, the runoff mixes with process wastewater and the combined liquid effluent is treated in the Biodenitrification Facility (BDN) towers to reduce nitrates and then flows through the BDN effluent treatment system. The combined treated effluent flows to Manhole–175 and on through an underground pipeline to the Great Miami River.

The second source of effluent is ***sanitary sewage***, which is processed at the Sewage Treatment Plant to remove biological contaminants. After treatment, the effluent is sent to Manhole–175 and on to the Great Miami River.

The third source of liquid effluent is ***controlled stormwater runoff.*** This effluent is produced from the collection of rain which has fallen in the area

Figure 27: Great Miami River, Paddy's Run, FEMP Outfall Ditch, and Effluent Line



LEGEND

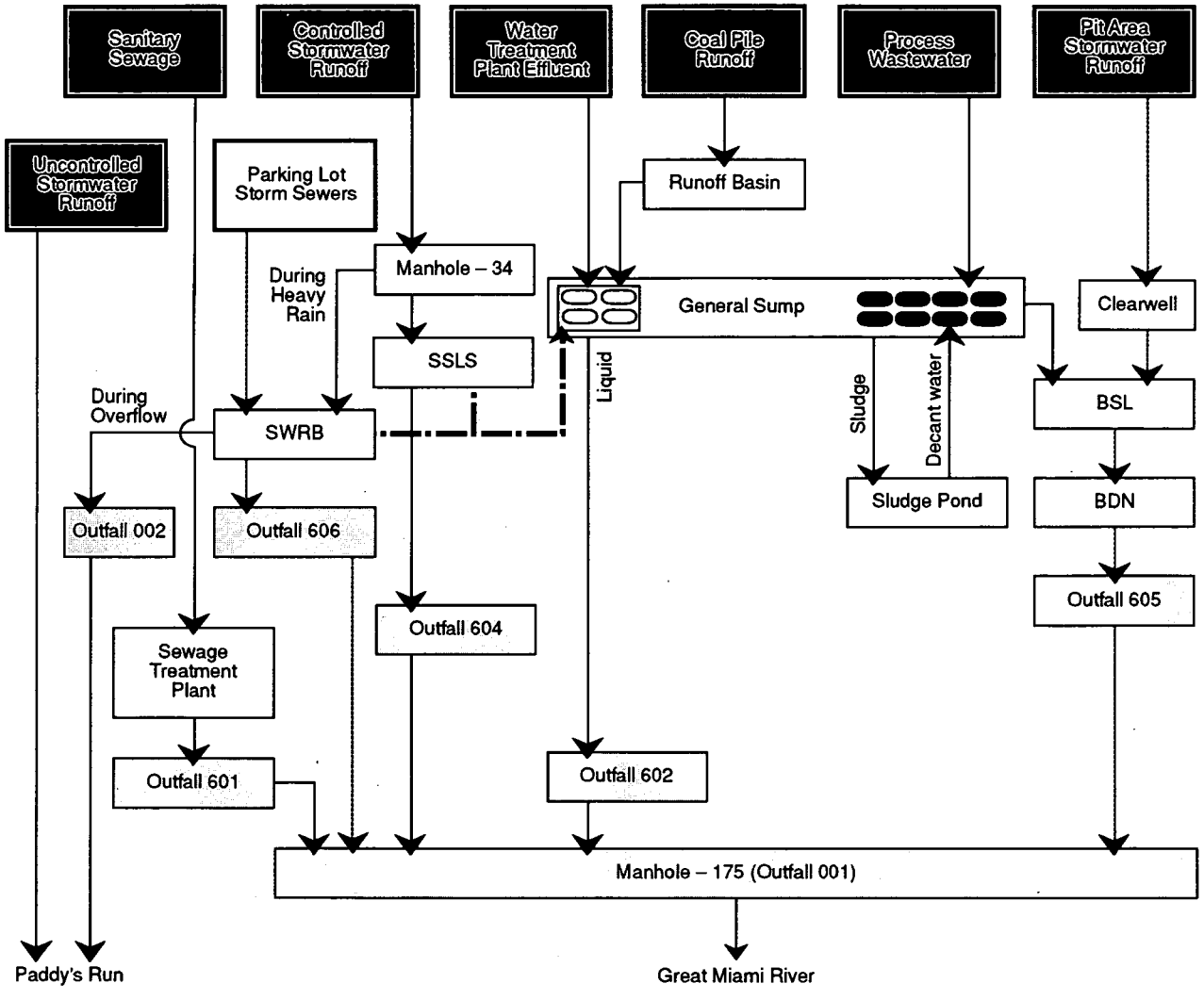
FEMP Site

Plant Perimeter

Production Area Perimeter

1588

Figure 28: FEMP Liquid Effluent Flow Diagram



SSLS & SWRB water can be diverted to the General Sump for treatment if necessary due to a spill entering the storm sewer system.

Source of effluent as described in text.

NPDES monitoring location.

Tanks used for holding water contaminated with uranium.

Tanks used for holding uncontaminated water.

shown in Figure 29. Stormwater runoff from the former production area is collected by a network of storm sewers that converge at Manhole–34. Dry weather flow is pumped to Manhole–175 by the Storm Sewer Lift Station (SSLS). Overflow and stormwater are then pumped to the Stormwater Retention Basin (SWRB) where they mix with liquids from the parking lot storm sewers and settle. All collected water is eventually pumped to Manhole–175.

The fourth source of liquid effluent is ***uncontrolled stormwater runoff***. This consists of stormwater that runs directly offsite, into Paddy's Run. This water is not controlled and is not monitored at a specific outfall.

The fifth source of liquid effluent is ***wastewater from the water treatment plant*** and ***runoff from the coal pile***. The effluent from the water treatment plant is sent to the General Sump. The liquid is then sent to Manhole–175, and the settled solids are sent to the North Lime Sludge Pond. After collecting and settling in the Coal Pile Runoff Basin, clarified stormwater runoff from the coal pile is also sent to the General Sump and handled in a similar manner.

In summary, the FEMP controls liquid effluents, including sanitary sewage, waste pit area and former production area stormwater runoff, and wastewater from the water treatment plant — all of which eventually enter Manhole–175. There, the effluents combine to form a single liquid from which a representative sample can be taken before the effluent flows to the Great Miami River.

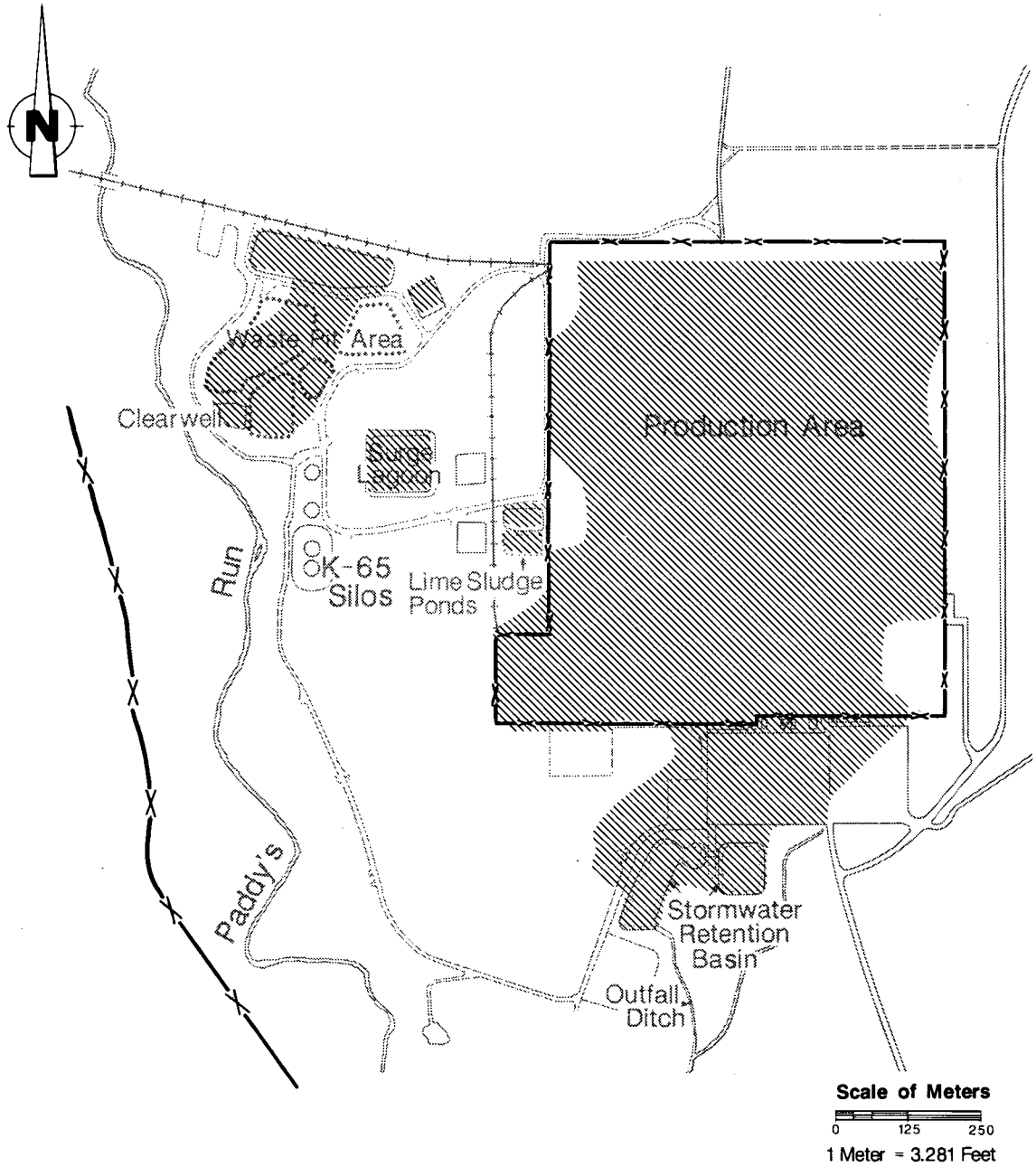
On an average day during 1991, 8,260,000,000 liters (2.18×10^9 gallons) of Great Miami River water flowed past the FEMP effluent line.[8] The FEMP discharged an average of 2,310,000 liters (6.1×10^5 gallons) of effluent into the river each day. Therefore, on average, each gallon of effluent discharged was combined with about 13,600 liters (3,600 gallons) of river water.

Sampling Methodologies

The mixed effluent, described above, is sampled at Manhole–175 by a flow-proportional sampler, a continuously operating device that collects a varying amount of the effluent in proportion to the volume of flow to the river. 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 on page 94).

A portion of each daily sample of effluent flowing through Manhole–175 was analyzed to determine the amount of total uranium discharged to the Great Miami River. In addition, portions of all daily samples collected during

Figure 29: Area of Controlled Stormwater Runoff



LEGEND

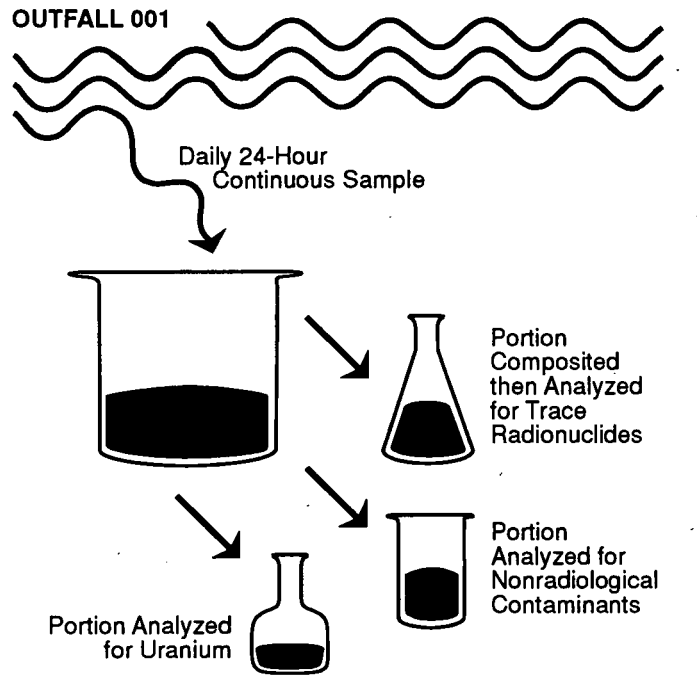
Shaded Areas are Collected and Eventually Discharged to the Great Miami River

Plant Perimeter

Production Area Perimeter

1588

Figure 30: Continuous Sampling at Outfall 001



each month were mixed to form either monthly composites, or, as with cesium–137, ruthenium–106, and strontium–90, three-month composites. The monthly composites were analyzed for the four uranium isotopes and 13 other radionuclides listed in Table 6. Composites, rather than daily samples, were analyzed because many of the radionuclides were present in only trace amounts, and it would be neither practical nor cost-effective to perform more frequent analyses for them.

The FEMP also monitors any discharges to Paddy's Run that occur from the overflow of the SWRB. During 1991, the SWRB did not overflow. Since the SWRB began operating in 1986, the amount of uranium entering the outfall ditch has been substantially reduced.

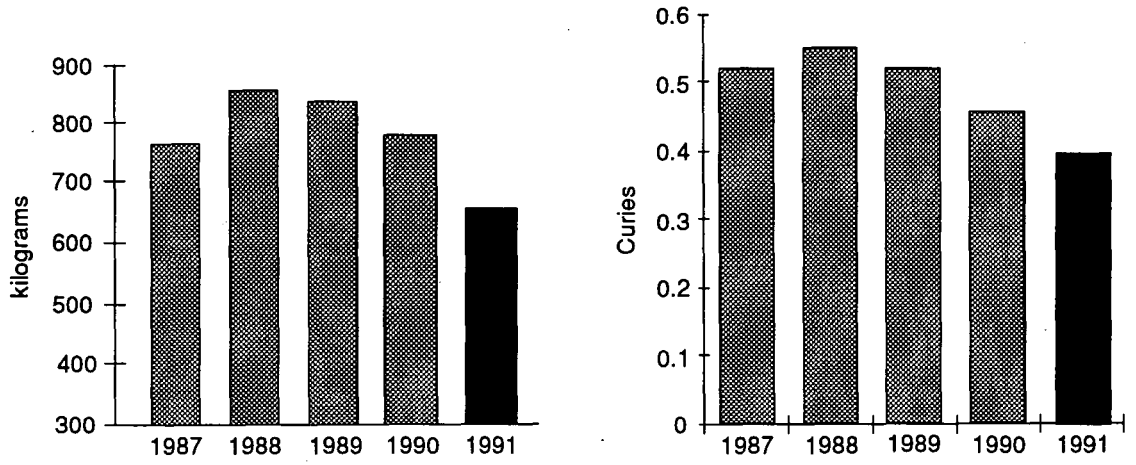
Results of Laboratory Analyses

Table 6 is a summary of the radionuclide analysis of the liquid effluent to the Great Miami River. The table shows the 1991 average concentration (in pCi/L) of each radionuclide compared to the total Curies discharged during 1990.

The average concentration of each radionuclide is compared to its Derived Concentration Guideline (DCG) or standard. DOE orders state that a dose must be estimated based on all the radionuclides present in the effluent. The annual average percentages of the DCG for each radionuclide, when added together, must not exceed 100%. Since the total is above 100%, the FEMP is required to use the Best Available Technology to reduce radionuclide concentrations in its effluent. An Advanced Wastewater Treatment Facility is being designed to accomplish this. An interim facility is planned to be operational in July 1992 and used until the advanced facility is operational.

During 1991, 0.40 Curies (663 kg or 1,489 pounds) of uranium was discharged to the Great Miami River through Manhole–175. This was a decrease of 13% on an activity basis and 15.6% on a mass basis, in comparison to the 0.46 Curies (786 kg or 1,733 pounds) of uranium discharged to the river during 1990. Comparisons of uranium discharges at Manhole–175 during 1991 and the four previous years are shown in Figure 31 (in Curies and kilograms).

Figure 31: Total Uranium (in Kilograms and Curies) Discharged through Outfall 001, 1987 – 1991



The FEMP reports an estimate of uranium in uncontrolled stormwater runoff to Paddy's Run to the USEPA. Based on a series of grab samples collected in various onsite drainage ditches that flow into Paddy's Run, the FEMP developed a general estimate of 4.5 kg (10 pounds) of uranium in the runoff to Paddy's Run for every inch of rain. For 1991, the estimate of uranium in stormwater runoff to Paddy's Run was reported as 147 kg (323 pounds). The FEMP is attempting to control stormwater runoff areas to address a major portion of this discharge. (See the section on Current Accomplishments and Issues in Chapter Three.)

Surface Water Sampling for Radionuclides

FEMP surface water sampling measures the effects of two sources of contamination: the discharge of liquid effluents into the Great Miami River and the effects of uncontrolled stormwater runoff into Paddy's Run.

As mentioned earlier, the liquid effluent to the river includes process wastewater, sanitary sewage, controlled stormwater runoff, and wastewater runoff from the water treatment plant and coal pile. There are two routes by which liquids from the FEMP can enter Paddy's Run. The first route is through the overflow of the SWRB (which did not occur during 1991), and the second route is through uncontrolled stormwater runoff. Figure 29 on page 93 shows the area of controlled stormwater runoff.

Sampling Methodologies

During 1991, 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 Paddy's 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 Paddy's Run (W5 – upstream from the site, W7, and W8).

Each week, one of the daily samples from each river sampling location was analyzed for total uranium. Portions of the daily samples collected along the Great Miami River were combined to form a monthly composite for each location, which was 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.

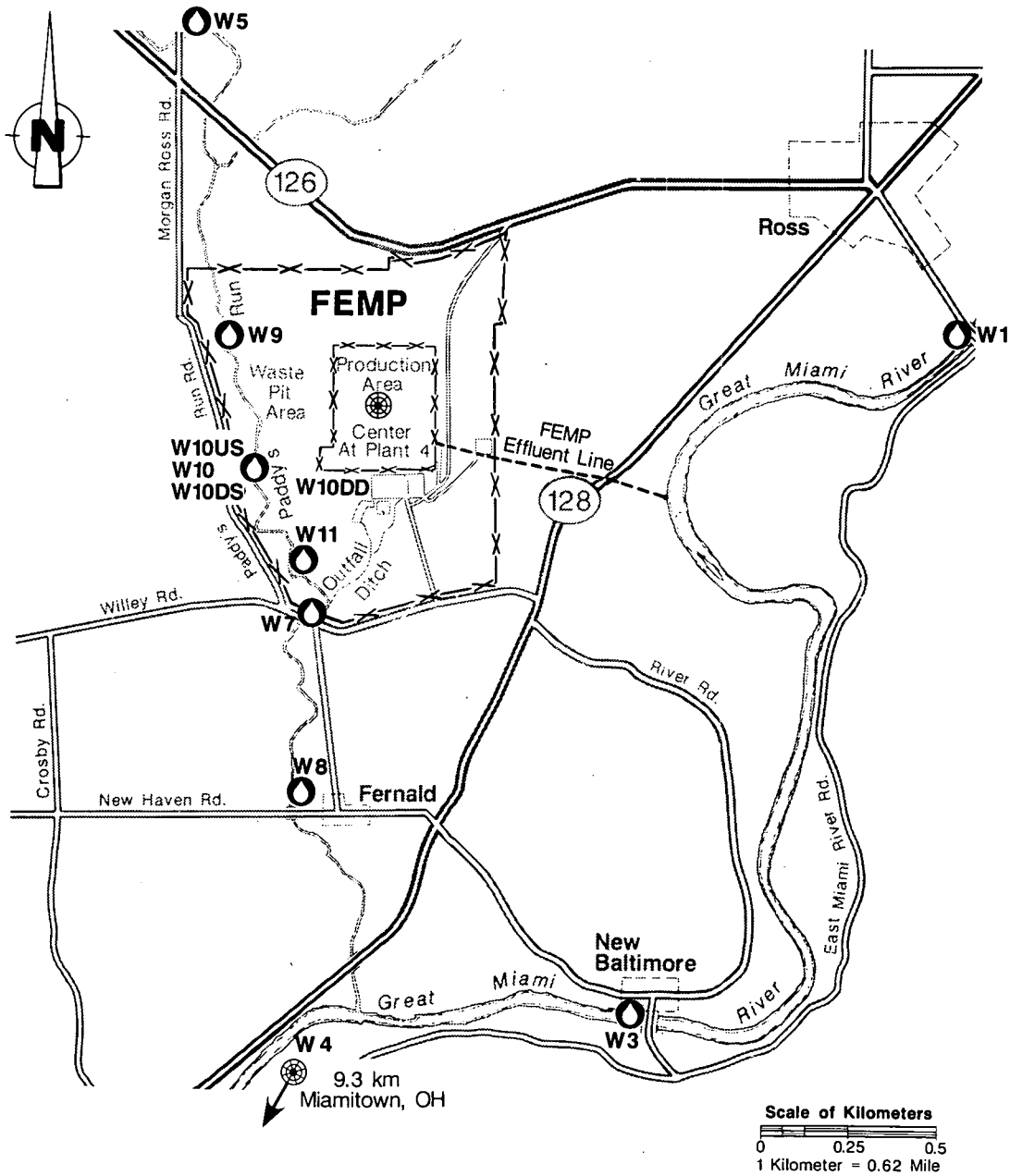
Weekly grab samples were collected at the five onsite locations along Paddy's Run and one location along the drainage ditch and analyzed for total uranium (often times there is not enough water present to collect a sample). Recently, uranium concentrations at W10 have varied greatly. Uranium concentrations 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 samples cannot be obtained because the effluent from the drainage ditch does not always have sufficient time to completely mix with the water in Paddy's Run to provide a homogeneous mixture for sampling. In order to account for this problem by collecting more representative samples, three additional sampling locations (W10–US — just upstream of W10, W10–DD — in the drainage ditch, and W10–DS — just downstream of W10) were added in 1991.

Results of Laboratory Analyses

The radionuclide concentrations found in surface water samples collected during 1991 are summarized in Table 7. The data indicate that the average uranium concentration in the Great Miami River was slightly higher at sampling locations W3 and W4 downstream of the FEMP outfall, than at the W1 upstream location. However, average uranium concentrations at W3 and W4 were well below DOE guidelines, at 0.22% and 0.23% of the DCG respectively.

There were no measurable increases in the concentrations of radium–226, radium–228, strontium–90, cesium–137, and technetium–99 found between

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

1588

location W1 upstream and locations W3 and W4 downstream in Great Miami River samples collected during 1991. These data support the results in Table 6, demonstrating that the concentrations of these radionuclides in the liquid effluent discharged to the river were very low and would result in very little, if any, increase in the concentrations already present in the river.

The FEMP also analyzed surface water samples collected from Paddy's Run. Upstream sampling point W5 is used to determine concentrations of uranium and radium normally present in this stream. The average uranium concentration at W5 was 0.79 pCi/L. Higher average uranium concentrations were found at the downstream sampling points (Figure 33). However, average uranium concentrations at all Paddy's Run monitoring locations were well within DOE guidelines, ranging from 0.27% of the DCG at W9 to 8.9% at W10–US. High average values from W10–US, W10, and W10–DS were due to a few very high weekly results. Therefore, in Table 7 the median value rather than the average is reported for those locations. The median better reflects the usual concentration of uranium in the stream. The averages of these locations are W10–US 55 pCi/l, W10 66 pCi/L, and W10–DS 49 pCi/L. The elevated levels in W10–DD and the fact that W10 is higher than W10–US would suggest that the drainage ditch is also a contributor to the uranium concentrations in Paddy's Run. Due to the increase in both the median and average concentration from W9 to W10–US, there is evidence that there are contributors other than the drainage ditch influencing the uranium concentration levels in Paddy's Run.

The onsite concentrations may be attributed to the previously stated varying flow rates and construction of environmental improvements projects. Stormwater runoff flowing into Paddy's Run upstream of W10 may be carrying more solids, including uranium, than in past years. In addition, the drainage ditch flows into Paddy's Run at this location.

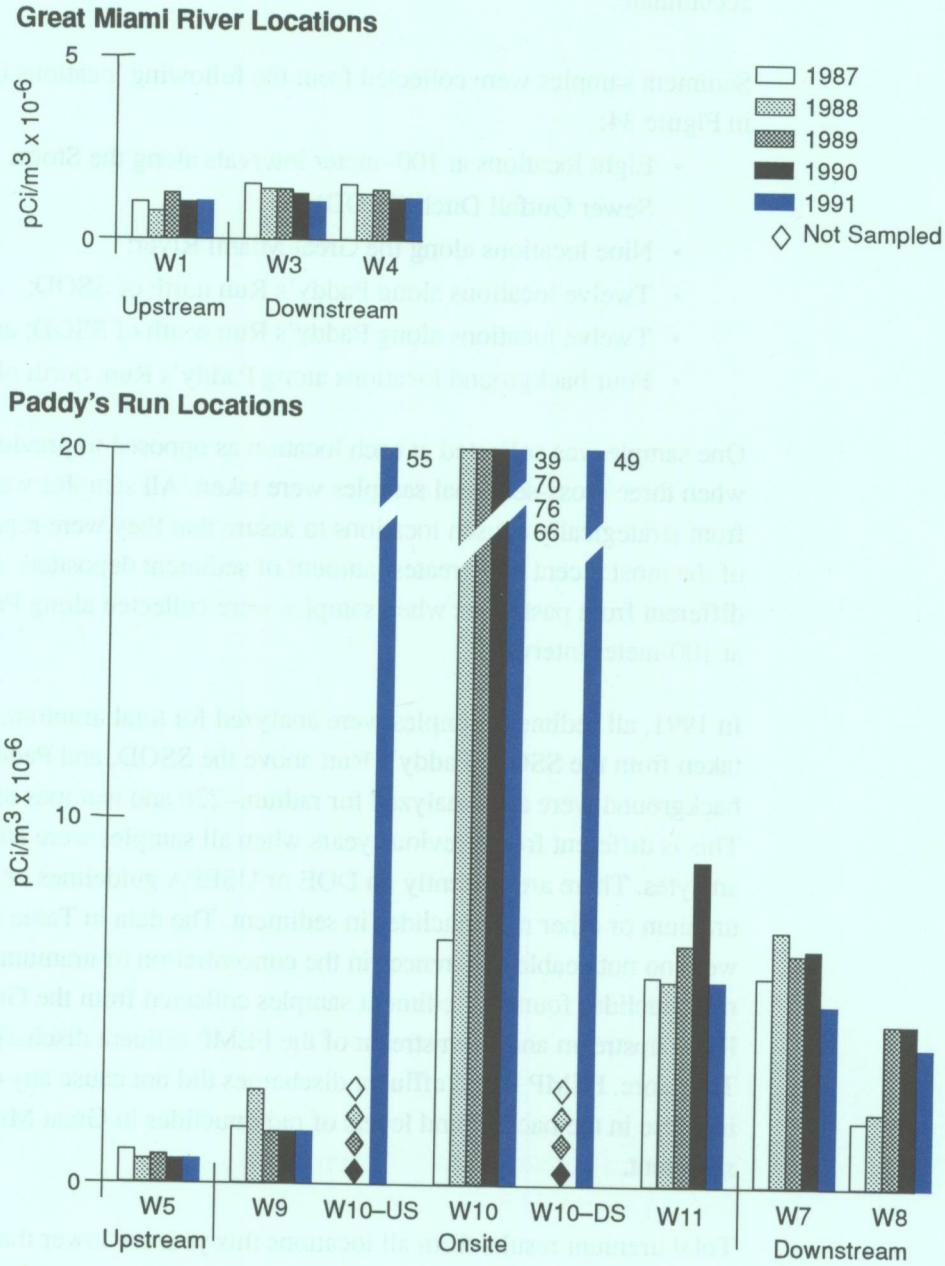
Sampling will continue in 1992, and with the completion of the Waste Pit Area Runoff Control Removal Action (see Chapter Three), the amount of uranium contaminated runoff to Paddy's Run will be reduced.

Sediment Sampling for Radionuclides

Contaminants present in surface water can settle or precipitate, and thereby accumulate in sediment. Thus, sampling and analysis of sediments 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 Paddy's Run.

From 1986 through 1990, the FEMP's sediment sampling program focused on characterizing the sediment in Paddy's Run. During the five-year period,

Figure 33: Average Uranium Concentrations in Surface Water, 1987 – 1991



the FEMP collected more than 750 sediment samples along Paddy's Run and had them analyzed by an offsite lab for 11 analytes. These data were reviewed by comparing results from year-to-year at each sampling location. No consistent patterns or high concentrations of uranium or other radionuclides were apparent. This is probably due to the scouring of the stream and its banks by periodic high, strong flows.

Once the stream sediments were characterized, the FEMP began a surveillance sampling program for sediments. This means that samples were collected only at those locations where sediment was most likely to accumulate.

Sediment samples were collected from the following locations identified in Figure 34:

- Eight locations at 100–meter intervals along the Storm Sewer Outfall Ditch (SSOD);
- Nine locations along the Great Miami River;
- Twelve locations along Paddy's Run north of SSOD;
- Twelve locations along Paddy's Run south of SSOD; and
- Four background locations along Paddy's Run, north of the site.

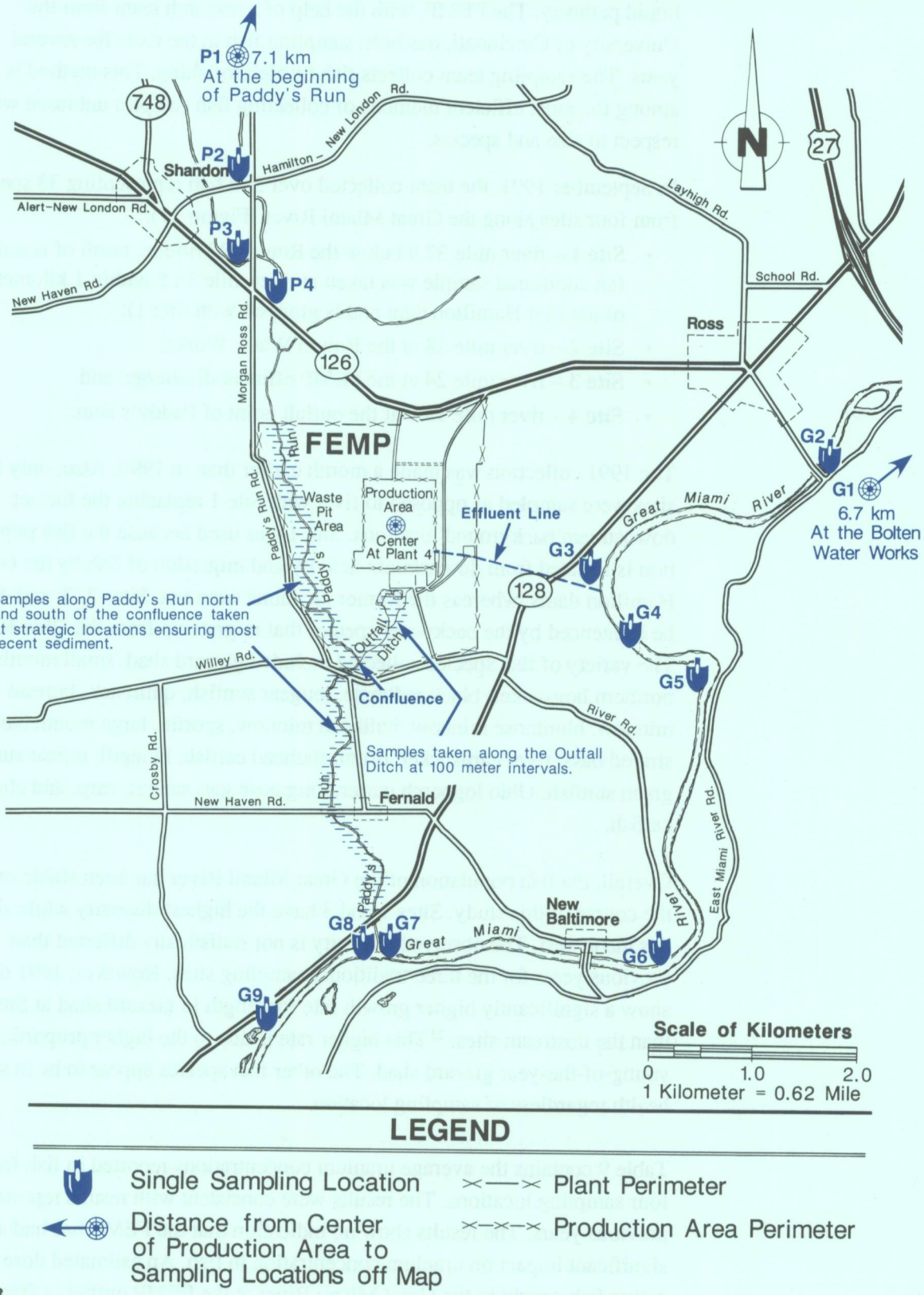
One sample was collected at each location as opposed to previous years when three cross-sectional samples were taken. All samples were collected from strategically chosen locations to assure that they were representative of the most recent and greatest amount of sediment deposited. This is also different from past years when samples were collected along Paddy's Run at 100-meter intervals.

In 1991, all sediment samples were analyzed for total uranium. Samples taken from the SSOD, Paddy's Run above the SSOD, and Paddy's Run background were also analyzed for radium–226 and isotopes of thorium. This is different from previous years when all samples were analyzed for 11 analytes. There are currently no DOE or USEPA guidelines or standards for uranium or other radionuclides in sediment. The data in Table 8 show there were no noticeable differences in the concentration of uranium and other radionuclides found in sediment samples collected from the Great Miami River upstream and downstream of the FEMP effluent discharge line. Therefore, FEMP liquid effluent discharges did not cause any discernible increase in the background levels of radionuclides in Great Miami River sediment.

Total uranium results from all locations this year are lower than in 1990. However, the average uranium concentration in the outfall ditch (1.8 pCi/g) was still above background levels even though it decreased 62% from last year. 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 outfall ditch over the years.

128

Figure 34: Sediment Sampling Locations



LEGEND

Single Sampling Location

Distance from Center of Production Area to Sampling Locations off Map

Plant Perimeter

Production Area Perimeter

1588

Fish Sampling for Uranium

The fish population of the Great Miami River is another component of the liquid pathway. The FEMP, with the help of a research team from the University of Cincinnati, has been sampling fish in the river for several years. The sampling team collects fish by electrofishing. This method is among the most efficient methods of collecting fish samples unbiased with respect to size and species.

In September 1991, the team collected over 500 fish representing 33 species from four sites along the Great Miami River (Figure 35):

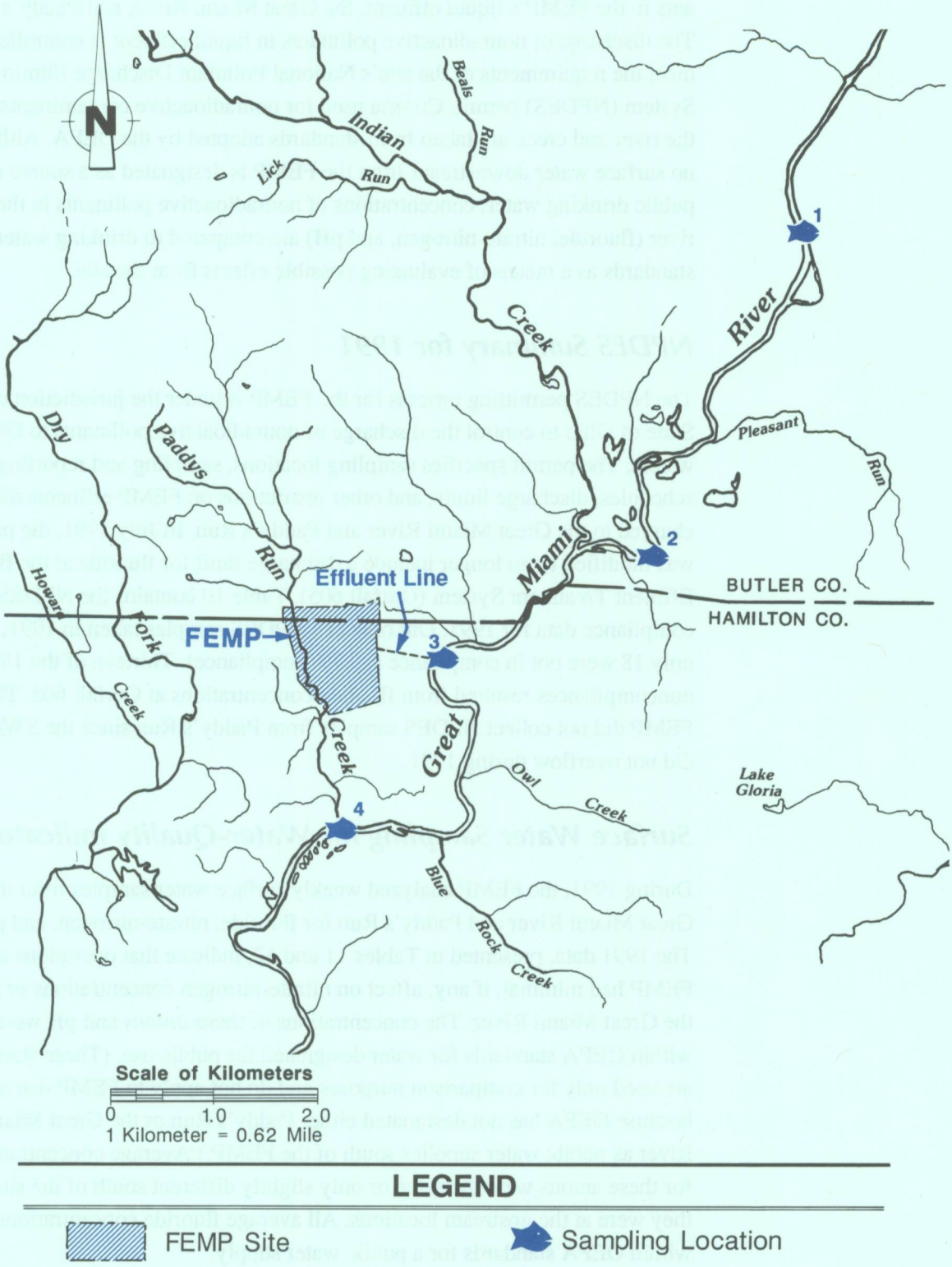
- **Site 1** – river mile 37.8 below the Route 127 bridge, north of Hamilton (an additional sample was taken at river mile 36.5 within 1 kilometer of the first Hamilton dam and is grouped with Site 1);
- **Site 2** – river mile 28 at the Bolton Water Works;
- **Site 3** – river mile 24 at the FEMP effluent discharge; and
- **Site 4** – river mile 19.3 at the outfall point of Paddy's Run.

The 1991 collection was made a month earlier than in 1990. Also, only four sites were sampled as opposed to five, with Site 1 replacing the former downstream background locations. Site 1 was used because the fish population is isolated from downstream activity and migration of fish by the two Hamilton dams, whereas the former locations were not. Sites 2, 3, and 4 may be influenced by the backwater species that migrate up from the Ohio River. The variety of fish species collected included gizzard shad, small mouth bass, northern hogsucker, black redhorse, longear sunfish, quillback, fathead minnow, bluntnose minnow, bullhead minnow, spotfin, large mouth bass, striped bass, river carpsucker, drum, flathead catfish, bluegill, redear sunfish, green sunfish, Ohio logperch darter, long nose gar, sauger, carp, and channel catfish.

Overall, the fish population of the Great Miami River has been stable over the course of this study. Sites 1 and 3 have the highest diversity while site 4 has the lowest. The observed diversity is not statistically different than previous years for the three traditional sampling sites. However, 1991 did show a significantly higher growth rate for length in gizzard shad at Site 4 than the upstream sites. [23] This higher rate is due to the higher proportion of young-of-the-year gizzard shad. The other fish species appear to be in similar health regardless of sampling location.

Table 9 contains the average uranium concentrations reported in fish from all four sampling locations. The results were consistent with results reported in previous years. The results show no indication that the FEMP has had any significant impact on uranium concentration in fish. An estimated dose from eating fish caught in the Great Miami River at the FEMP outfall is discussed in Chapter Seven.

Figure 35: Fish Sampling Locations



1588

Monitoring for Nonradioactive Pollutants

This section of the chapter looks at concentrations of nonradioactive pollutants in the FEMP's liquid effluent, the Great Miami River, and Paddy's Run. The discharge of nonradioactive pollutants in liquid effluent is controlled to meet the requirements of the site's National Pollutant Discharge Elimination System (NPDES) permit. Criteria used for nonradioactive contaminants in the river and creek are taken from standards adopted by the OEPA. Although no surface water downstream from the FEMP is designated as a source of public drinking water, concentrations of nonradioactive pollutants in the river (fluoride, nitrate-nitrogen, and pH) are compared to drinking water standards as a means of evaluating possible effects from the site.

NPDES Summary for 1991

The NPDES permitting process for the FEMP 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 FEMP effluents discharged to the Great Miami River and Paddy's Run. In July 1991, the permit was modified to no longer include a discharge limit for fluoride at the BDN Effluent Treatment System (Outfall 605). Table 10 contains the NPDES compliance data for 1991. Out of 6,219 NPDES samples taken in 1991, only 18 were not in compliance (99.7% compliance). Thirteen of the 18 noncompliances resulted from fluoride concentrations at Outfall 605. The FEMP did not collect NPDES samples from Paddy's Run since the SWRB did not overflow during 1991.

Surface Water Sampling for Water-Quality Indicators

During 1991, the FEMP analyzed weekly surface water samples from the Great Miami River and Paddy's Run for fluoride, nitrate-nitrogen, and pH. The 1991 data, presented in Tables 11 and 12, indicate that operations at the FEMP had minimal, if any, affect on nitrate-nitrogen concentrations or pH in the Great Miami River. The concentrations of these *anions* and pH were all within OEPA standards for water designated for public use. (These standards are used only for comparison purposes and do not apply to FEMP discharges because OEPA has not designated either Paddy's Run or the Great Miami River as public water supplies south of the FEMP.) Average concentrations for these anions were the same or only slightly different south of the site than they were at the upstream locations. All average fluoride concentrations were within OEPA standards for a public water supply.

Summary of Liquid Pathway: Effluent and Surface Water Monitoring Results

The FEMP extensively monitors its liquid effluent and the local surface water systems to detect and track the movement of contaminants that can originate from the site. The quantities of individual radionuclides discharged to the Great Miami River were within DOE guidelines. The FEMP is planning an Advanced Wastewater Treatment Facility to reduce the amount of both radioactive and nonradioactive pollutant discharges to the river. The FEMP complied with the NPDES requirements for nonradioactive contaminants 99.7% of the time during 1991. Surface water sampling results indicated that uranium concentrations in Paddy's Run on and below the site were higher than the upstream location, especially near the K–65 silos. A project is underway to reduce uncontrolled stormwater runoff to Paddy's Run from the waste pit area that will decrease the amount of uranium and other contaminants entering this stream (see Chapter Three).

By controlling the concentration of radionuclides in the effluent and by reducing the amount of stormwater runoff to Paddy's Run, the FEMP 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.

4030

Liquid Pathway: Groundwater Monitoring

134

6

Liquid Pathway: Groundwater Monitoring

This chapter continues the discussion of the liquid pathway, as surface water runoff and leaching through the soil may contaminate the groundwater. The FEMP carefully monitors the groundwater under 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 samples from drilling operations to learn much about the soil and its ability to restrict the movement of contaminants into the groundwater. This enables the FEMP to better define the steps it should take to control present contamination and to prevent additional contamination from occurring.

Results in Brief: 1991 Liquid Pathway: Groundwater

Since production ended in 1989, groundwater transport has emerged as the primary pathway of concern for contamination from FEMP radioactive and nonradioactive pollutants. The FEMP monitors this pathway at more than 200 locations on- and offsite. Results from 1991 were consistent with previous years' results in that contamination above the applicable water standards was confined to beneath the site and to an area of known uranium contamination to the immediate south.

Radioactive Pollutants *– Only three private wells, none of which are currently used as a source of potable water, exceeded the DOE guideline of 22 pCi/L for uranium in water. Four offsite FEMP monitoring wells and 18 onsite wells also had uranium concentrations above the guideline.*

Nonradioactive Pollutants *– Of the substances regulated by USEPA Primary Drinking Water Standards, only arsenic, fluoride, lead, and vinyl chloride were measured at concentrations exceeding their standards. All but two of these primary detections were at onsite locations — the other two were in an industrial area south of the site. Parameters which were measured in 1991 above USEPA secondary standards were chloride, iron, manganese, pH, sulfate, total dissolved solids, and zinc. None of these secondary detections are considered to be a risk to human health or the environment.*

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, eleven monitoring wells were installed 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, above-background concentrations of uranium were found in other wells near the FEMP. This information was reported to the State in November 1981.

These findings prompted an expansion of groundwater monitoring around the FEMP. Environmental Monitoring began sampling existing area wells in February 1982, and by 1984, the ***Radiological Environmental Monitoring (Private Well) Program*** was officially established with the monthly sampling of 19 privately owned wells.

Around this same time, attention was also focused on onsite groundwater contamination. The disposal of the barium chloride in Waste Pit 4 from 1980 to 1983 led to the establishment of the ***RCRA Detection and Groundwater Assessment Programs***, separate from the existing Environmental Monitoring activities. Federal and state environmental regulations required the FEMP 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 suspicions of contamination, the RCRA Groundwater Assessment Program was begun 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 1991.*)

Also in May 1988, additional groundwater sampling was initiated as part of the ***Remedial Investigation and Feasibility Study (RI/FS).*** This CERCLA-driven study was initiated in 1986 to investigate the nature and extent of potential environmental impacts from past and current operations at the site, with particular regard to the Great Miami Aquifer. (The complete RI/FS is discussed in more detail in Chapter Eleven.)

By late 1989, more than 200 wells were being sampled under the various programs. To eliminate duplication of efforts, 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, the RCRA Assessment Program, and the RI/FS.

Today, as this Comprehensive Groundwater Monitoring Program monitors FEMP 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 FEMP comprehensive sampling program.

DOE Guideline for Uranium in Drinking Water

In addition to comparison 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. These standards and guidelines are always set lower than the lowest concentration known to cause illness or injury to humans or the environment.

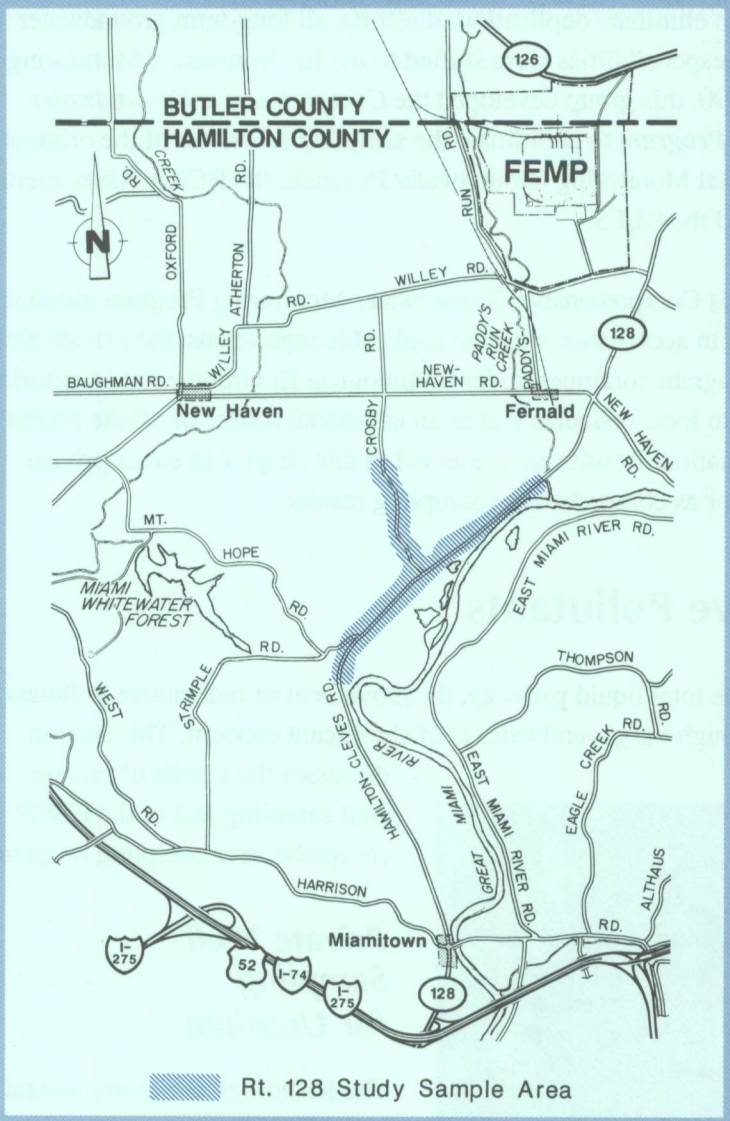
USEPA is responsible for setting standards for substances in drinking water throughout the United States; National Primary Drinking Water Standards are enforceable by federal law. However, in the absence of a USEPA standard for a particular substance, guidelines are set by other agencies such as DOE 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 30 parts per billion (ppb) or 22 pCi/L. Past FEMP reports have used this reference for comparison. However, in 1991, USEPA proposed a standard for uranium in drinking water of 20 ppb or 13.5 pCi/L. Over the past year, there have been on-going discussions to determine which standard is applicable to the site. This report will continue to use the DOE guideline of 30 ppb or 22 pCi/L as the official reference for groundwater monitoring results, as it is the only official guideline for groundwater activities at the site.

Private Well Sampling for Uranium

The Radiological Environmental Monitoring Program encompasses all sampling of privately owned wells. The program itself is divided into three subprograms: special sampling, routine sampling, and, recently, the State Route 128 study (discussed separately on the next page.)

At a property owner's request, any drinking water well near the FEMP site will be sampled for uranium to gain additional information about local groundwater quality, and the one-time sample results are given to the well owner. If one of these



State Route 128 Study

In December 1990, a private well about 4 km (2.5 miles) south of the site and on the north bank of the Great Miami River was sampled at the property owner's request. This "special request" sample showed a total uranium concentration of 5.5 pCi/L. Although within the DOE guideline of 22 pCi/L, this concentration was above the background range for the area and prompted a special study of uranium concentrations in neighboring wells. As part of this study, the FEMP sampled 18 wells and some cisterns along a two-mile stretch of SR 128 south of the site. The wells were sampled on a monthly basis from April to September 1991, and the cisterns were sampled once from those properties that chose to participate in the cistern study. From this special study, three wells were added to the routine sampling schedule; their groundwater uranium concentrations have remained within the 22 pCi/L guideline.

"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 is asked to join the routine sampling program. This program has grown from 19 wells in 1984 to 37 wells in 1991. (Wells 39, 40, and 41 were added to the program during 1991; well locations are shown in Figure 36.) The data from the routine sampling program are presented in Table 13. Figure 37 shows average uranium concentrations found in offsite wells from 1987 to 1991.

During 1991, offsite wells belonging to individuals and companies in the vicinity of the FEMP were sampled monthly and analyzed for total uranium. Average uranium concentrations in all but three wells were less than 3.6 pCi/L, and therefore, less than 16% of the DOE guideline. These concen-

Figure 36: Private Well Locations

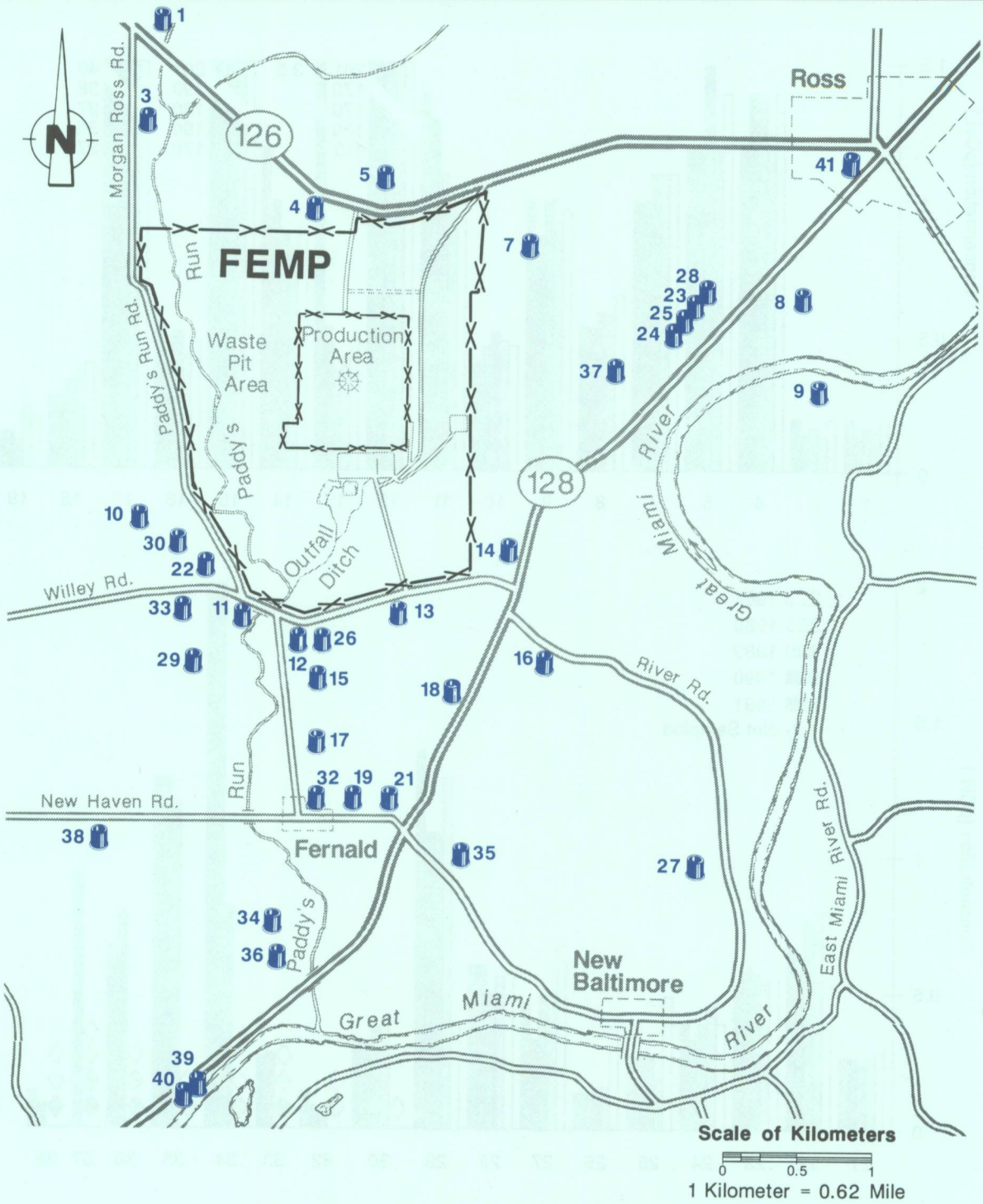


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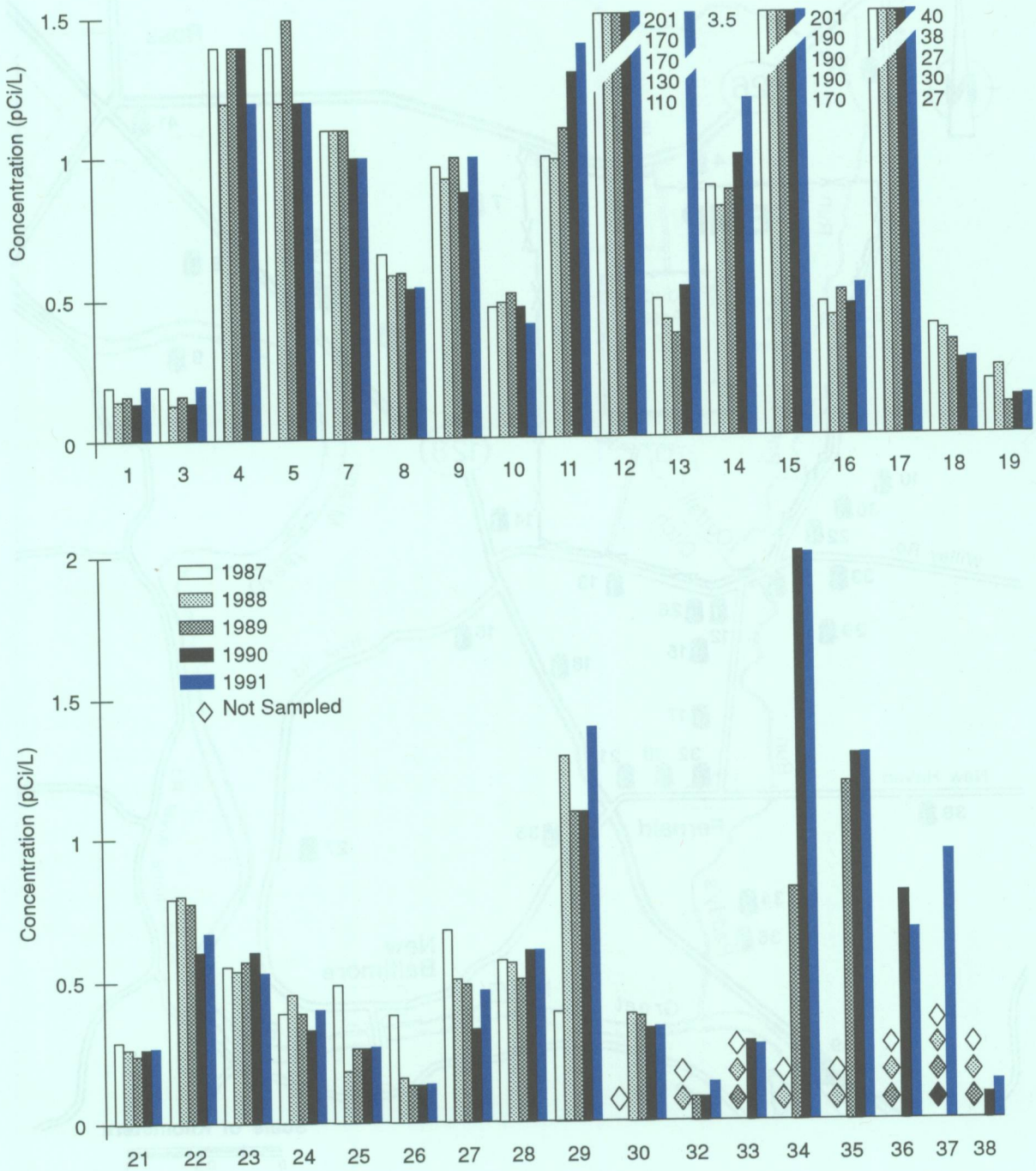
Figure 37: Average Uranium Concentrations in Private Wells, 1987 – 1991



140

South Groundwater Contamination Plume

Groundwater monitoring results over the past seven years have led to the identification of the South Groundwater Contamination Plume, an area immediately south of the site with known levels of uranium contamination. As part of a response under CERCLA, the FEMP has initiated a removal action to control further southward movement of the plume, to limit access and exposure to contaminated groundwater, and to protect the groundwater environment.

Because of the magnitude of this project, the removal action has been divided into five parts:

- *Supply an alternate water source to a local industry whose well water showed concentrations of uranium greater than the action level of 22 pCi/L agreed to by USEPA and DOE,*
- *Install groundwater recovery wells in the plume area,*
- *Remove additional uranium from onsite wastewater to compensate for uranium in the recovered groundwater,*
- *Continue groundwater monitoring in the South Plume area, and*
- *Continue groundwater modeling and additional groundwater investigations.*

The status of each of these removal action parts is discussed further in Chapter Three under "CERCLA Ongoing Removal Actions."

trations can also be compared to national background levels for total uranium in groundwater of 0.068 to 6.8 pCi/L, and local background levels for total uranium of 0.068 to about 2.2 pCi/L.[24,25] As in past years, only wells 12, 15, and 17 exceeded the DOE guideline in 1991, and these are no longer used as sources of *potable* water. One drinking water well, Well 13, has shown increasing uranium concentrations, although all 1991 detections at this location were still within the guideline. This well is located just south of the site, in an area of known groundwater contamination. This south plume of uranium-contaminated water will be pumped from the aquifer as part of the South Groundwater Contamination Plume Removal Action, discussed further to the left.

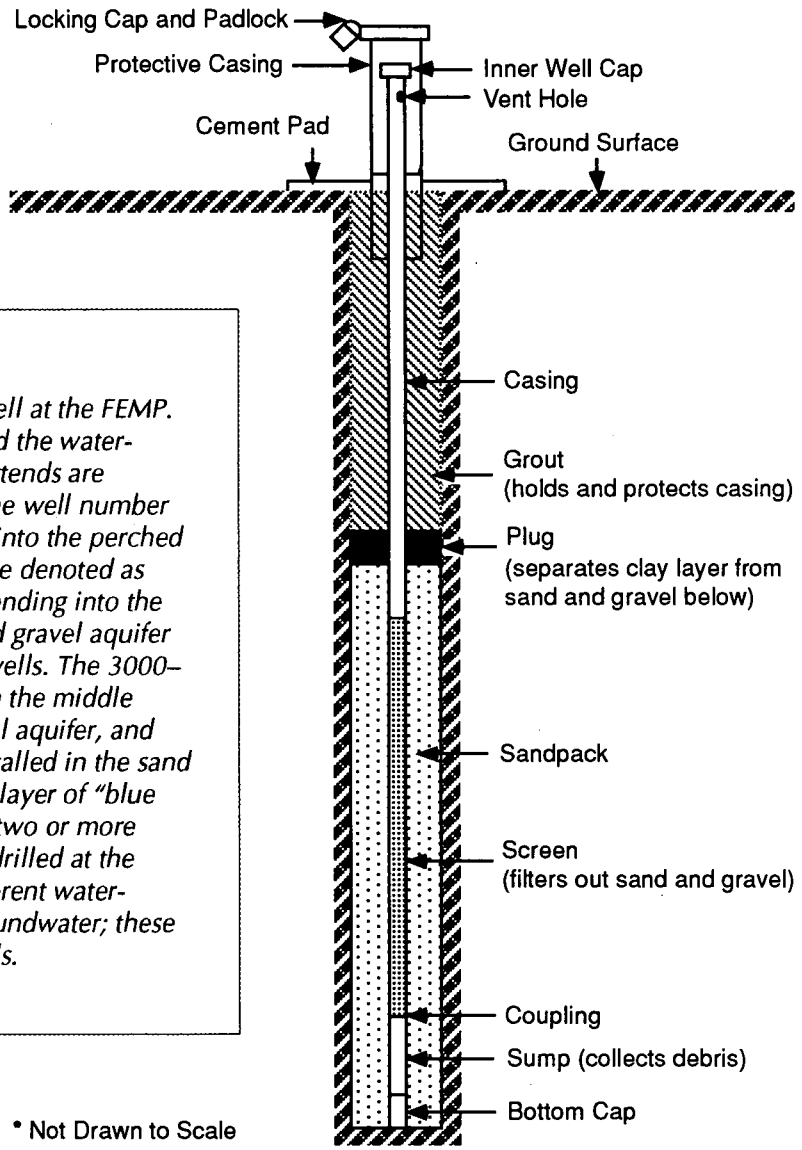
Comprehensive Sampling for Radionuclides

The Comprehensive Groundwater Monitoring Program encompasses all sampling of FEMP-owned monitoring wells. Not all wells are monitored each quarter, nor are they all monitored for the same constituents. As discussed earlier, sampling is performed 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 movement of uranium in the groundwater has been a key factor in determining the sources of contamination at the FEMP. The Groundwater Monitoring Program received results from 640 analyses for total uranium from 1991 samples at 403 on- and offsite locations. Of the uranium analyses for the last three quarters of 1991, the highest concentration was 7,196 pCi/L, well above the DOE guideline. This sample was drawn from Well 3084 in the middle of the aquifer directly beneath the waste pits. Other above-guideline detections at this same location were 169 pCi/L and 6,203 pCi/L. Most above-guideline detections at the other sampled wells were below 1,000 pCi/L. Uranium concentrations in 40 other samples at 18 onsite and four offsite locations were also above the USEPA drinking water

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 FEMP site. They range from 11 – 76 meters (35 – 250 feet) deep.



* Not Drawn to Scale

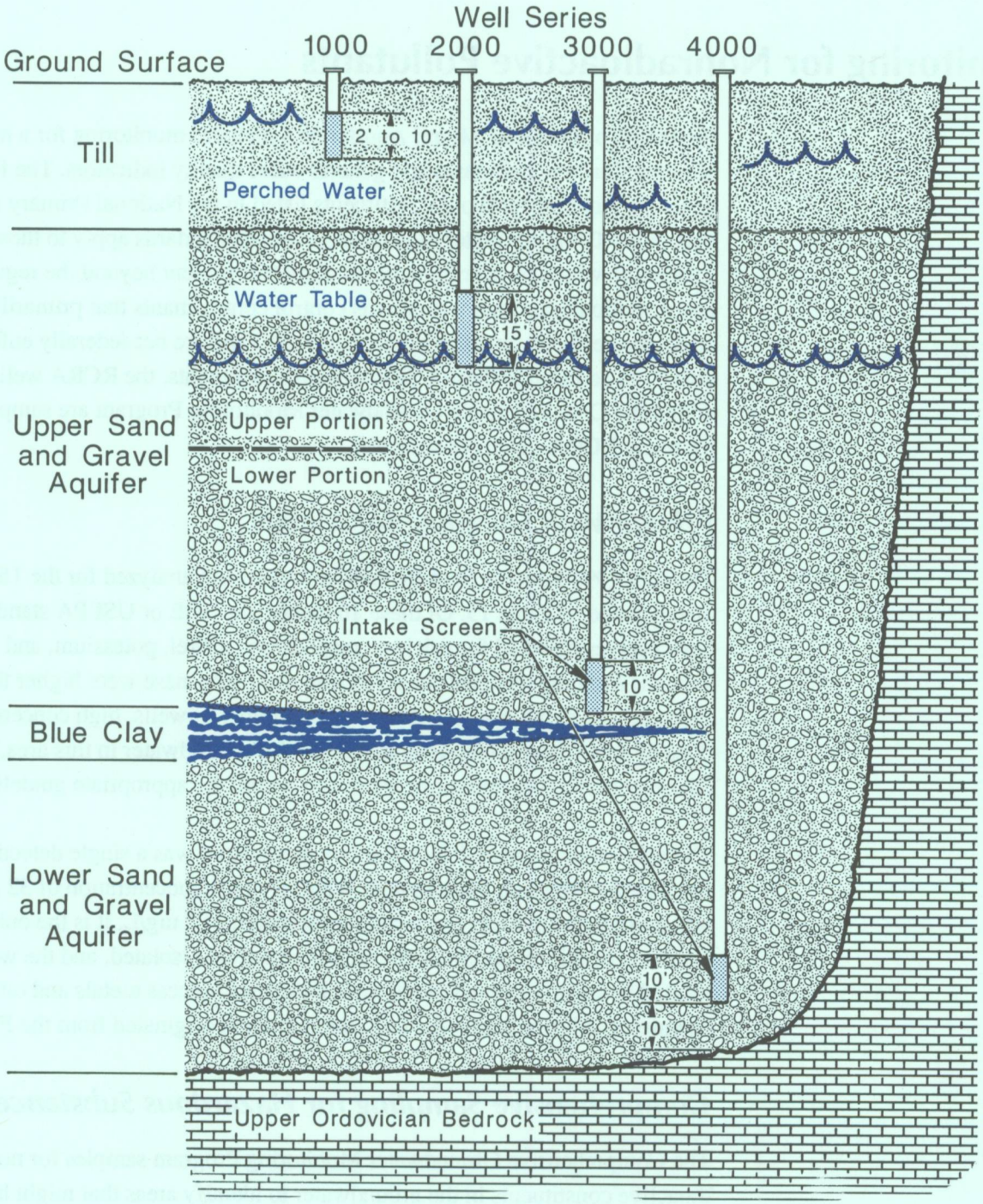
FEMP Groundwater Wells

Figure 38 depicts a typical well at the FEMP. The depth of a FEMP well and the water-bearing zone into which it extends are denoted by the first digit of the well number (Figure 39). 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.

guideline. (All four offsite locations were in the South Plume area, currently being addressed by a RI/FS removal action — see Chapter Eleven.) These 41 above-guideline sample concentrations and their relative locations are listed in Table 14.

Other radioactive elements primarily sampled for under the comprehensive program are radium, strontium, technetium, and thorium. Gross alpha activity, gross beta activity, cesium, plutonium, ruthenium, and neptunium in

Figure 39: Monitoring Well Depths and Screen Locations



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the groundwater are also monitored as indicators of radionuclide contamination. However, due to delays in the sample shipment, delays in analysis of some samples, and invalid data for other sample analyses, 1991 laboratory results for these radiological parameters were not available at the time of this report. These results will be reported in next year's ASER.

Monitoring for Nonradioactive Pollutants

Protection of the Great Miami Aquifer also includes monitoring for a number of nonradioactive pollutants and general water quality indicators. The FEMP generally samples for those constituents listed in the National Primary and Secondary Drinking Water Standards. (Primary standards apply to those substances which 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.[26]) 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

The July 1991 samples from the private wells were analyzed for the 16 metals listed in Table 15. Of these 16 metals, no DOE or USEPA standards have been established for calcium, magnesium, nickel, potassium, and sodium. Although concentrations of iron and manganese were higher than the secondary drinking water guidelines in a number of wells, high concentrations of those natural elements are typical for groundwater in this area.[5, 16, 33] All other metal concentrations were well within the appropriate guidelines.

The only other element detected above its standard was a single detection of zinc south of the site. Even though Well 15's zinc concentration of 32 mg/L was more than six times the secondary standard of 5 mg/L, it is the only detection of this metal. Since the measurement was isolated, and the well is located in an area where several local industries process metals and other chemicals, it is not likely that this contamination originated from the FEMP.

Comprehensive Sampling for Hazardous Substances

The Comprehensive Groundwater Monitoring Program samples for nonradioactive constituents in the groundwater to identify areas that might have harmful chemical concentrations as a result of production operations. All FEMP wells sampled under the comprehensive program are analyzed for metals, volatile organic compounds (VOCs), and water quality indicators listed in the National Primary and Secondary Drinking Water Standards.

This section focuses on the occurrences of these constituents above the applicable standards; in addition, those wells with detections above the primary standards are mapped in figures 40 through 43 on pages 118 through 121.

Detections above Primary Standards

The FEMP analyzes its comprehensive groundwater samples for 10 metals and 15 VOCs which have applicable Primary Drinking Water Standards. These constituents known to be a threat to human health in high concentrations are:

Metals

- Arsenic
- Barium
- Cadmium
- Chromium
- Fluoride
- Lead
- Mercury
- Nitrate
- Selenium
- Silver

Volatile Organic Compounds (VOCs)

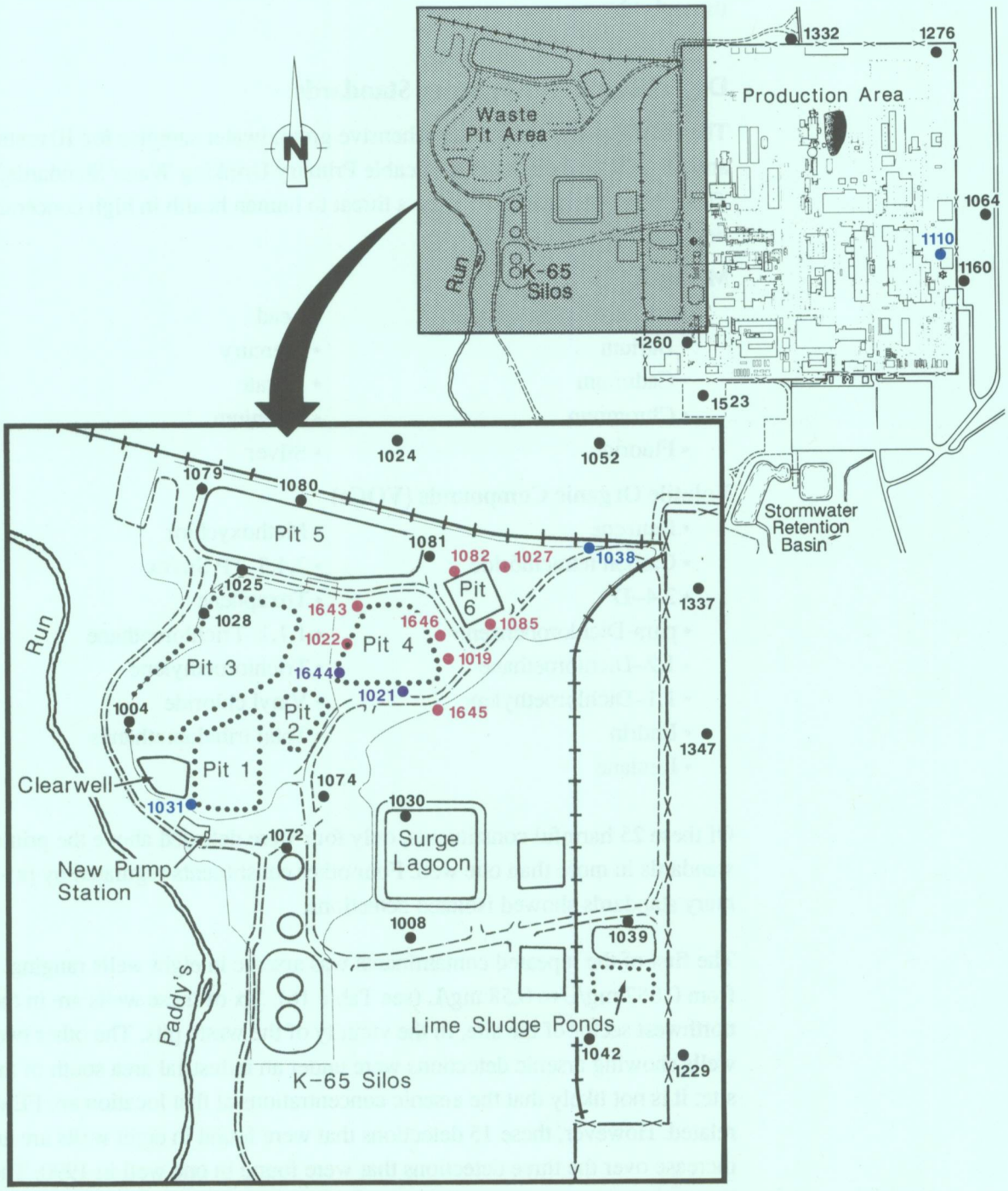
- Benzene
- Carbon tetrachloride
- 2,4–D
- para-Dichlorobenzene
- 1,2–Dichloroethane
- 1,1–Dichloroethylene
- Endrin
- Lindane
- Methoxychlor
- 2,4,5–TP Silvex
- Toxaphene
- 1,1,1–Trichloroethane
- Trichloroethylene
- Vinyl chloride
- Total trihalomethanes

Of these 25 harmful constituents, only four were detected above the primary standards in more than one well. Four other constituents regulated by primary standards showed isolated detections.

The first of the repeated contaminants was arsenic in eight wells ranging from 0.057 mg/L to 0.58 mg/L (see Table 16). Six of these wells are in the northwest sector of the site, in the vicinity of the waste pits. The other two wells showing arsenic detections were under an industrial area south of the site; it is not likely that the arsenic concentrations at that location are FEMP-related. However, these 15 detections that were found in eight wells are an increase over the three detections that were found in one well in 1990. The FEMP will continue to monitor arsenic concentrations in these areas in an effort to determine the source(s) of contamination.

Fluoride was detected above the primary standard of 4.0 mg/L in only two onsite wells. One of these wells is in the waste pit area, and the other is in the former production area. Detections ranged from 5.4 mg/L to 8.1 mg/L.

Figure 40: 1000–Series Wells



LEGEND

●1000 Series Well ●0000 DOE Guideline–Total U Detection

●0000 Primary NDWS Detection ●0000 Primary and Total U Detection

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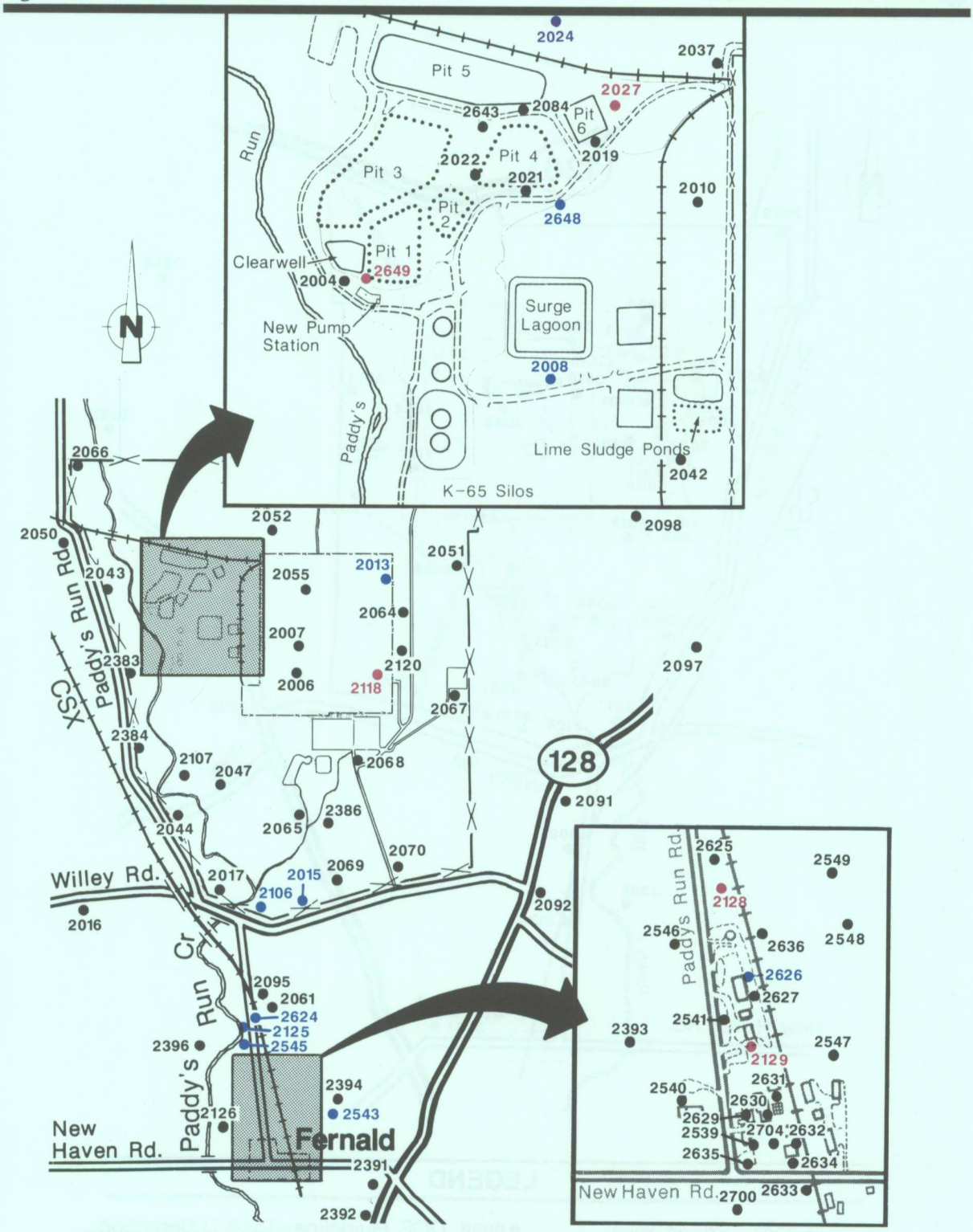
Figure 41: 2000–Series Wells



LEGEND

- ● 2000 Series Well
- ● 0000 DOE Guideline–Total U Detection
- ● 0000 Primary NDWS Detection
- ● 0000 Primary and Total U Detection

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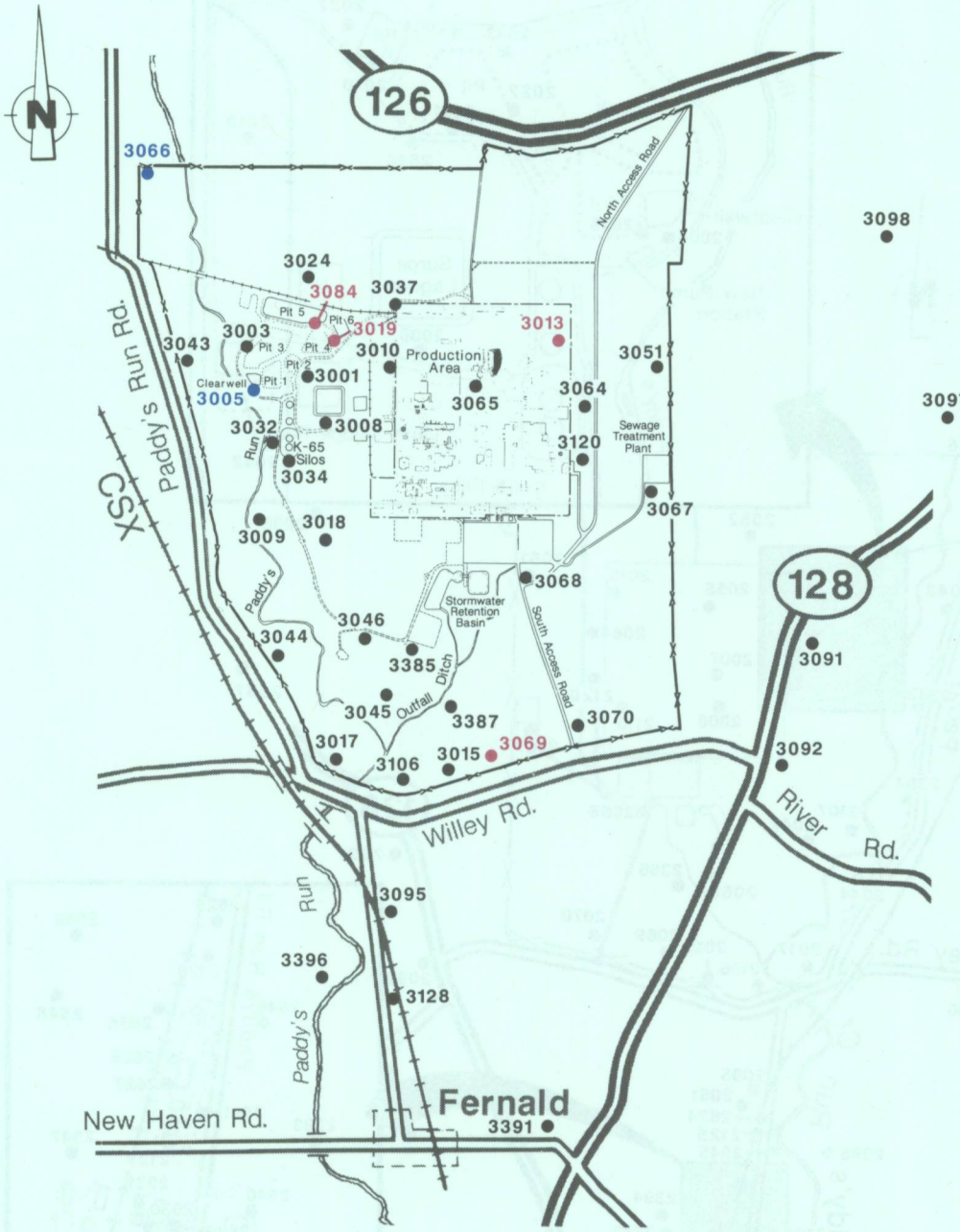
Figure 42: 3000–Series Wells



LEGEND

- ● 3000 Series Well
- ● 0000 DOE Guideline–Total U Detection
- ● 0000 Primary NDWS Detection
- ● 0000 Primary and Total U Detection

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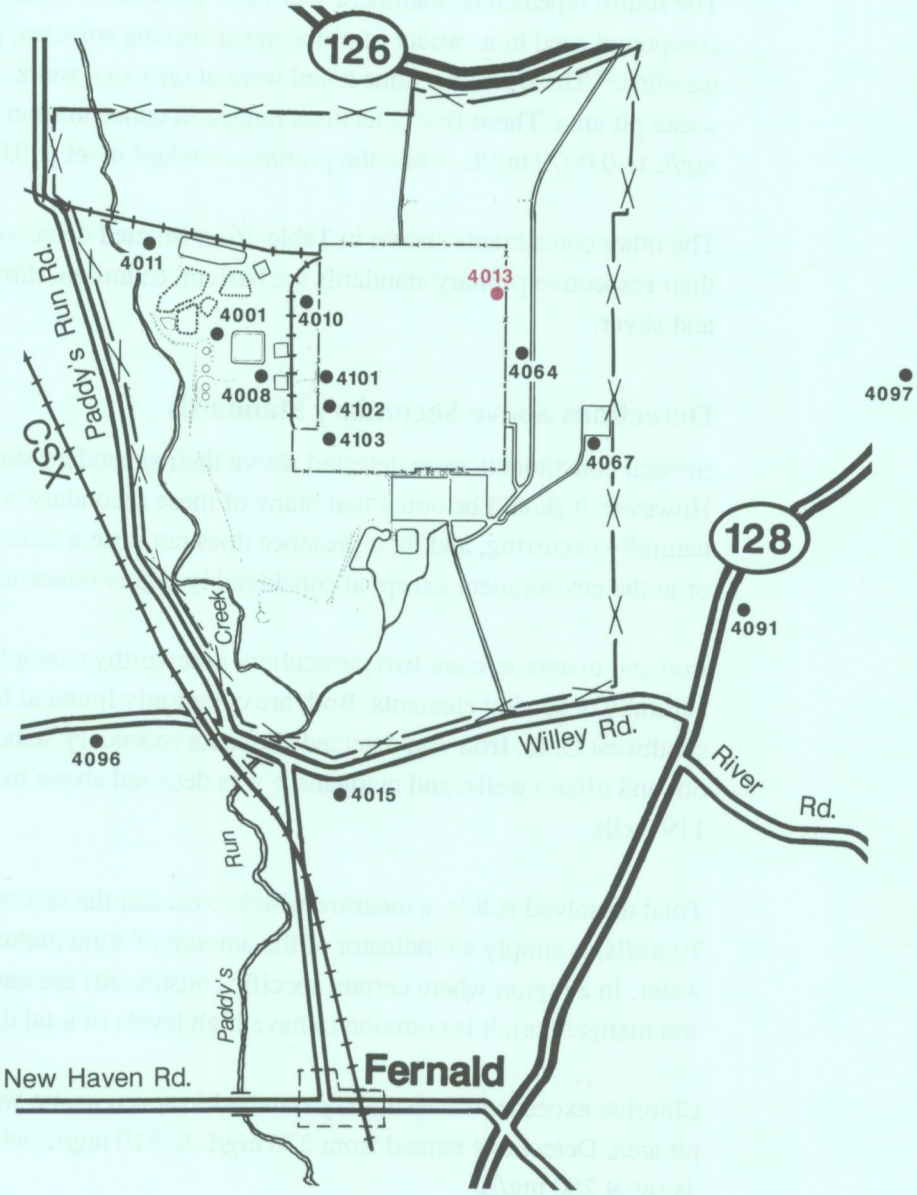
Figure 43: 4000–Series Wells



LEGEND

● 4000 Series Well ● 0000 DOE Guideline–Total U Detection

● 0000 Primary NDWS Detection ● 0000 Primary and Total U Detection

1588

Lead was detected above the primary standard of 0.05 mg/L in only three wells — two in the waste pit area and one in the former production area. However, the highest concentration was only 0.071 mg/L, less than 50% over the standard's maximum contaminant level.

The fourth repeated contaminant was vinyl chloride, a volatile organic compound used in a variety of processes involving solvents, paints, and gasoline.[27] The five detections noted were at only two wells, both in the waste pit area. These five detections ranged in concentration from 0.0050 mg/L to 0.0070 mg/L, while the primary standard is set at 0.002 mg/L.

The other constituents shown in Table 16 as isolated detections above their respective primary standards are barium, cadmium, nitrate, selenium, and silver.

Detections above Secondary Standards

Several constituents were detected above their secondary standards in 1991. However, it should be noted that many of these secondary constituents are naturally occurring, and their presence does not pose a threat to human health or to the environment except at considerably higher concentrations.[28]

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 116 on- and offsite wells, and manganese was detected above its standard at 119 wells.

Total dissolved solids, a measure which exceeded the secondary standard at 70 wells, is simply an indicator of the amount of solid matter dissolved in the water. In a region where certain specific constituents are naturally high (iron and manganese), it is common to have high levels of total dissolved solids.

Chloride exceeded its secondary standard in seven onsite wells in the waste pit area. Detections ranged from 270 mg/L to 910 mg/L, while the standard is set at 250 mg/L.

Sulfate, one of the major *anions* in water, was found above its standard in 17 wells in the waste pit area and in six wells in the former production area. Detections ranged from 253 mg/L to 1200 mg/L, while the secondary standard is set at 250 mg/L.

Finally, pH levels in the groundwater were measured outside of the acceptable range (6.5 to 8.5 Standard Units) at seven onsite wells. All seven wells showed basic (less acidic) tendencies.

The RCRA Groundwater Assessment Program

This subprogram has grown from 41 wells in 1987 to 54 wells by the end of 1991. Results from these onsite wells are used to determine the rate and extent of contamination in the vicinity of Waste Pit 4.

The onsite RCRA Groundwater Assessment Program wells are not only monitored for drinking water standards; they are also monitored for many additional RCRA parameters. These wells are sampled for 24 metals, 36 VOCs, and 14 water quality indicators. Sampling in 1991 detected at least one site-specific parameter in 12 of the onsite wells in the glacial overburden and in 22 onsite wells in the sand and gravel aquifer. As compared to 1989 and 1990 RCRA results, 42% of glacial overburden monitoring well concentrations are increasing with time. However, 83% of sand and gravel aquifer well concentrations are decreasing with time.[29] Complete results from this program are discussed in the *1991 RCRA Annual Report.*

Of the 51 Hazardous Waste Management Units (HWMUs) identified in 1991, the RCRA regulations have defined nine areas that require groundwater monitoring. The FEMP developed a plan to meet the groundwater monitoring requirements for these HWMUs and to integrate the requirements into the CERCLA process. This plan will monitor the downgradient boundaries of the facility as well as the downgradient boundaries of the Production Area and Waste Pit Area. These areas will be monitored quarterly and the analytical results will be compared to the action levels established in the RCRA Groundwater Monitoring Plan. If the analytical results are above the action levels, the CERCLA group is notified of the event and is required to evaluate the groundwater in the area.

Summary of Liquid Pathway: Groundwater Monitoring

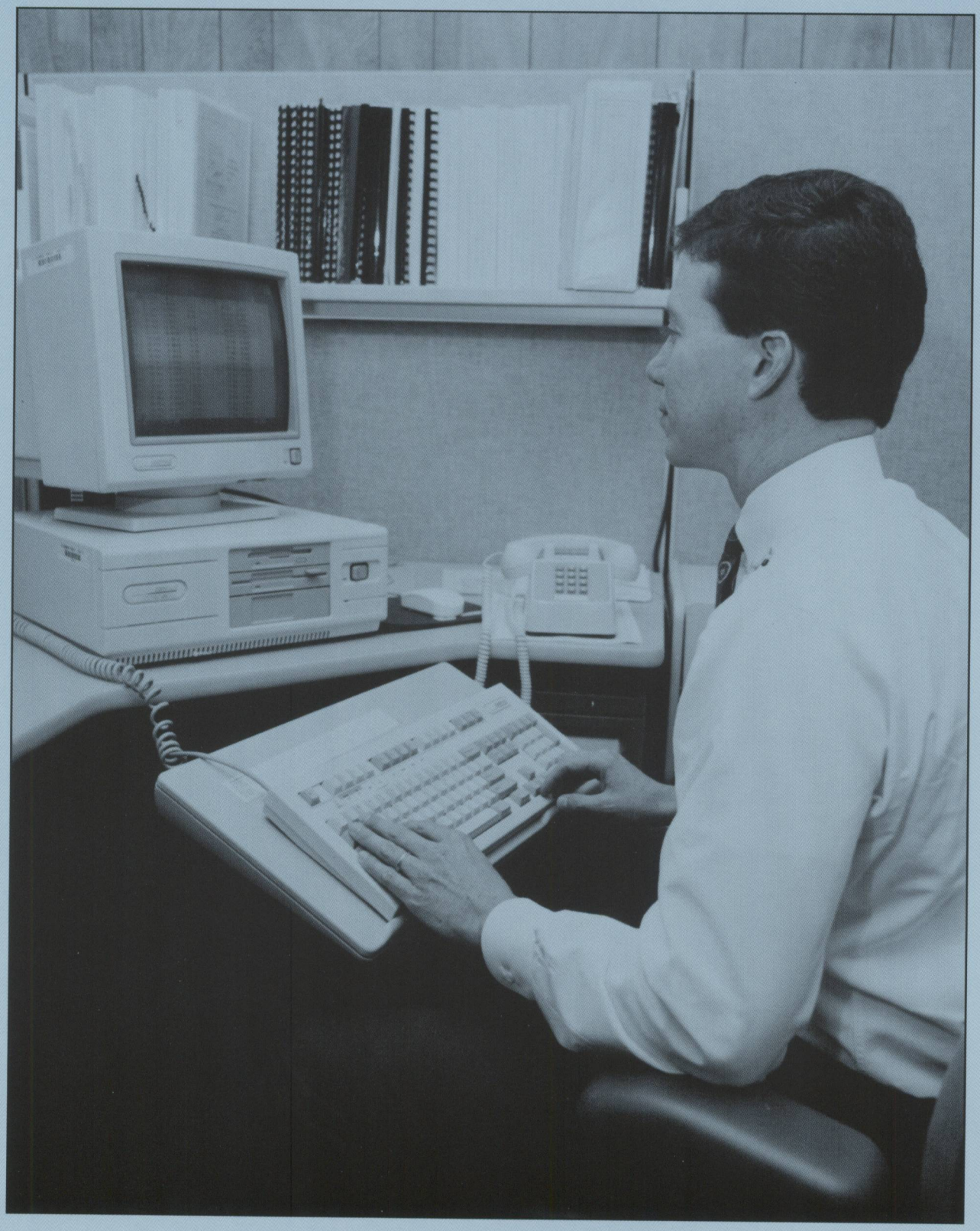
In 1991, the Comprehensive Groundwater Monitoring Program continued to sample more than 200 FEMP wells for more than 50 radiological and nonradiological parameters, and the Radiological Environmental Monitoring Program routinely sampled 37 private wells for uranium and metals. Analyses for uranium were consistent with previous years' data in that only three privately owned wells and four offsite FEMP wells showed concentrations above the DOE guideline. All of these offsite uranium detections were located in an area immediately south of the site known as the South Plume. (This South Plume area is being addressed by the South Plume Groundwater Contamination Plume Removal Action — see Chapter Three for more detail.)

Analyses for nonradiological parameters showed that metals and VOC contamination are, for the large part, restricted to the waste pits and the former production area onsite. The only exceptions to this local contamination were arsenic concentrations in an industrial area south of the site — not thought to be caused by FEMP activities — and widespread high concentrations of iron, manganese, and total dissolved solids, all of which are known to be naturally occurring.

Next, Chapter Seven will discuss the use of the concentrations of radionuclides reported here and in the previous two chapters to estimate potential radiation doses for 1991.

4030

Estimated Radiation Doses for 1991



153

Estimated Radiation Doses for 1991

One of the chief 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. One way the FEMP addresses this concern is by monitoring the ways in which radioactive material could move through the environment and reach people. Background radiation levels and naturally occurring radioactive materials present technical as well as practical problems in trying to directly measure the dose people may actually receive from the FEMP; therefore, dose is estimated using models and the results of environmental samples. Information in this chapter:

- Explains how dose estimates are calculated,
- Provides 1991 dose estimates from several different pathways, and
- Interprets the significance of these estimated doses.

Results in Brief: 1991 Estimated Doses

DOE orders and USEPA regulations require that the FEMP 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.[8,10] (This excludes radon–222 emissions, which are covered under different regulations. Radon regulations, emissions, and estimated dose from radon is presented in Chapter Eight of this report.[30]) Moreover, to show that the site is well within the DOE limit of 100 mrem* dose from all exposure pathways, the FEMP estimates doses from other components of the air and liquid pathways, as well as direct radiation from materials stored onsite. These doses for 1991 are presented in Table 17 and are also summarized below.

Air Pathway

CAP–88 modeling – The estimated maximum effective dose to a member of the public from 1991 airborne emissions was calculated as 0.3 mrem.

Produce – The estimated committed effective dose from eating produce grown within three miles of the site was 1.3 mrem, less than the estimated dose of 1.8 mrem received from eating produce grown beyond seven miles from the FEMP.

Liquid Pathway

Great Miami River – Although the river is not used as a source of public drinking water, the estimated committed effective dose from drinking river water downstream of the FEMP effluent line was 0.03 mrem. The small increase from the 1990 dose is due to lower river flow in 1991, and therefore less dilution of FEMP effluent.

Groundwater – The estimated committed effective dose from drinking water from the most contaminated offsite well was 26 mrem. This well did not supply drinking water during 1991 — it was used for monitoring purposes only.

Fish – The estimated committed effective dose from eating fish from the river near the FEMP effluent line was less than 0.01 mrem.

Direct Radiation Pathway

The maximum estimated dose from direct radiation to the person living closest to the K–65 silos was 8.8 mrem for 1991.

* 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, received over a 50–year period.

Environmental and Dose Modeling

As described in Chapter One, pathways are the routes along which radioactive material moves and may deliver a dose to the public. Monitoring of the air and liquid pathways provide the basis for the extensive environmental sampling described in chapters Four, Five, and Six. The direct radiation pathway is monitored through the use of environmental dosimeters, which are designed to measure any direct radiation that reaches the site boundary in the form of gamma rays from radioactive materials stored onsite. From this information, a dose from each pathway can be estimated by using models which predict the estimated dose. The FEMP, like many other nuclear facilities, uses models extensively to estimate doses to the public. These models are briefly explained in the following paragraphs.

An environmental model 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 simple 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, a mathematical formula can be developed that models the process. This model can then be used 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, a dose model can be constructed 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, known as codes, to conveniently handle the data and calculations.

Models play an important role in environmental monitoring because current technology makes it impractical to measure environmental doses with instruments. The nature of radioactivity and the presence of naturally occurring radioactive materials creates difficulties in distinguishing between natural radioactivity and radioactivity from the FEMP. 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 FEMP if models were not used.

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 FEMP may lead to differences between predicted and actual concentrations or doses. The results or outputs of models always involve some uncertainty in the accuracy of the estimated dose, and many have built-in assumptions which strongly influence the results. The most beneficial use of models may be their ability to estimate the upper limit of the dose and identify the most influential pollutant or pathway of exposure.

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 these primary and secondary routes (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 FEMP, dose estimates from airborne emissions are obtained using a set of computer codes called CAP–88. The FEMP used CAP–88 to determine compliance with the NESHAP requirements of the Clean Air Act. Within the CAP–88 set of codes, the AIRDOS code calculates concentrations of radionuclides in 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 CAP–88 codes calculate both individual and collective doses. Collective dose is the sum of individual doses to people in the FEMP area and is reported in the units of *person-rem.* (For example, if 10 people each receive 1 rem, the collective dose is "10 person-rem;" if 20 people each receive 0.5 rem, that collective dose also is "10 person-rem.") The person-rem unit is used as a broad measure of the radiological impacts of the FEMP and is useful in comparing the risks from FEMP operations with other facilities and industries.

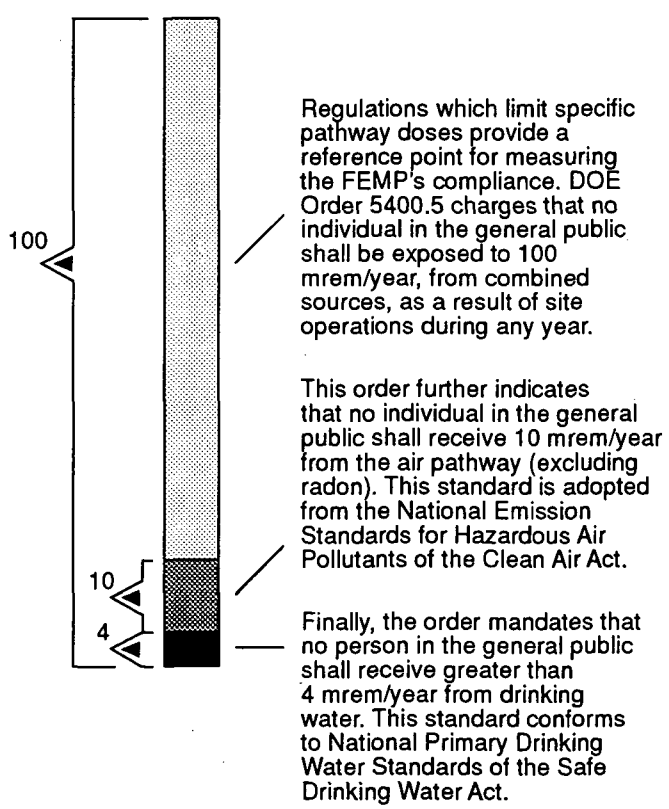
The CAP–88 codes require a large amount of data to estimate dose. The number, height, and location of release points, wind speed and direction, the amount of radioactive material released, and population distribution in the FEMP area are examples of required data. (Wind rose data are shown in Figures 7 and 8 in Chapter One, and estimated airborne radionuclide emissions and population distribution are presented in Tables 18 and 19.) Although some of the data were obtained through measurements and sampling, many data were not readily available and were estimated. Examples of

157

estimated data are the amounts of airborne radioactive material released from the waste pits, Laboratory Building, and Water Cooling Towers. The FEMP 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 for error. Conservative estimates of emissions are used to ensure that dose estimates are not underestimated but are the maximum doses that could have resulted from FEMP operations during 1991.

Results of the CAP–88 codes estimated the maximum dose from 1991 airborne emissions to be 0.3 mrem to a person located 1,100 meters (3,600 feet) north of the center of the former FEMP production area. This dose estimate assumed that the person remained outside his or her home 100% of the time in 1991. The dose was well below the NESHAP standard of 10 mrem from the air pathway and was only a tiny fraction of the DOE guideline of 100 mrem/year from all pathways (Figure 44).

Figure 44: Department of Energy Dose Limits



The collective effective dose from 1991 airborne emissions (not including radon) to the population within 80 km (50 miles) of the FEMP was also calculated by CAP–88. This dose was estimated to be 1.2 person-rem for a population of 2,640,000. For comparison, the same group of people received an estimated collective effective dose of 264,000 person-rem from background radiation, excluding radon.

Method Used to Determine Airborne Emissions

Measured and estimated uranium emissions for 1991 totaled 0.29 kg (0.64 pounds). This represents more than a ten-fold reduction from the 1990 estimated air emissions. The decrease is consistent with trends in FEMP emissions as restoration activities improve site conditions and decrease emissions to the environment. Airborne emissions are expected to remain at these low levels for several years. However, as final remediation of the site occurs, an increase in airborne emissions is possible as contaminated buildings and equipment are torn down and removed from the site. Uranium discharges from monitored stacks were the only emissions that were actually measured; emissions from all other sources listed here were estimated.

These 1991 airborne emissions used in the CAP–88 computer codes were organized as follows:

Emission Category	Percentage of Uranium Emission	Sources	Comments
Monitored Stacks	1.8%	Two stacks	Decrease from 33 stacks in 1989 reflects end on production
Unmonitored Stacks	17.2%	Decontamination and decommissioning building and Plant 8	Some estimated emissions were from the processing of wastes for shipment offsite
Water Cooling Towers	55.2%	Cooling towers at the Boiler Plant	Estimated using uranium concentration of cooling water and loss of water as mist
Lab Emissions	0.93%	Exhausts from fume hoods where radioactive materials are analyzed	Estimated based on 0.1 gram of uranium released per operating fume hood
Fugitive Emissions from Waste Pits	24.1%	Uranium-contaminated soil and dust from the waste pits	Estimated according to USEPA method[31]

Estimated Dose from Eating Produce Grown near the FEMP

Since the CAP–88 codes calculated doses from only 1991 airborne emissions, additional dose calculations were made to estimate doses from past emissions that may have accumulated through the food chain. These additional calculations show potential dose from eating locally grown fruits and vegetables.

Uranium deposited in soil during the years the FEMP was in production may be absorbed by produce and, therefore, deliver a secondary pathway dose. This estimated dose is based on the conservative assumption that 100% of a person's diet of fruit and vegetables comes from gardens and farms in the FEMP area. This model diet assumes an annual consumption of 45 kg (100 pounds) of above-ground vegetables, 68 kg (150 pounds) of fruit, and 28 kg (62 pounds) of below-ground vegetables.[32] Tomatoes, apples, and beets

sampled from local gardens and farms were analyzed for uranium to represent the foods in the diet. Dose conversion factors convert the intake of a particular radionuclide to dose. The conversion factors themselves are the result of modeling the radioactive decay and metabolism of radionuclides in the body.[33] The effective dose received over the course of 50 years was calculated to be 1.3 mrem, a small fraction of the DOE dose limit of 100 mrem per year for all pathways. As a comparison, the effective dose received from produce grown at locations distant from the FEMP was calculated to be 1.8 mrem. In comparison to the natural occurrence of uranium in foods found at locations distant from the FEMP, the dose attributable to FEMP emissions is insignificant.

Estimated doses for 1991 are higher than the 1990 estimated doses for both locations. This increase is attributed to higher concentrations observed near the site, far from the site, and in the overall averages. For example, near the site in 1990, location 1 had a tomato result of 0.029 pCi/g versus 0.27 pCi/g in 1991, far from the site, location 16 had a tomato result of 0.027 pCi/g in 1990 versus 0.61 pCi/g in 1991, and the average tomato concentration for all locations in 1990 was 0.033 pCi/g versus 0.26 pCi/g in 1991. The higher concentrations are probably the product of the analytical technique rather than from site emissions (fluorometric uranium was used in 1991 and kinetic phosphorescence was used in 1990.)

Estimated Doses at the Air Monitoring Stations

Average air concentrations of uranium measured at the seven fenceline air monitoring locations were entered in a variation of the CAP–88 code, which calculates dose using measured air concentrations. Data on the concentrations of trace radionuclides were not available for dose calculations, but since the largest portion of the dose in the air pathway is from uranium, the calculated doses provide a good estimate of the total dose at each station. Table 20 presents the estimated committed effective doses that could be accumulated for the next 50 years by a person breathing the air at any one of the stations 100% of the time during 1991.

By comparing doses obtained by this method with doses obtained using estimated emissions (uranium and trace radionuclides) in the CAP–88 code, an evaluation can be made of the accuracy of the estimated emissions. If these dose estimates are similar, then an accurate estimate was made for unmeasured, unmonitored airborne emissions. The comparison shows a reasonable agreement between estimated doses from measured and estimated emissions. This suggests that the calculations to estimate emissions were accurate.

Comparison of Estimated and Measured Effective Dose at Air Monitoring Stations

AMS Number	*Estimated Dose Using Model (mrem)*	*Dose from Measured Concentrations (mrem)*
1	*0.3*	*0.1*
2	*0.1*	*0.2*
3	*< 0.1*	*0.2*
4	*< 0.1*	*0.1*
5	*0.1*	*0.1*
6	*0.2*	*0.1*
7	*0.1*	*< 0.1*

Liquid Pathway Dose Calculations

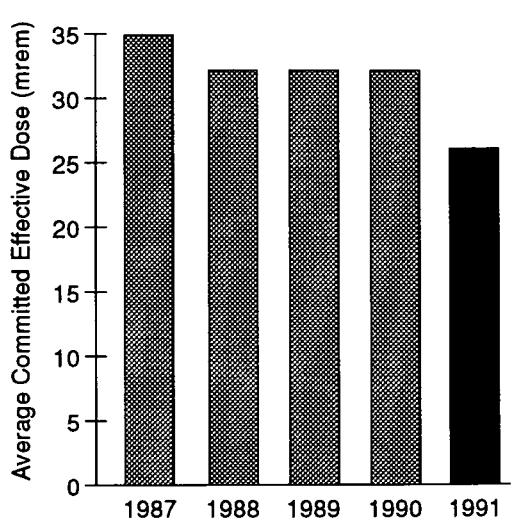
Dose estimates from the liquid pathway are calculated using environmental sample results and dose conversion factors. Measurements of radionuclide concentrations in the Great Miami River, groundwater, and fish from the river are used to estimate dose from the liquid pathway. Descriptions of the sampling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

Estimated Dose from Drinking Groundwater from Well 15

Although Well 15 (located just south of the FEMP — see Figure 36) is no longer used as a drinking water source, an estimate of the dose received from drinking water from the well is provided as a measure of the upper limit of the dose received from drinking well water in the FEMP area. Using a consumption rate of two liters of water per day and the average 1991 uranium concentration, the effective dose received over the course of 50 years would be 26 mrem (Figure 45).[32] The slight decrease in dose from past years is attributable to the lower uranium concentrations measured in Well 15 during 1991.

Because Well 15 is not used as a drinking water well, calculating a dose received from Well 15 water does not represent an accurate estimate of dose to members of the public. In order to provide more accurate dose estimates, future FEMP ASERs will not contain calculated dose from Well 15. However, the FEMP will continue to monitor this well.

Figure 45: Well 15 Dose



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

As discussed in Chapter Six, the FEMP monitors a number of private wells which have uranium concentrations within the range of background levels. For Ohio, the range of background concentrations is considered to be 0.1 to 2.7 parts per billion (0.07 to 1.8 pCi/L). In order to develop a better understanding of the dose received from background levels of uranium in well water, the FEMP estimated the dose received from this range of background concentrations. Using a consumption rate of 2 liters (0.5 gallons) of water per day, the effective dose

received over the course of 50 years would range between 0.01 mrem and 0.3 mrem. The actual dose received would depend on the concentration present in the private well. This range of background doses is useful information in developing a perspective for evaluating the small, incremental dose attributable to FEMP emissions.

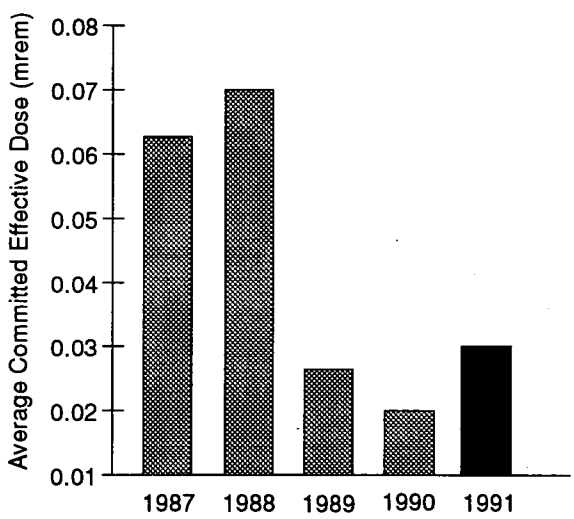
Estimated Dose from Drinking Great Miami River Water

Although the Great Miami River downstream of the FEMP is not designated as a public water supply by the OEPA, the FEMP estimated the radiation dose to an individual if that person drank only the water from the river downstream of the FEMP discharge point after mixing had occurred. Assuming a daily consumption of 2 liters (0.5 gallons) of water, the effective dose received over the course of 50 years would be 0.03 mrem (Figure 46).[32] This dose is larger than the dose calculated for 1990 due to the lower river flow (and therefore less dilution of FEMP effluent) in 1991.

Estimated Dose from Eating Fish from the Great Miami River

To estimate dose from eating fish from the river, the average uranium concentrations in fish collected at upstream, FEMP outfall, and Paddy's Run sampling locations (see Figure 35) were compared; the highest of these values was used to estimate the dose. Assuming an annual consumption of 4.4 kg (9.7 pounds) of fish from the Great Miami River, the effective dose received over the course of 50 years would be less than 0.01 mrem.[32] This dose is well below the DOE guideline of 100 mrem/year from all pathways.

Figure 46: Great Miami River Dose



Direct Radiation Dose

Unlike the air and liquid pathways where a radionuclide in the form of particulate or gas delivers its dose after inhalation or ingestion, direct radiation dose is the effect of gamma rays reaching nearby residents 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. Unlike dose from the air and liquid pathways, direct radiation dose is measured rather than estimated through the use of models.

Doses from direct radiation to people living near the site are periodically measured using a pressurized ionization chamber; long-term measurements are made with environmental *thermoluminescent dosimeters* (TLDs). The pressurized ionization chamber measurements are chiefly used to monitor the direct radiation emitted from the K–65 silos, while the environmental TLDs are used to monitor direct radiation emitted from all the radioactive materials stored onsite, including the silos. The annual dose from direct radiation is calculated using net TLD results (typically four TLD results per year) from each location (Table 21). The annual dose from direct radiation in 1991 was estimated to be 8.8 mrem per year to the person living closest to the K–65 silos. This dose assumes that the shielding provided by the house and the percentage of time the house is occupied reduces the dose by 50%.

The bentonite slurry layer added to the K–65 silos has since reduced the direct radiation dose received from the silos by over 90%. However, because the bentonite slurry was added late in 1991, the direct radiation dose from the silos is near the 9 mrem reported in 1990. The direct radiation dose is expected to decrease further in 1992.

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 FEMP area who receives the most dose, the results of the individual pathways and the CAP–88 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 1991 airborne emissions (excluding radon), eating produce grown in the FEMP area, drinking water from the Great Miami River (even though the river is not a source of drinking water south of the FEMP), eating fish from the Great Miami River, and the direct radiation dose at the home nearest the K–65 silos. The conservative assumptions

used throughout the dose calculation process assure that the dose to the maximally exposed individual is the upper limit of the actual dose any member of the public receives. For comparison, the dose attributable to background radiation and concentrations of naturally occurring radionuclides is also provided.

Dose to Maximally Exposed Individual

Pathway	***Dose Attributable to FEMP***	***Applicable Guideline***	***Dose Attributable to Background***
Air			
Estimated 1991 emission	*0.3 mrem*	*10 mrem/air*	
Produce grown in FEMP area	*– mrem**	*100 mrem/all pathways*	*1.8 mrem*
Liquid			
Water from Great Miami River	*0.03 mrem*	*4 mrem/drinking water*	
Fish from Great Miami River	*< 0.01 mrem*	*100 mrem/all pathways*	*36 mrem***
Direct			
At home near K–65 silos	*8.8 mrem*	*100 mrem/all pathways*	*56 mrem*
Maximally exposed individual	*9.1 mrem*	*100 mrem/all pathways*	

**No measurable dose from eating produce grown in the FEMP area.*
***Total dose from natural radionuclides taken into the body from food and water.*

Significance of Estimated Radiation Doses for 1991

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

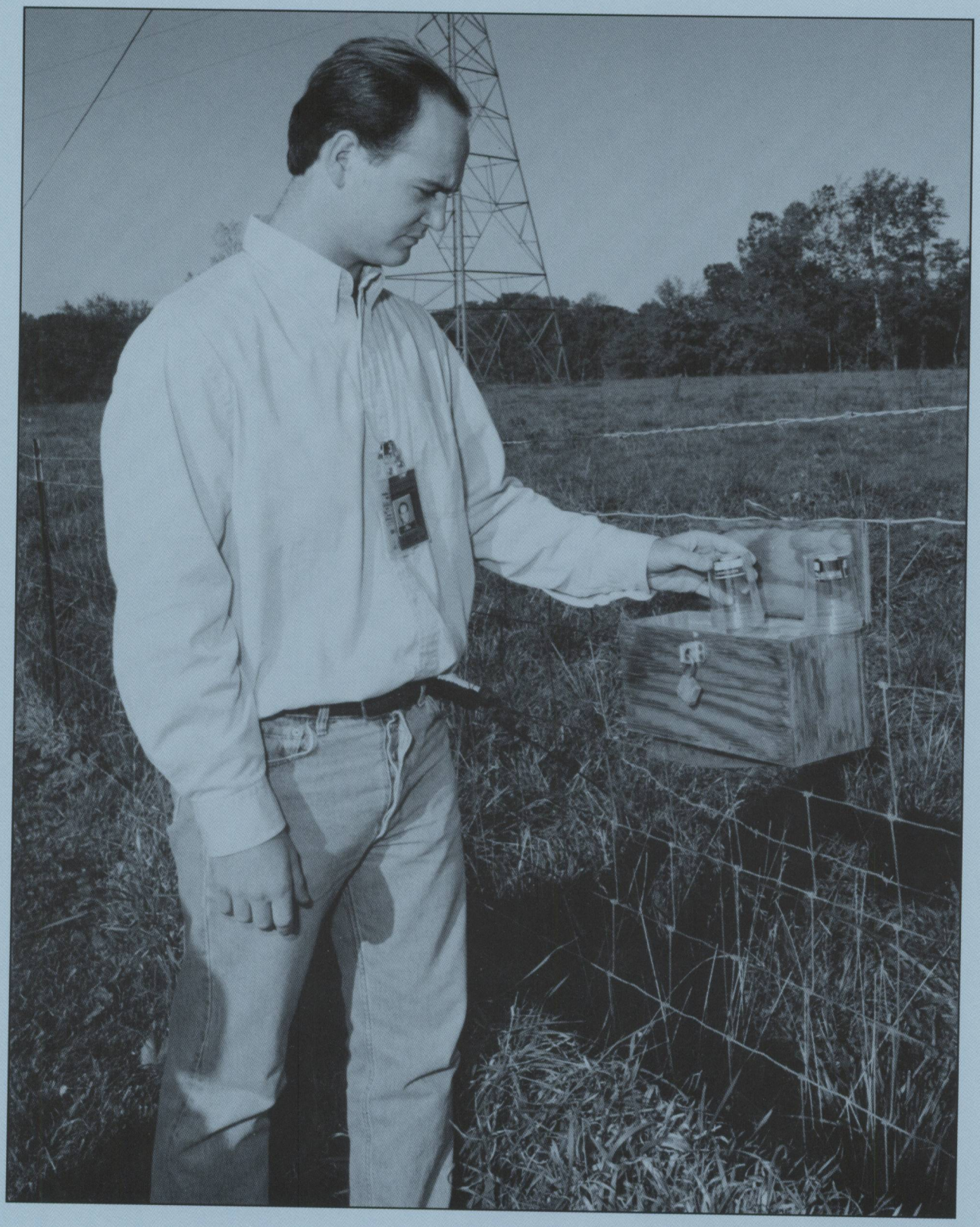
Another method of determining the significance of the estimated doses is to compare them with dose limits developed to protect the public. The ICRP has recommended that members of the public receive no more than 100 mrem/year, and the DOE has incorporated this limit into Order 5400.5 as well. All estimated doses from FEMP operations for 1991 were well within this limit.

Summary of Estimated Radiation Doses for 1991

Results of the dose estimate calculations indicated that the radiation dose from the FEMP to nearby residents was a small fraction of the background radiation dose a person receives each year from natural sources. The estimated dose to the maximally exposed individual was well below the DOE guideline of 100 mrem per year from all pathways.

The next chapter discusses the regulations which apply to radon and the methods used to monitor radon emissions and estimate dose from radon at the FEMP.

The Radon Monitoring Program



The Radon Monitoring Program

Although radon has always been present in the atmosphere, it has recently become a topic of increasing concern to the public through media attention. Nearly everyone has either read newspaper articles, magazine articles, or viewed televised presentations on the topic. Many individuals have also had their homes tested for the presence of radon. Detection of radon requires special monitoring apparatus. Governmental agencies and the scientific community have devoted considerable time and money to developing ways to detect and study the effects of radon.

The concern stems in part from the fact that radon is a radioactive gas that occurs naturally throughout the environment. The presence of radon is also a concern because radon cannot be seen, tasted, smelled, or in anyway detected through our normal senses. Furthermore, even though it cannot be sensed, high levels of radon have been linked to negative health effects if inhaled. Radon can, however, be detected by using various sampling equipment which will be discussed later in this chapter.

Everyone is continuously exposed to radon at varying concentrations, and exposure to radon is part of the annual *background radiation* dose that we all receive. It contributes approximately 55% of our average annual dose. Radon has also been found in particularly high concentrations in the lower levels of homes and other buildings where there are cracks or leaks in foundations that allow radon to enter into the house. Structures with poor ventilation also allow radon concentrations to build up.

Radon levels have been routinely monitored at the FEMP since the early 1980s. The Radon Monitoring Program at the FEMP operates in compliance with the requirements set forth in DOE Order 5400.5, "Radiation Protection of the Public and the Environment."

Introduction to Radon

Three isotopes of radon are found in the environment. They are a part of the uranium–238, thorium–232, and uranium–235 (actinium) decay series. These decay series or chains are formed by a series of natural radioactive decays, with many individual isotopes having extremely long half-lives. Radon–219 (actinon) is the seventh decay product in the actinium decay chain. Radon–220 (thoron) is the fifth decay product in the thorium decay chain. Radon–222 (radon) is a decay product from the uranium–238 decay chain. It is the sixth decay product in the chain. These decay chains are shown in Figure 47.

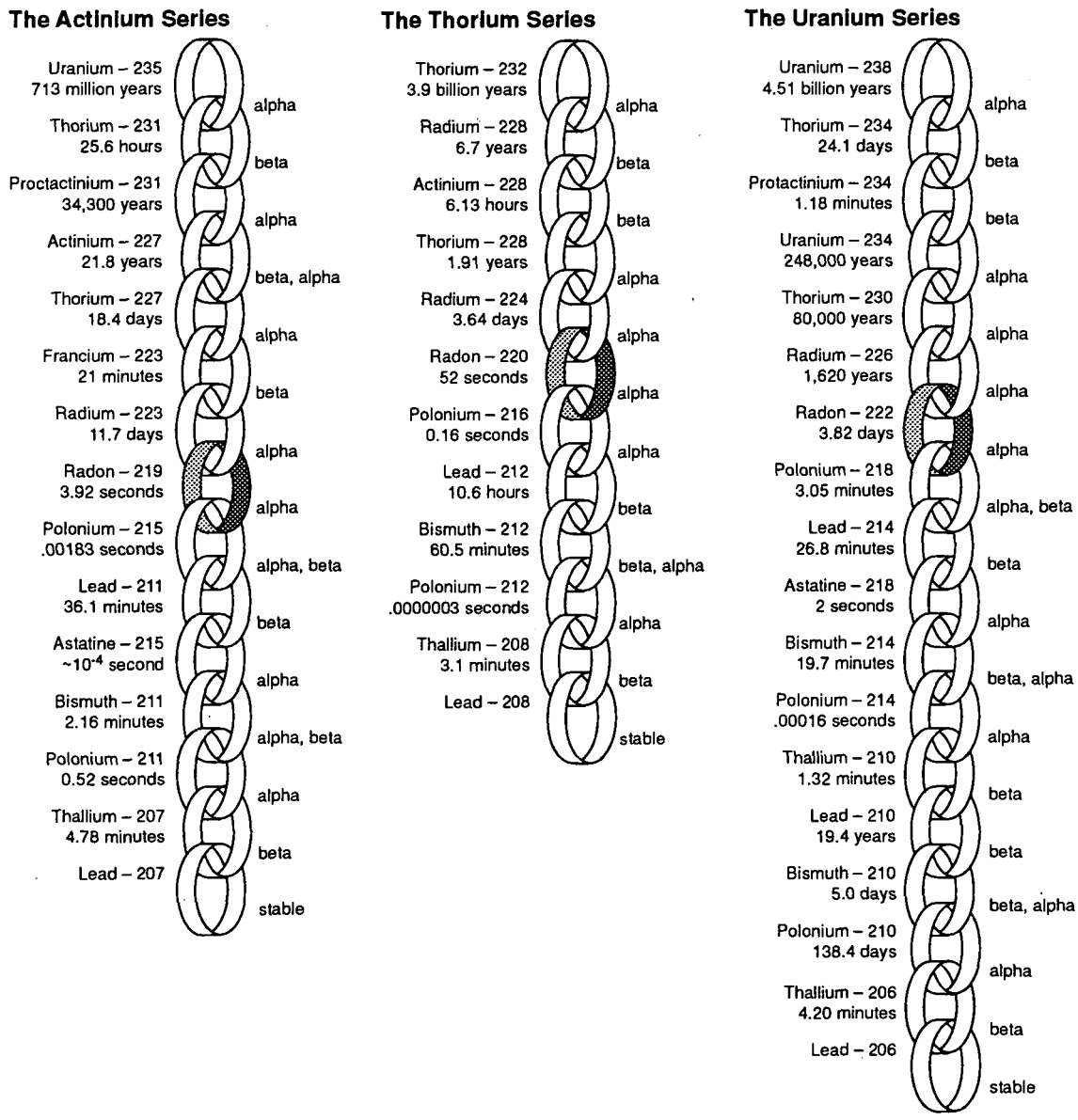
Of minor importance is radon–219 due to its 3.96 second half-life and the fact that it comes from uranium–235, which has a very low natural distribution in the environment. Radon–220, with a significantly longer half-life of 55.6 seconds, can be a significant contributor to the potential radiation dose to people. This occurs primarily in geographic regions that have shallow deposits of thorium-rich soils. Although the area on which the FEMP is located does not contain thorium-rich soils, the FEMP monitors for radon–220 because thorium compounds have been stored at the site since the early 1970s. At one time, the FEMP studied possible uses for thorium and had processed the material for use at other government facilities.

Radon–222 is a naturally occurring decay product of uranium–238 which is widespread in the earth's crust. Radon–222 has the longest half-life of the radon isotopes, 3.8 days, and it gives rise to the majority of the concern for risks from radon exposure. Since this isotope is the cause of most concern in the environment, the general term radon refers to this isotope. Radon–222 is virtually everywhere because of the widespread distribution of its parent radionuclides, radium–226 and uranium 238, in the earth's crust.

Isotopes and Radionuclides
Atoms with the same atomic number but with different mass numbers are referred to as isotopes. Isotopes have the same chemical properties as one another but frequently have very different radiological properties. Isotopes are often confused with radionuclides. However, an isotope has a much more limited definition. It signifies one form of an element, while radionuclides refer to any radioactive element, including many isotopes.

Radon decays into a series of short-lived radionuclides that are collectively referred to as radon "daughters," or radon decay products. Some of these short-lived daughters emit alpha particles. As alpha particles are easily shielded by the skin, the primary concern of radon exposure is the internal dose received by inhalation. When these radon daughters are inhaled and alpha particles are released within the lungs, the cells lining the airways may be damaged and lung cancer may ultimately result. This dose is attributed to the radon daughters. As discussed in Chapter Two, an alpha particle

Figure 47: Decay Chains



consists of two protons and two neutrons and, therefore, has a positive charge. As the positively-charged radon daughter alpha particle moves through the electrons of this newly-formed atom, some electrons are knocked out of orbit, leaving the atom with a deficiency of electrons. This deficiency will eventually be made up, but until it is, the atom will be attracted to anything with a negative charge. The atom will decay about four more times in less than an hour, producing additional particles.

Radon in the Environment

Outdoor Concentrations

Radon's importance as a source of background radiation depends principally on three factors: the concentration of the parent material, the physical characteristics of the rocks and soil, and its half-life. The amount of *parent material* in the area is a significant factor in determining the amount of radon found there. The last two factors determine its ability to migrate into air and water. The relatively short half-life of radon allows some media to become an effective filter barrier.

Some of the radon produced by radium escapes into the air spaces around soil particles and then diffuses into the atmosphere. As the decay series progresses and radon gas forms, radon leaves the soil or rock that the parent material is found in and then enters the surrounding soil or water. From there, radon is released into the atmosphere. Consequently, radon is always present in outdoor air and is a source of background radiation. However, specific concentrations will depend on the local environment.

The outdoor concentration of radon in the atmosphere shows daily and seasonal patterns. 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, radon concentrations rise 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.)

Indoor Concentrations

When radon is released into an enclosed space, it cannot disperse into the atmosphere. These on-going releases result in increased radon concentrations. This occurs in underground mines as well as in buildings.

The majority of the radon found in homes comes from the soil beneath and immediately around the house. Basements, then, tend to have the highest levels, and upper floors have the lowest. Radon, however, can be transported far away from where it was formed by dissolving in groundwater and then traveling the groundwater path until it reaches an air pathway such as a foundation or sump. Releases from building materials and domestic water are a common secondary source of radon. Radon from unvented natural gas usage is a minor source in some houses.

Indoor radon concentrations are ordinarily several times higher than those observed outdoors because radon cannot disperse as easily. Sealing any

cracks in the foundation and gaps around sumps or places where pipes or conduit enter the foundation frequently will reduce indoor radon concentrations. Indoor radon concentration can, in some cases, also be reduced markedly with the use of ceiling fans and by dilution with outside air. Ventilation as a means to remove the buildup of radon from houses, however, can produce mixed results; depressurizing a house with exhaust ventilation may pull more radon from the soil into the house.

Radon at the FEMP

In addition to the radon formed naturally in the environment, the FEMP stores some materials onsite which are parent materials of radon. The FEMP has monitored radon levels routinely since the early 1980s. At that time, advanced technology made it possible to monitor radon relatively accurately and easily.

It is believed that the principal source of radon emissions from the FEMP is currently the ***K–65 silos*** because of their radon-emitting ore residues. Radon can escape through the cracks, and access ports, on top of the K–65 silos. To ensure that radon emissions are monitored as efficiently as possible, radon concentration measurements are taken in the air at points immediately adjacent to the silos and at points on the FEMP facility fenceline, as well as in the headspace of the silos themselves. A bentonite sealant was placed over the residues to reduce the amount of radon emitted into the headspace. This removal action is discussed later in this chapter.

Waste pits 1, 2, and 3 are sources of radon because they contain radium, which is the parent material for radon. In November 1991, Large Area Activated Charcoal Canisters were used to monitor the radon flux emanating from these pits. The results are discussed later in the next section, "Radon Monitoring at the FEMP."

Another potential source of radon emissions is ***Waste Pit 4*** which was capped and covered with a hypalon layer. Waste Pit 4 will be monitored in 1992 according to a USEPA agreement. ***Waste Pit 5*** is a potential source of radon emissions when it is not covered with water. In 1991, Waste Pit 5 was only uncovered at times of repair to its liner membrane. Waste Pit 6 is not considered a source of radon since very few radium-bearing materials are contained in it.

Radon Monitoring at the FEMP

It is DOE's objective to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained As Low As Reasonably Achievable (ALARA). Therefore, DOE facilities monitor all releases applicable to site activities and also assess radiation exposures to members of the public. Aside from providing protection to members of the public, it is DOE's objective to protect the environment from radioactive contamination.

Since the FEMP still stores radium-bearing materials onsite, radon concentrations in the atmosphere above facility surfaces or openings are regulated by DOE Order 5400.5. This order presents radiological protection requirements and guidelines for cleanup of residual radioactive material and 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. Since the FEMP stores radium-bearing materials onsite, the Radon Monitoring Program operates under these guidelines. When added to background levels, these concentrations must not exceed the following limits:

- 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.

NESHAP subpart Q also has a flux-rate requirement but will not be applicable as a requirement until on-going remedial actions have been conducted and the final remedial action to abate the radon emission problem has taken place. These actions are conducted in compliance with the requirements of the Federal Facility Compliance Agreement/Federal Facility Agreement (FFCA/FFA). Therefore, all actions related to the control and abatement of radon–222 at the FEMP are performed in cooperation with USEPA.

Methodologies

To determine radon concentrations in the environment, the FEMP uses two types of detectors to monitor the alpha particles that are produced as radon gas decays: alpha-track etch detectors and real-time scintillation detectors.

An ***alpha-track etch detector*** is a cup which contains a special plastic chip inside. When alpha particles from radon (or its daughter products) interact with certain types of plastic, they will leave latent tracks in the material.

172

The tracks can be made detectable by chemical or electrochemical etching. The number of etches or tracks in the material is equal 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 and be measured. All environmental radon data reported in the 1991 ASER are from the alpha track-etch radon detectors, and they can be found in Table 22. These detectors are changed every three months and provide long-term radon measurements.

Data are obtained from 21 locations at the site boundary using alpha track-etch monitoring cups. Data are also obtained from three area residences and four background locations as shown in Figure 48 on page 144. The alpha track-etch monitoring cups are also used for measurement adjacent to the silos and in the predominant wind direction from them.

In 1991, the FEMP used the same four locations as in 1990 to determine the background radon level. (The background locations are air monitoring stations 15 and 16 and background locations 1 and 2.)

Real-time monitors, which record radon concentrations on an hourly basis, detect alpha particles from the decay of radon gas by using a *scintillation cell*. These monitors provide an immediate readout of radon concentrations in the ambient air where it is needed. In 1992, these monitors will be used to provide continuous monitoring of radon concentrations in the silo headspace. Air is not pulled into the monitor. Rather, it diffuses into the monitor through a foam barrier (a technique called passive sampling); any radon gas present in the diffused air decays into its daughter products, some of which are alpha particle emitters. The emitted alpha particles strike the alpha sensitive scintillator which lines the interior, producing light pulses. These light pulses are amplified and then counted. It takes about a half-hour to achieve the same radon gas level inside the cell as is present in the surrounding air. (This equipment is not affected by humidity, dust, or changes in temperature.) The locations of these monitors are shown in Figure 49 on page 145.

Since not all the alpha particles result in light pulses, the raw counts must be compensated to account for the alpha particles which do not get counted. A special value, known as sensitivity (S), compensates for missed alpha particles and is used for converting the raw counts into a measure of the radon gas concentration. (Sensitivity is determined as part of the calibration process, prior to actual monitoring.)

Figure 48: Offsite and Fenceline Radon Monitoring Locations

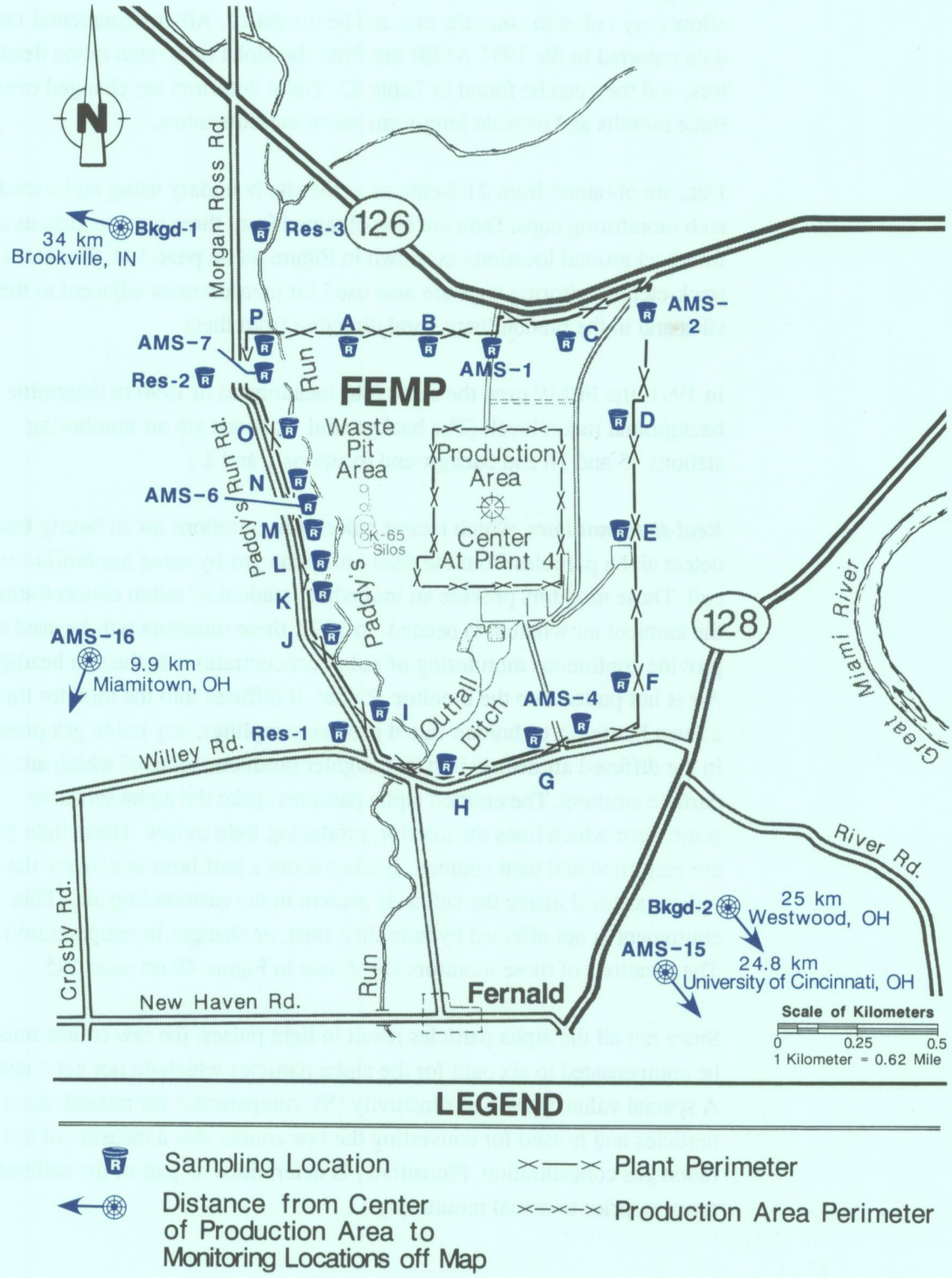


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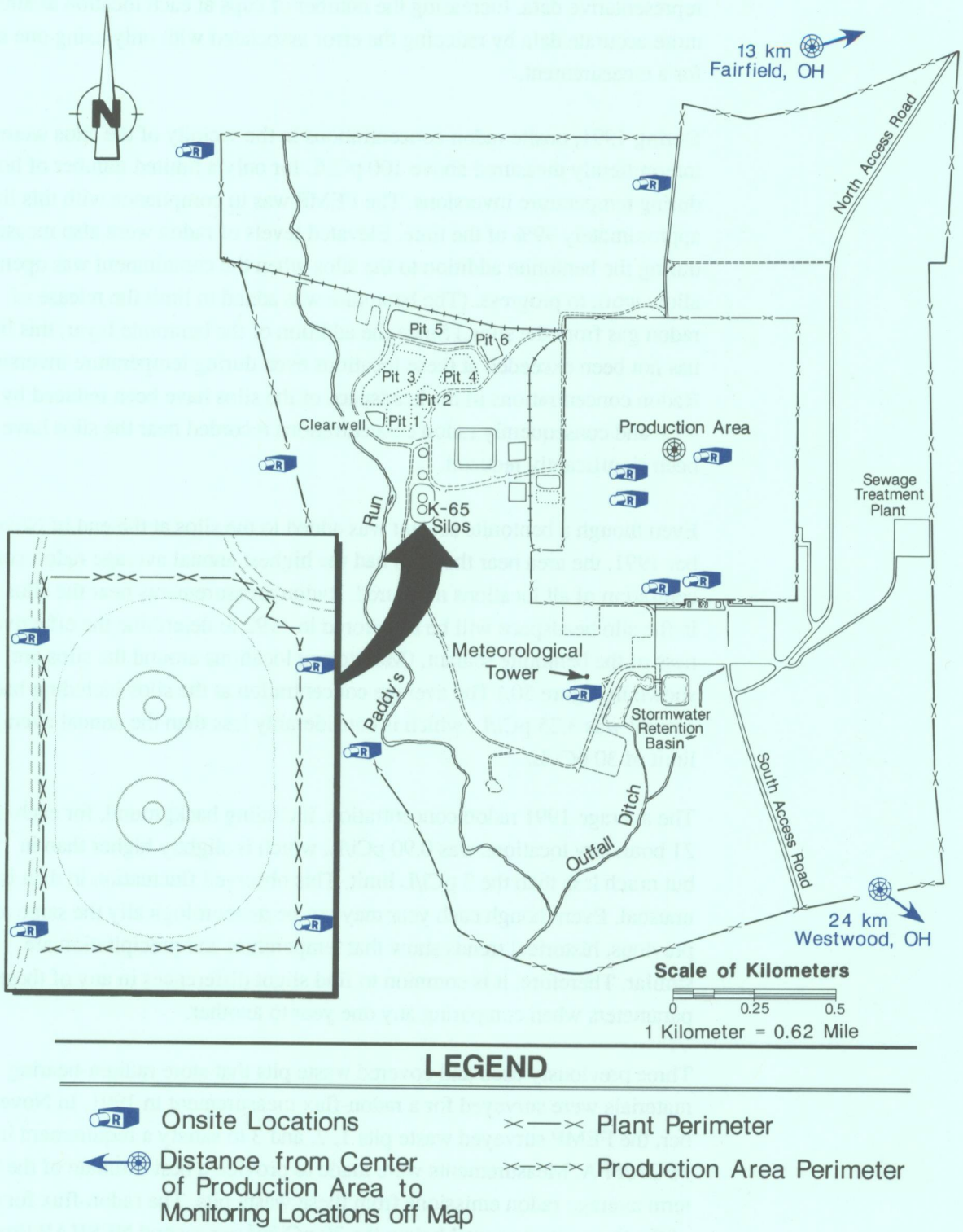
Figure 49: Real-Time Radon Monitoring Locations



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1991 Radon Monitoring Results

Over the years, the Radon Monitoring Program at the FEMP has increased the number of detectors used at each monitoring location to gather more representative data. Increasing the number of cups at each location assures more accurate data by reducing the error associated with only using one cup for a measurement.

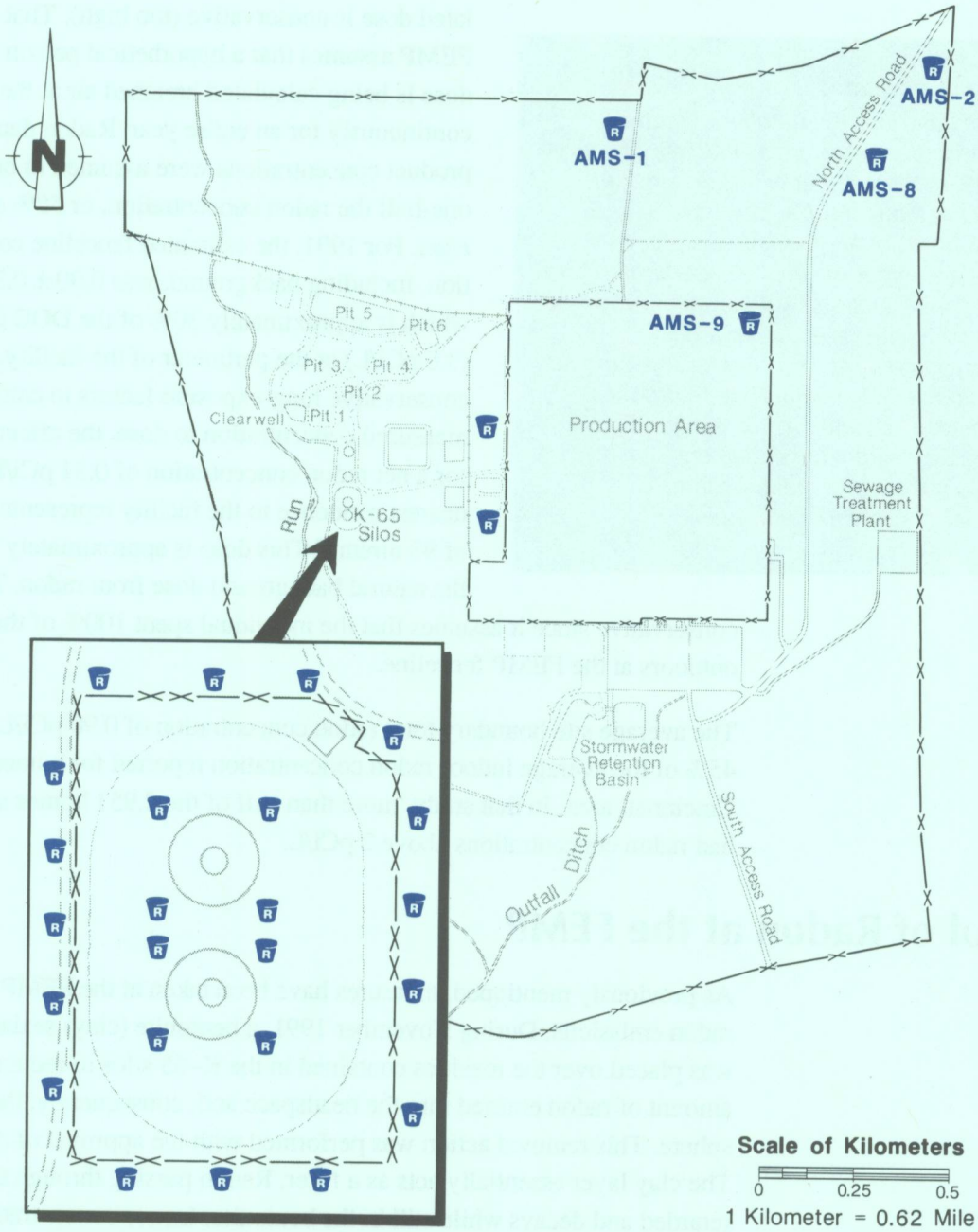
During 1991, onsite radon concentrations in the vicinity of the silos were intermittently measured above 100 pCi/L for only a limited number of hours during temperature inversions. The FEMP was in compliance with this limit approximately 99% of the time. Elevated levels of radon were also measured during the bentonite addition to the silos when the containment was open to allow work to progress. (The bentonite was added to limit the release of radon gas from the silos.) Since the addition of the bentonite layer, this limit has not been exceeded at these locations even during temperature inversions. Radon concentrations in the headspace of the silos have been reduced by 99% and consequently radon concentrations recorded near the silos have been significantly reduced.

Even though a bentonite sealant was added to the silos at the end of November 1991, the area near the silos had the highest annual average radon concentration of all locations measured. Radon measurements near the silos and in the silo headspace will be monitored in 1992 to determine the effectiveness of the bentonite sealant. (Monitoring locations around the silos are shown in Figure 50.) The average concentration at the silos including background was 3.25 pCi/L, which is considerably less than the annual average limit of 30 pCi/L.

The average 1991 radon concentration, including background, for each of the 21 boundary locations was 0.90 pCi/L, which is slightly higher than in 1990, but much less than the 3 pCi/L limit. This observed fluctuation in data is not unusual. Even though each year may not be meteorologically the same as the previous, historical trends show that temperature and precipitation are similar. Therefore, it is common to find slight differences in any of these parameters when comparing any one year to another.

Three previously used and covered waste pits that store radium-bearing materials were surveyed for a radon-flux measurement in 1991. In November, the FEMP surveyed waste pits 1, 2, and 3 to satisfy a requirement in the FFCA/FFA. Measurements were made to provide a best estimate of the long-term average radon emissions from these waste pits. The radon-flux for each of the three pits was well below the 20 pCi/m^2 per second NESHAP flux limit. In fact, the highest average of the measured radon-flux for each of the three pits was only approximately half of this limit.

Figure 50: Radon Monitoring Locations Near the Silos



LEGEND

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

1588

Estimated Radiation Dose from Radon

To be certain that the calculated dose received from radon has not been underestimated, the FEMP uses an assumption that ensures that the calculated dose is conservative (too high). That is, the FEMP assumes that a hypothetical person whose dose is being calculated breathed air at the fenceline continuously for an entire year. Radon daughter product concentrations were assumed to be equal to one-half the radon concentration, or *50% equilibrium*. For 1991, the estimated fenceline concentration, including background, was 0.90 ± 0.30 pCi/L, which is approximately 30% of the DOE guideline (3.0 pCi/L) at the perimeter of the facility. Using conservative lung-exposure factors to convert the measured concentration to dose, the effective dose for a net radon concentration of 0.31 pCi/L at the nearest residence to the facility represents a dose of 93 mrem.[33] This dose is approximately 50% of the natural background dose from radon. This is conservative since it assumes that the individual spent 100% of the year outdoors at the FEMP fenceline.

Percent Equilibrium
This term describes the number of radon's daughter products that are available in the air compared to the amount of radon in the air. If half of the daughter products have been removed from the air, then the daughter products are said to be in 50% equilibrium with radon. Instances of 100% equilibrium are extremely rare, even under artificial laboratory conditions. It would take two times more radon at 50% equilibrium to produce the same dose as radon at 100% equilibrium. In general, air with a lower percent equilibrium is safer to breathe than air with a higher percent equilibrium.

The average site boundary total radon concentration of 0.90 pCi/L is about 45% of the average indoor radon concentration reported for homes in the Cincinnati area. In that study, more than half of the 2,951 homes studied had radon concentrations above 2 pCi/L.

Control of Radon at the FEMP

As previously mentioned, measures have been taken at the FEMP to control radon emissions. During November 1991, a bentonite (clay) sealant layer was placed over the residues contained in the K–65 silos to reduce the amount of radon emitted into the headspace and, consequently, the atmosphere. This removal action was performed with the approval of the USEPA. The clay layer essentially acts as a filter. Radon passing through the layer is retarded and decays while still in the bentonite. Lower concentrations of radon are then observed in the silo headspace. Additional headspace data measurements have been conducted since the bentonite addition and will be continued through 1992. The data is being analyzed and reported to the USEPA to assess the effectiveness of the bentonite sealant layer. Radon concentrations in the silo headspaces have been reduced by 99%. No values greater than the DOE limit of 100 pCi/L have been observed at environmental monitoring stations since the bentonite sealant layer application.

Also, the FEMP's waste pits have been closed which helps to control the release of radon into the air from the buried radium bearing materials. Waste pits 1, 2, and 3 have been covered with a layer of fill dirt after use. Waste Pit 4 was covered with a clay bentonite cap and subsequently covered with a thick plastic/rubber covering. Waste Pit 5 is a water-covered pit; in accordance with the NESHAP regulations, this pit has no radon emissions when covered with water.

Summary of the Radon Monitoring Program

Radon is monitored closely at the FEMP by a routine Radon Monitoring Program that uses both alpha-track etch and real-time radon detectors on- and offsite to monitor radon levels. All data in the 1991 ASER is from the alpha-track etch detectors. The average fenceline location concentration (including background) of 0.90 pCi/L is much lower than the guideline (3.0 pCi/L). Of this concentration, 0.31 pCi/L are attributable to the FEMP. This contributes an effective dose of approximately 93 mrem.

Although some of the radon concentrations for 1991 were slightly higher than those for 1990, they are still well below the DOE limits. The slight variation in data is attributed to normal variations. There have been periods measured in the past year at background locations that have been higher than onsite locations. The difference is primarily due to varying meteorological conditions and may fluctuate accordingly at any location.

Next, Chapter Nine will explain the Quality Assurance measures taken at the FEMP that ensure quality data results are reported.

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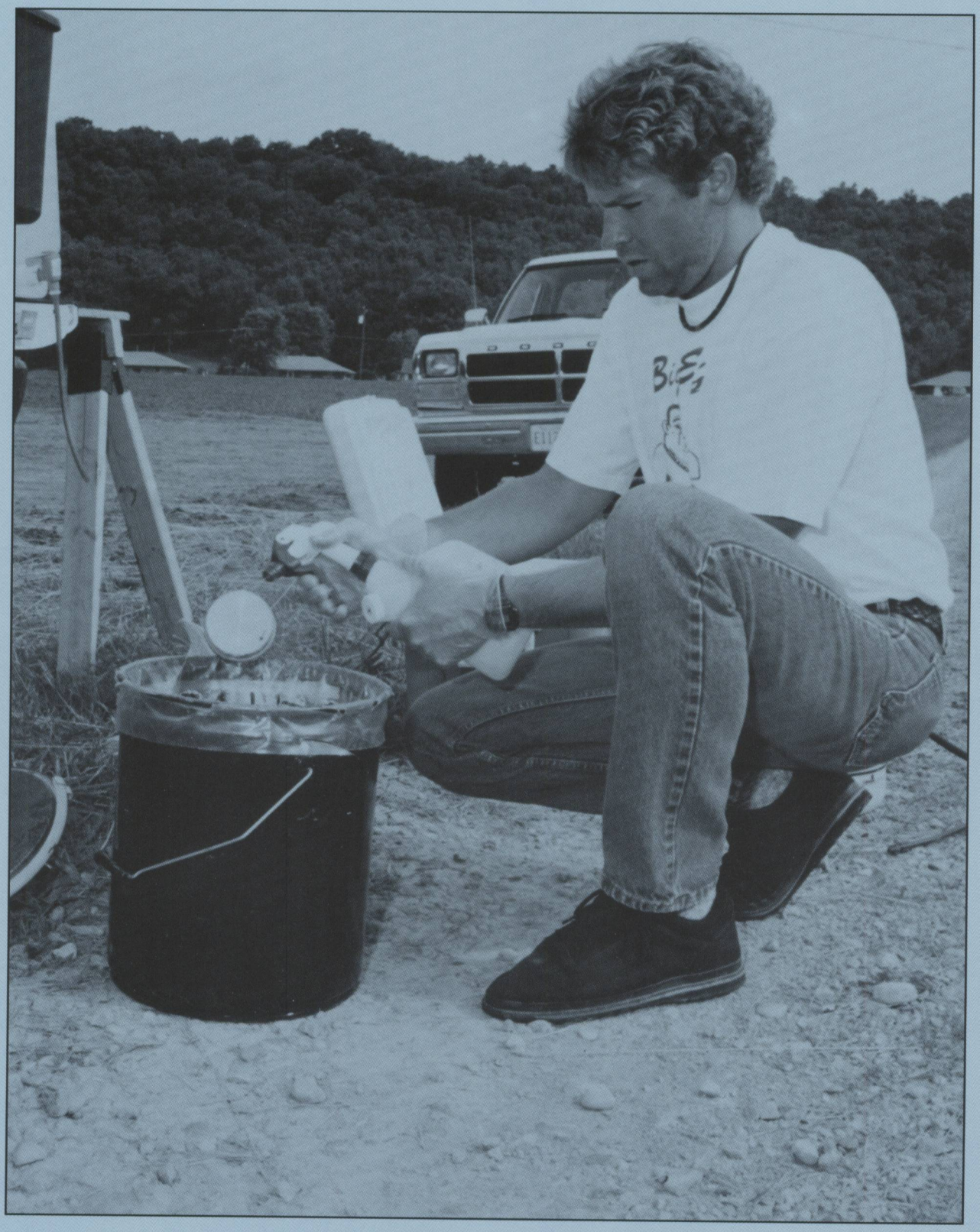
Quality Assurance for the Environmental Monitoring Program



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Quality Assurance for the Environmental Monitoring Program

The Environmental Monitoring program at the FEMP is a result of environmental regulations and DOE Orders. As identified in Chapter Three, compliance with the regulations is managed through various programs to meet the objectives of CERCLA, RCRA, CAA, and CWA. As each of these programs have different objectives, a cohesive approach is needed to manage the volumes of environmental data. Quality Assurance (QA) provides this cohesion by identifying the requirements and defining what the objectives should be. As such, QA is considered early in program development.

Acquiring data of known quality is essential to environmental monitoring. Because environmental management decisions are made and regulatory compliance is derived from environmental data, the FEMP has developed comprehensive procedures that define how environmental monitoring activities are to be conducted. These procedures generate consistency between programs and ensure that USEPA, DOE, and industry accepted practices and standards for conducting environmental monitoring activities are used. Quality Assurance provides the measures necessary to monitor the performance of these procedures in a controlled and consistent manner. The measurements specified in Data Quality Objectives (DQOs) are applied in field activities, laboratory services, data validation, and project verification.

Adherence to QA requirements generates confidence that environmental data are reliable. Use of the DQO process identifies the variability in a project, establishes the objectives, and defines the level of confidence needed to meet the objectives. Field activities' QA measures the consistency and precision of sampling and field analysis. QA in the laboratory measures the accuracy and precision of the analyst and analytical procedures used.

An example of a QA measure is the packaging of air filters in individual plastic bags to prevent contamination during transfer between the laboratory and air monitoring stations. Another example of QA is measuring the accuracy of analysis of spike samples having known concentrations of chemicals or radionuclides. In addition, a system of planned audits, surveillances, and inspections ensures that deviations from the requirements are identified and corrected.

Data Quality Objectives

Prior to sample collection, the Data Quality Objective (DQO) process is implemented. 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. In designing the sampling and analysis plans, the variables established through the DQO process are used to determine the number of original samples and the number of QA samples, and to ensure the total level of uncertainty from sampling and analysis is correctly assessed. An understanding of the sources of error is essential. Biases and variability can accumulate during the measurement process to the point where the data become unsuitable for meeting the objectives of the study. At the FEMP, quality assessments are being developed to identify the extent of biases and variability in the measurement process and to determine whether or not the DQOs are being met.

An example of the DQO process can be seen in the Environmental Monitoring Program for ambient air. DOE orders and USEPA define air emission standards, which set maximum allowable levels of pollutants in air. The DQO process establishes the requirements that must be met to determine if the FEMP is in compliance with the air emissions standards. Experienced scientists, field technicians, and managers consider many factors along with DQOs to determine the best approach for monitoring ambient air around the FEMP. The factors include environmental needs, administrative burdens, and cost. As the DQO process develops, the number of monitors needed and the locations and frequencies where the measurements are taken are identified.

Quality Assurance: Field Activities

QA in field activities is an important part of the environmental monitoring process. FEMP 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. Following are examples of the FEMP field activities.

Field Analysis

Field measurements offer benefits in time and cost. The measurements provide real-time results for environmental conditions, ensuring that the FEMP maintains compliance with certain parameters. Measurements are made with instruments calibrated against known standards and according

to accepted methods. QA measures for EM instrumentation include routine testing, maintenance, and calibration to help ensure proper operation and accurate field measurements.

Field QA/Representative Sampling

Environmental samples that are collected must be representative of actual conditions in the environment. As such, sampling programs are designed to reduce analyte degradation, sampling variability, and cross contamination.

Precautions are taken to prevent alteration of sample constituents, beginning with the purchase of the sample containers. Such precautions are necessary to prevent changes that can occur in some samples due to bio-degradation from microorganisms, the loss of volatile compounds with increasing temperature, or the loss of trace metals from solution by adsorption on 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.

Sampling variability is reduced by using standardized procedures. This precaution ensures that sampling will be performed within the same guidelines each time. Sampling variability is measured by taking duplicate samples of the various types of environmental media. The precision of the FEMP's sample collection and laboratory reproducibility is demonstrated when the analysis results for the duplicate samples are within acceptable limits, as with the Ohio Department of Health (ODH) Split Sampling Program.

The quality of the sampling collection process is also evaluated by means of trip, field, and equipment blanks. These sample blanks provide valuable data by monitoring the sampling process for cross-contamination. The blanks are transported along with the empty 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 the different types of blanks follows.

Trip blanks are prepared in the laboratory by filling sample containers with de-ionized water. Any chemicals that will be added to the samples to preserve them after collection are 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. The analytical results of the trip blanks detect any contamination of samples from empty sample containers and preservatives.

Field blanks are prepared in the laboratory or in the field by filling the containers with de-ionized water. The field blanks are exposed to the air while samples are being collected. Results from the field blanks serve to determine if airborne contamination may have entered the field samples during the collection process.

Equipment rinsate blanks consist of a composite from the de-ionized water that has been used as a final rinse of cleaned sampling equipment before it is reused for collecting samples. Results of equipment blanks provide data to evaluate whether or not sampling equipment was free of contamination before being used to collect samples.

Sample Custody

Most environmental samples must be managed according to USEPA protocols. These protocols establish preservation techniques and holding times which are dependent on sample matrix and analytes of interest. Another protocol is referred to as *chain-of-custody* (COC). Sample integrity must be preserved to the fullest extent possible throughout the environmental sampling process. The custody procedure provides requirements for maintaining sample custody by project personnel. The procedure begins with the cleaning or purchase of the sample containers. A sample container and sample must be under custody at all times through final disposition.

All environmental monitoring samples are controlled and documented according to a COC procedure. All personnel relinquishing and receiving samples are required to sign, date, and note the time on a COC record. This practice is done so that all EM data can be used as legal evidence, if necessary.

Field Documentation

Results of field measurements and information pertinent to sample collection must be accurately recorded for subsequent evaluation and reference. Procedures direct the environmental monitoring sampling process, from before collection begins to delivery to the laboratory. Field logbooks are used for recording events and observations such as weather, location, and time of sampling. Signing and dating all documents helps ensure the traceability and accountability of results when needed in the future.

Analytical Laboratory Quality Assurance

Quality Assurance is an integral part of the FEMP's Analytical Laboratories' operations. Laboratory QA consists of a structured program of actions taken to help ensure that reliable results are obtained when analyzing environmental samples. It typically begins with the receipt of samples from the field technicians. Laboratory QA is designed to:

- Ensure use of approved analytical methodologies and compliance with USEPA protocol where applicable,
- Evaluate analytical performance systematically and objectively,
- Detect and prevent the use of questionable data, and
- Identify appropriate corrective actions.

Analytical Methods

Many of the analytical methods used at the FEMP are stipulated by regulations. For example, when hazardous waste characterizations are made, RCRA specifies how they are to be done. Other regulatory programs, such as NPDES monitoring and CERCLA investigations, will also mandate the analytical methods that must be used. From time to time, modifications to these methods are needed to adjust for matrix effects or other interferences. In addition, other methods, as used in radiological analysis, are not mandated at all.

As part of QA, surveillances of the procedures provide verification that the appropriate procedures are being used and modified procedures have been validated.

Analytical Performance

Day-to-day evaluation of the performance of FEMP laboratories is made using Quality Control (QC) sample analysis results. QC samples include National Institute of Standards and Technology reference materials, USEPA radionuclide solutions, standardized reference solutions, duplicate field samples, spike samples (field samples into which known amounts of contaminants have been added), blank samples, and external proficiency samples.

In addition, the FEMP's Analytical Laboratories' Quality Control and Data Management (QC&DM) section prepares QC samples and submits them to the various laboratories for analyses. At least 10% of the total number of samples analyzed are QC samples that are processed along with the field samples.

The FEMP's Quality Departments evaluate the QC sample results and regularly submit reports to the laboratories for use in identifying potential areas of concern. In addition to analyzing QC samples, the individual laboratories perform daily instrument calibrations, stability checks, and reagent checks to monitor for laboratory contamination.

Procedural performance is also monitored through sample and matrix spikes. Percent recoveries of known amounts of analytes added to the samples are determined. Matrix interferences can be identified and the accuracy of the procedures can be established.

Detection of Data Problems and Corrective Action

As part of the FEMP QA program, surveillances of the laboratory operation are performed by internal and external quality groups. On-the-job training and test sample performance is required to approve new analysts and routine performance checks assess their ability to correctly perform the analytical procedures. The accuracy of the analytical method is measured by reviewing the results of QA samples. If a problem is indicated, the Quality Department notifies the laboratories so that corrective actions can be taken and suspect results for field samples can be evaluated and rejected or flagged. As a means of managing variations that occur in the analytical and data generation process, deviations are recorded on Corrective Action Reports (CARs). The CARs are issued to the responsible manager and can be used as a means for tracking improvements in the quality system.

Independent Evaluations of FEMP Laboratories

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

External QA evaluations are conducted in the following manner. The organization conducting the evaluation prepares QC samples to which they add known amounts of a chemical or radioactive components. For example, a QA water sample for fluoride analysis may be prepared by adding an accurately weighed amount of sodium fluoride to pure, deionized water. The chemist can then calculate the known concentration of the solution. The true concentration of the components may also be established by multiple analyses of an environmental material by one or more laboratories and then applying statistical formulas to derive the demonstrated values.

The QA samples, but not the known values of the test components, are distributed to the participating laboratories which analyze the samples and return the results. The organization administering the program then provides a performance evaluation report comparing the laboratory's results to the true values of the test components. In most cases, the report contains a comparison of the results obtained by the other participating laboratories. These comparisons show whether the laboratory's analyses are within acceptable limits of accuracy or if improvements are required. The various proficiency programs are described below.

DOE's Environmental Measurements Laboratory

The Environmental Measurements Laboratory (EML) Program evaluates the performance of laboratories carrying out radionuclide analyses on environmental samples. Routinely, the FEMP receives and analyzes water, air filter, and soil samples for uranium and submits results for comparison with other laboratories in the program. In making the comparison, the DOE computes a ratio by dividing the FEMP result by the EML result for each analyte. The ratio would equal 1.00 if the results agreed exactly.

The ratios for samples analyzed for uranium during 1991 are listed in Table 23. The FEMP and EML results for uranium in the two water samples were in agreement since the ratios between each laboratory were 1.01 and 1.17.

The FEMP and EML results for the 1991 QA soil sample were in acceptable agreement since the ratio of the two results was 0.83. It is not uncommon for the results obtained by two reliable laboratories analyzing the same soil sample for uranium at the parts per million level to differ by as much as 25%. Consequently, the difference between the FEMP and EML values for the 1991 soil sample is not excessive, and the agreement for this sample is acceptable.

The 1991 air filter samples ratios ranged from 1.08 to 1.37. This indicates that the FEMP may have been over-estimating the amount of uranium in the environmental air samples. The procedure is written to be conservative in order to not underestimate dose.

USEPA's Discharge Monitoring Report

All laboratories that perform NPDES permit wastewater analyses are required to participate in the Discharge Monitoring Report (DMR) QA program. The DMR QA evaluations of the performance of FEMP laboratories 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 FEMP laboratories are discussed in Chapter Five under NPDES Summary for 1991. USEPA evaluates the results for the QA samples as acceptable or unacceptable.

Results obtained by FEMP laboratories for the 1991 DMR QA samples are summarized in Table 24. All FEMP results submitted during 1991 for DMR QA were assessed as acceptable by USEPA.

Commercial Proficiency Environmental Testing

FEMP laboratories also participate in the Proficiency Environmental Testing (PET) QA program. This is a voluntary program administered by a commercial vendor of analytical laboratory QA services. Each laboratory pays a fee to participate. Periodically, the FEMP's Analytical Laboratory Quality Control (ALQC) group submits PET samples to the various onsite laboratories. The analysis is concurrent with field samples. Results obtained for the QA samples are compiled by the QC&DM group and submitted for evaluation. A monthly evaluation report is then provided by the vendor comparing the FEMP laboratories' results to the reference values for each sample and to the results obtained by other laboratories participating in the PET program.

A summary of the performance of FEMP laboratories in the PET QA program during 1991 is provided in Table 25. For the 36 parameters reported, 92% of the results met acceptable criteria. The use of this commercial service provides the FEMP with an additional resource for evaluating their laboratory performance. Any problems or errors can be detected and eliminated.

Ohio Department of Health Split Samples

Another enhancement to the FEMP QA program is the ODH Split Water and Milk Program. The FEMP has participated in this program with the State since 1987. As the split sample program compares results on samples collected directly from the environment, the true variability in sampling and analysis between laboratories is measured.

This program is very similar to the duplicate sample program described earlier. Although the sampling is similar, the duplicate samples measure a single laboratories' performance. The ODH split program measures proficiency between two laboratories.

To obtain split samples, FEMP and ODH sampling team members alternately add a portion of the sample being collected to their individual sample bottles. This collection method helps ensure that both samples are as identical as possible. Split samples are then submitted to the FEMP and ODH laboratories for analysis of uranium.

The FEMP did not receive the ODH results for samples collected during 1990 in time to be included in the 1990 ASER, so they are presented in this report (Table 26). In comparing uranium results obtained by both laboratories, the uncertainty term provided by ODH is taken into account. An uncertainty range is calculated by multiplying the uncertainty term by 1.414. If the difference between the FEMP and ODH results is less than the uncertainty range, the two laboratory results are considered equivalent.

Contract Laboratory Quality Assurance

Because of the great number of analyses required to support all the various environmental monitoring activities, the FEMP uses commercial laboratories to supplement its onsite analytical resources. 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 management, operations, and performance. These reviews are conducted before and also during the service life of the contract. Topics typically reviewed during the audits are:

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

Results obtained in independent QA programs are also reviewed as part of the evaluation of each candidate laboratory's analytical capabilities. Onsite audits of the laboratories' facilities and operations are then conducted by FEMP 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 their performance on a continuing basis.

As part of the ongoing activities for evaluating the performance of contract laboratories, the FEMP regularly sends QA samples along with field samples to the laboratory that analyzes offsite air filter samples. Twenty-nine QA air filter samples, prepared with amounts of uranium known only to the FEMP, were submitted to the laboratory with 1991 field samples. The known amounts of uranium on the QA filters were in the range of the amounts normally present in field samples. The results of these analyses are not available at this time.

The FEMP employed the same Quality Assurance measures to evaluate the contract laboratory's analysis of uranium in milk samples. Figure 51 shows the percent recovery for the milk QA spike samples sent to the three contract laboratories used during 1991. Spike sample recoveries measure the precision of the analysis. As the figure illustrates, Laboratory 2 reported poor recoveries for all 1991 samples. As a result of the QA program, the problem was identified, new contracts were established with additional contract laboratories, and the invalid data was deemed unreportable. The QA process was able to identify a problem in time to acquire more reliable milk data increasing our confidence for 1991.

Unreliable analysis results can also be attributed to delays at the contract laboratory. When the laboratory accumulates a significant backlog of samples from the FEMP and other facilities, delays in processing occur. As a result, the extended storage time causes separation of the liquid and solid components of the milk, making it very difficult to obtain homogenous fractions of the samples for analysis. The uranium results for such non-homogeneous sample fractions could be either higher or lower than the correct value.

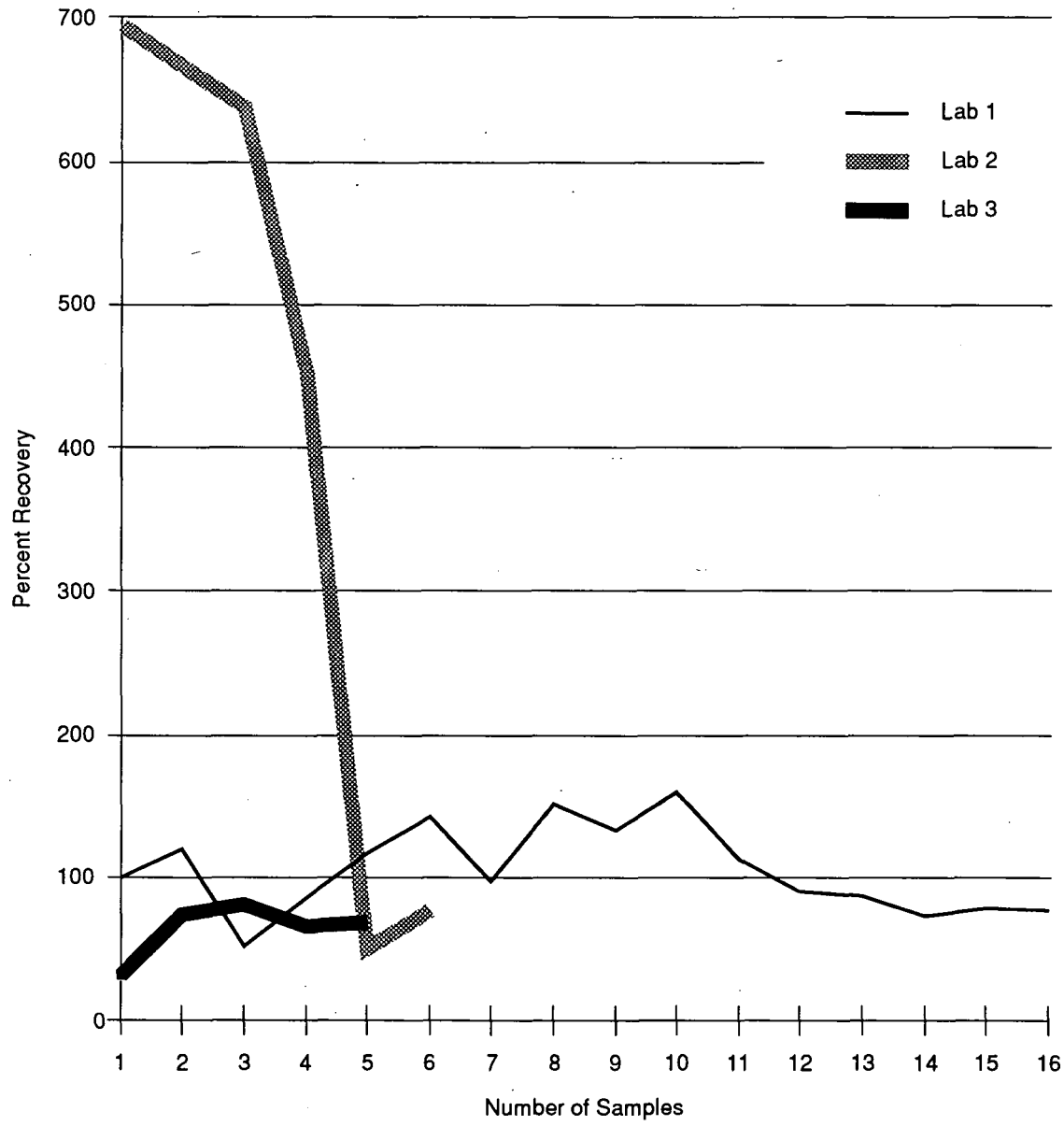
To further enhance the QA performance of the milk sampling program, the FEMP is using milk collection containers which are certified to be free of uranium contamination. Additionally, methods for improving the milk collection, preservation, and storage before analysis are being investigated. As discussed in Chapter Four, the high percent recoveries and positive uranium results reported for some 1991 milk samples from the local dairy were not caused by FEMP uranium releases, but rather reflect problems which occurred in the analytical procedure used.

Summary of Quality Assurance Activities

Many practices and procedures are used to ensure that the environmental monitoring data provide an accurate representation of the conditions at the FEMP. With these procedures, QA can offer a cohesive and consistent approach in managing the large volumes of environmental data generated at the FEMP. QA can be accomplished by implementing the following steps:

- The establishment of DQOs;
- The design of field sampling strategies, laboratory specs, and data acceptance criteria;
- The implementation of the sampling and analysis strategies; and
- The data quality assessment.

Figure 51: Milk/Uranium QA Samples, 1991



Data Quality Objectives offer quantitative and qualitative statements developed by data users stating the quality of data needed for each data collection activity. Appropriate sampling procedures must be followed and proper analytical procedures practiced. Data must be examined, validated, and presented in a meaningful form; and results must be properly reported. Quality Assurance provides the means to measure the quality and performance of the environmental monitoring process. As determined by the internal and external QA programs, the level of quality needed is measured to ensure that reliable data were obtained for determining compliance with

environmental regulations and for making valid environmental management decisions. Through a sophisticated matrix of standardized procedures, duplicate and spiked samples, blanks, audits, and reports, Quality Assurance can enhance the reliability of the Environmental Monitoring Program and can create confidence in environmental management decisions.

Although the FEMP's overall QA performance was good for 1991, there is room for improvement. When a poor recovery on a spike sample occurs, the FEMP must take time to identify the cause and correct the error. If a chain-of-custody (COC) is lost, another sample must be taken. When the Corrective Action Reports (CARs) identify where and when the FEMP is deficient, the deficiency must be recognized and corrected.

The next section of the 1991 ASER focuses on cleanup of the site. Chapter Ten describes the FEMP's waste management activities. Chapter Eleven, Remedial Investigation and Feasibility Study, provides an update on remediation activities at the FEMP.

Cleanup

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Cleanup

The 1970s brought about many changes in environmental regulation in the United States. Many of these changes were the result of new laws being adopted by the government. Two such laws adopted during this time were The Resource Conservation and Recovery Act of 1976 (RCRA), and The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The FEMP must operate within the limits of these and other federal regulations.

In 1989, FEMP production activities were suspended, and at that time the FEMP focused its energies on site cleanup and restoration. The Waste Management Program (regulated by RCRA) and the Remedial Investigation and Feasibility Study (RI/FS) process (driven by CERCLA) are the two main FEMP activities geared toward site cleanup.

RCRA's objective is to ensure that hazardous chemicals are not discarded in ways that may cause harm to humans or the environment. It provides for management of more than 450 chemical wastes and requires specific permits for treatment, storage, and disposal of hazardous wastes. The Waste Management Program's objective is to store, treat (if necessary), minimize generation, and dispose of the onsite waste in accordance with RCRA standards.

While RCRA regulates all ongoing industrial operations, CERCLA provides for the cleanup of old waste sites — landfills, waste pits, sludge ponds, and warehouses — where potentially dangerous and hazardous chemicals have been abandoned. In order to remediate facilities such as these at the Fernald site, the FEMP began a RI/FS in 1986. The RI/FS process is outlined by CERCLA legislation and is conducted according to USEPA regulations. The RI/FS process will provide a list of alternatives for remediation of the site facilities.

Waste Management Activities

Waste Management Activities

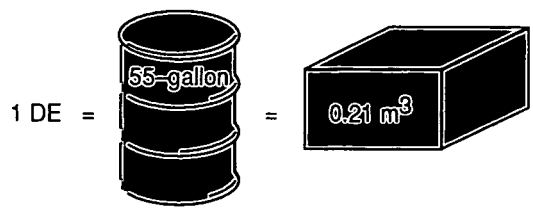
Although production activities at the site have ended, the FEMP's Waste Management Program continues as a key element in preventing the release of pollutants into the environment. Indeed, as FEMP environmental cleanup activities proceed, contaminated soil, old building materials, used protective clothing, and other wastes will be generated in significant amounts.

Generally, the FEMP's Waste Management Program seeks to characterize, store, treat (as necessary), and dispose of radioactive, hazardous, mixed, and sanitary waste from the site in a safe and environmentally sound manner while complying with all applicable regulations. They also oversee waste minimization efforts throughout the facility. However, there is still an onsite *backlog* of approximately 160,000 *drum equivalents* (see Figure 52) of waste generated by the chemical and metallurgical processes during the years of production. These backlog wastes were generated after the waste pits were closed but before offsite waste disposal shipments began. The FEMP maintains this backlog in a safe manner in proper storage containers and on concrete pads until final disposition occurs. In addition to managing the backlog wastes, the Waste Management Program is also responsible for wastes generated by the ongoing cleanup efforts, utility, maintenance, and administrative services.

The FEMP manages waste safely until final disposition is implemented by ensuring that the public, site workers, and the environment are protected from the hazards associated with waste materials. Another FEMP objective is to comply with federal and state regulations, particularly the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA),

Figure 52: Drum Equivalents

In order to consistently track and report the quantities of low-level radioactive waste being generated and disposed, the FEMP has adopted a uniform unit of measure — the "drum equivalent." This is defined as the number of 55-gallon drums that it would take to contain a given volume of waste. One drum equivalent (DE) is equal to the volume of a single 55-gallon drum which is 0.21 m^3 (7.4 cubic feet). A unit based



on volume was adopted since most packaged wastes at the site are stored in drums, and drums are a common unit used for shipping waste offsite for disposal. This report will use "Drum Equivalent" as a unit of measure whenever possible.

and DOE orders. The FEMP's strategy for meeting these objectives consists of:

- Shipping as much waste offsite as possible to permitted treatment and/or disposal facilities;
- Maintaining and upgrading storage facilities for waste that cannot be disposed of or eliminated;
- Integrating requirements of RCRA, CERCLA, and the National Environmental Policy Act (NEPA);
- Pursuing a waste minimization program, such as the Total Quality Recycling Team and the Waste Minimization and Pollution Prevention Program; and
- Developing and implementing programs to reduce disposal costs.

This chapter highlights 1991 FEMP activities related to management of wastes within the administration and former production areas of the site. For the most current information available on waste management activities at the FEMP, refer to Chapter Three. Other sources of updated information concerning waste management at the FEMP are the Administrative Record and FEMP monthly progress reports, available at the Public Environmental Information Center (PEIC).

Categories of Waste at the FEMP

The wastes generated and stored at the FEMP can be grouped into three general categories: low-level radioactive waste, hazardous or mixed waste, and conventional industrial waste. Examples of each of these types of waste are listed below:

Low-Level Radioactive Waste

- Process residues (slags, neutralized raffinates, sump sludges, etc.);
- Construction rubble;
- Thorium materials;
- Sediments from the Stormwater Retention Basin (SWRB) and the Biodenitrification Surge Lagoon (BSL);
- Scrap wood (pallets);
- Scrap metal (baled drums, process equipment, pipe, etc.);
- Decontamination materials; and
- Contaminated personal protective equipment (PPEs).

Hazardous or Mixed Waste

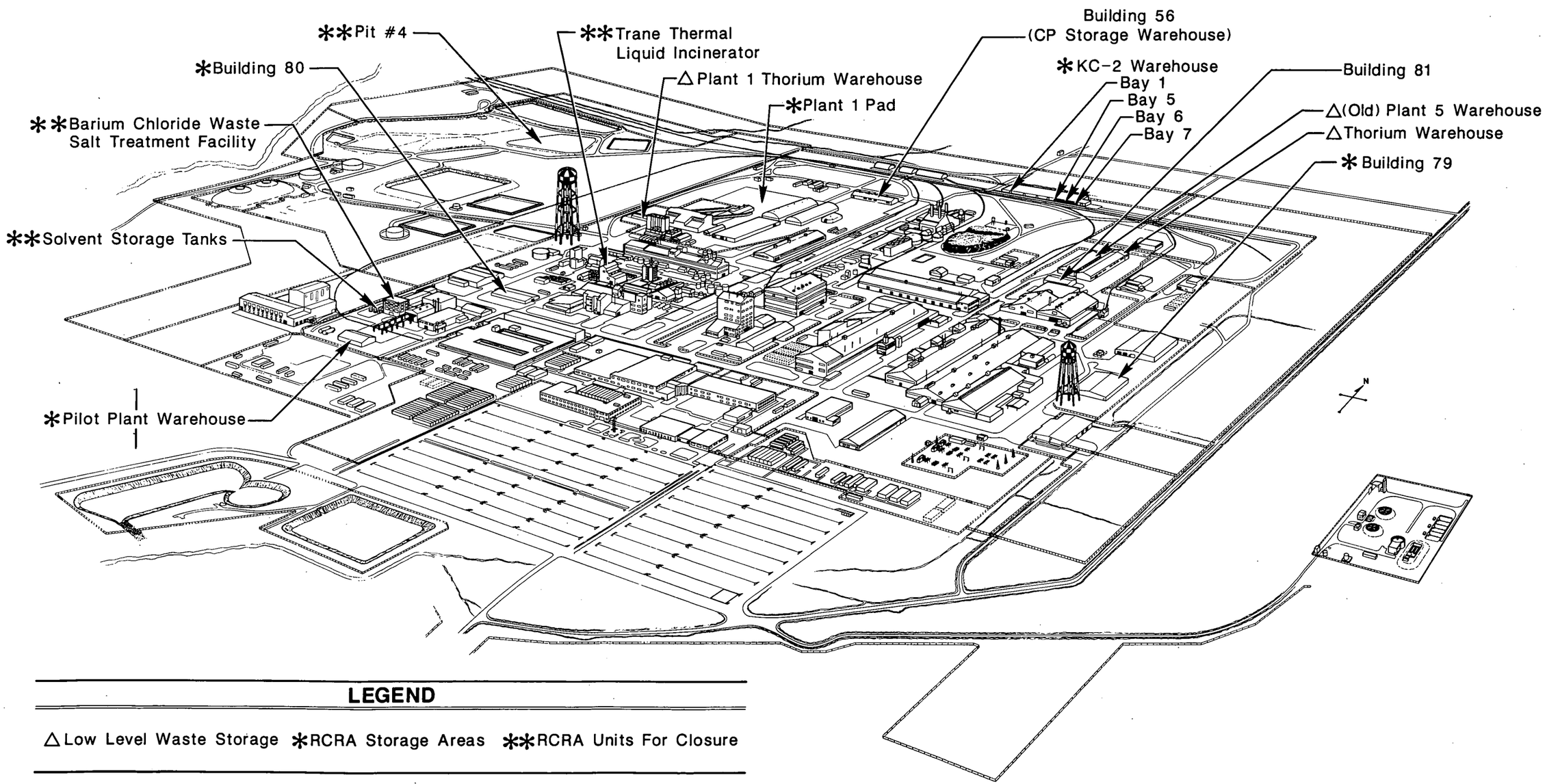
- Cutting and cooling oils contaminated with solvents or lead;
- Solvent still-bottoms and sludges;
- Barium chloride salts;
- PCB-containing materials;
- Contaminated extraction solvents (tributyl phosphate/kerosene and diamylamylphosphonate);
- Spent solvents (1,1,1–trichloroethane, xylene, etc.);
- Materials used to clean spills of waste covered under RCRA; and
- Lead-containing materials (residue from paint removal, etc.).

Conventional Industrial Waste

- Nonprocess trash from the administration area;
- Boiler Plant flyash;
- Noncontaminated construction rubble; and
- Spent lime sludge from the water treatment plant.

The FEMP facilities and areas within which these wastes are managed and stored are shown in Figure 53 on page 168.

Figure 53: FEMP Waste Management Areas



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Low-Level Radioactive Waste Management

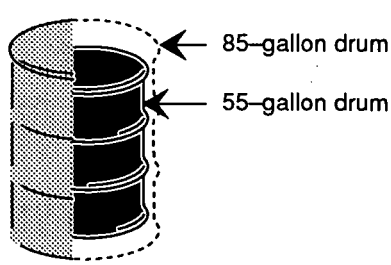
Low-level radioactive wastes (LLW) are those materials contaminated with radionuclides, such as uranium and thorium, at concentrations which are not economically viable for recovery or reuse. During 1991, there were more than 158,000 DEs of low-level radioactive waste stored onsite, exclusive of the scrap metal piles and the pit and silo wastes discussed in Chapter Eleven. Some of the LLW at the site are also contaminated with hazardous constituents as defined under RCRA. Because of additional regulatory requirements, these wastes cannot be disposed or handled as LLW. These wastes are discussed in the section "Mixed Waste Management."

Storing Low-Level Radioactive Wastes

Because the low-level radioactive wastes and uranium residues are no longer going into onsite disposal pits or being processed to recover uranium, they are stored in drums as an interim measure until the FEMP ships them to an approved disposal facility. Nevada Test Site (NTS) is currently the only approved disposal facility the FEMP can utilize. Some of these drums and other containers have corroded and possibly leaked. To prevent further deterioration and potential releases of contaminants, the FEMP began a major program to improve storage conditions in 1989 and continued it through 1991. These improvements included redrumming wastes, *overpacking* old drums (see Figure 54), and storing drums in the now-idle production buildings. Over 35,000 drums have been overpacked into new containers, and more than 25,000 drums have been moved from outdoor pads to covered storage areas. In addition, the FEMP rebuilt storage pads, established minimum spacing requirements for drums, improved temporary diking, and increased inspections to detect problems as they develop. About 38,000 drums remained outdoors at the end of 1991.

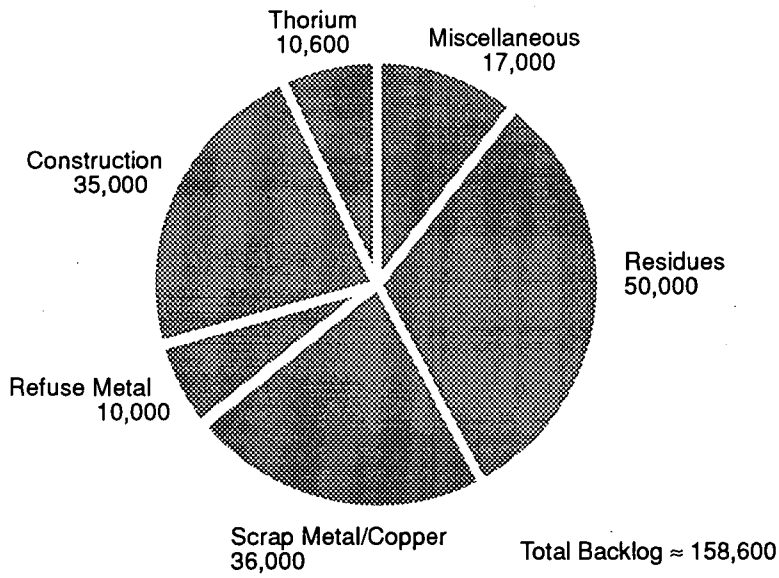
Figure 54: Overpacking of Drums

Some of the drums stored at the FEMP have deteriorated because of age and exposure to precipitation, sunlight, etc. The FEMP has overpacked many of these older drums into new containers. Overpacking means that the deteriorating drum is placed inside a new, larger drum to prevent further deterioration or the possible release of contaminants during storage.



In an effort to provide even better temporary storage for the backlog of low-level wastes awaiting shipment to NTS for disposal, two additional temporary fabric structures were erected on the Plant 1 Pad. Each of the new structures is larger than the one constructed in 1990, and the three structures together provide a capacity for indoor storage of up to 21,000 drums. The FEMP plans to add enough fabric structures to provide indoor

Figure 55: FEMP Backlog Waste, 1991 (in drum equivalents)



storage for the remainder of the drums stored onsite. Such structures cost much less than permanent buildings because they can be built quickly while generating much less waste during both construction and eventual demolition. Overall, the FEMP has improved storage conditions for and conducted rigorous inspections of more than 60,000 drums of low-level radioactive waste and residues. Backlog waste totals for 1991 are presented in Figure 55.

Disposing of Low-Level Radioactive Wastes

The low-level radioactive wastes generated at the FEMP are regulated under the Atomic Energy Act and can be disposed of only in designated radioactive waste disposal facilities. As previously mentioned, the principal disposal site for FEMP low-level radioactive wastes is NTS. During 1991, the FEMP shipped over 47,000 DEs of low-level waste to NTS. Since waste shipments began in 1985, more than 250,000 DEs have been shipped offsite.

In April 1990, NTS instituted new audit requirements of all waste generator sites, including the FEMP. The NTS conducted an annual audit of the FEMP waste shipping program during 1991 and, as a result, renewed its approval for FEMP waste shipments.

The greatest volume of low-level radioactive wastes generated at the FEMP in the past has been residues and by-products from the uranium production process. These wastes are in the forms of sludges, filter cakes, slags, dust collector residues, and uranium metal chips or turnings from machining operations. Although the termination of production eliminated new contaminated process residues, current waste management, maintenance, and cleanup operations continue to generate contaminated sludges and other wastes.

Other low-level wastes include items once used in the production process which have become contaminated with uranium and cannot be decontaminated or used again. These items include metal drums, wooden pallets, and

trash such as rags, paper, and wood. Most of the wastes now generated are from cleanup and other environmental restoration activities and renovation projects.

Scrap Metal Activities

If scrap metal is not contaminated and is potentially usable, it is stockpiled for use elsewhere at the site or for shipment to local scrap dealers. During 1991, the FEMP decontaminated 5,000 DEs of reusable scrap metal to levels suitable for unrestricted release. Contaminated scrap metal that cannot be used again is packaged and shipped offsite for disposal.

The FEMP is also storing about 1,225 metric tons (1,350 tons) of radiologically contaminated scrap copper on a concrete pad in the northwest part of the site. The scrap copper, consisting mostly of motor windings but possibly some asbestos insulation also, was transferred to the FEMP as a result of the upgrading of other DOE facilities during the 1970s.

Managing Thorium at the FEMP

Since the early 1970s, the FEMP has served as the federal government's storage site for thorium, a naturally occurring radioactive element. Even before its designation as the federal repository, the FEMP studied possible uses for thorium and had processed the material for use at other government facilities. All thorium processing at the FEMP ended in 1979. There are about 1,100 metric tons (1,200 tons) of thorium stored in steel drums and other containers onsite. About two-thirds of this material was processed onsite, with the remaining portion delivered from other DOE facilities.

The FEMP is carefully managing the thorium to reduce the potential radiation hazard to employees, local residents, and the environment to keep personnel exposure As Low As Reasonably Achievable (ALARA).

In June 1991, approximately 1,094 metric tons (1,190 tons) of thorium were declared waste. Once this affirmation occurs, the FEMP prepares to move the thorium offsite. In September 1991, nearly 150 metric tons (160 tons) were sold to a commercial vendor. However, this declaration does not change the way the FEMP manages the thorium while it is onsite.

The thorium stored at the FEMP consists of various materials, principally thorium oxides (generally a fine powder), processing residues in a variety of forms, and a small quantity of thorium metal. The majority of the thorium materials, about 13,300 containers (containers vary in size from 55–gallon drums to drums as small as one gallon), is stored in the Thorium Warehouse,

the (Old) Plant 5 Warehouse, the Plant 1 Thorium Warehouse, and the Pilot Plant Warehouse (Figure 53). About 9 metric tons (9.9 tons) of thorium nitrate solution are stored in Pilot Plant Tank 2. The remaining thorium material consists of about 175 metric tons (190 tons) of bulk thorium oxide, plus inert materials like an absorptive, silica-rich deposit which had been contained in the Plant 8 silo and bins prior to their dismantling in 1989. This material is now safely packaged in new, double containers and is stored in Building 60.

The FEMP is in the final stage of a comprehensive three-project plan for improving the temporary storage conditions for the thorium inventory. All of the thorium materials have been identified and inventoried. Repackaging and overpacking activities began in 1991.

The first project, completed in March 1989, addressed the bulk thorium materials in the Plant 8 silo and bins. As the bulk thorium was removed from the silo and bins, it was placed in double-containment drums called overpacks (a 48–gallon drum is packaged inside a 55–gallon drum), inventoried, and monitored. The drums were then stored in an onsite warehouse located along the northern edge of the production area, away from daily plant operations. The silo and bins were then decontaminated and demolished.

The second project was the overpacking of the 241 containers (212 of the containers were drums) stored outdoors. A remote system to handle, identify, and overpack the 241 thorium drums and containers was designed. Each container was inventoried, weighed, and overpacked, then placed in temporary storage at the FEMP. This thorium repackaging project was completed in March 1990.

The third project, overpacking 13,000 containers of thorium, was begun in 1991. Overpacking in the Thorium Warehouse was completed; overpacking in the Plant 1 Thorium Warehouse and the Pilot Plant Warehouse are scheduled for completion by September 1992. The FEMP has proposed to complete the overpacking in the (Old) Plant 5 Warehouse by the end of 1993.

By completing two of these projects, the FEMP has significantly reduced the potential for any accidental release of thorium through a structural failure or a deteriorating container. The new overpack containers will also protect the thorium materials from the weather and greatly reduce the possibility of any thorium being released to the environment. By removing the Plant 8 silo and bins and storing the thorium farther from daily operations, exposures from the thorium to employees working in the production area will be kept to a minimum.

Hazardous or Mixed Waste Management

Another major category of waste at the FEMP is mixed radioactive/hazardous waste, referred to as mixed waste. Strictly hazardous waste contributes very little to the total amount of waste at the FEMP. Most of these wastes are co-contaminated with radionuclides and are, therefore, considered mixed wastes. The hazardous component of these wastes is regulated under subtitle C of RCRA, while the radionuclide component of these wastes is regulated under the Atomic Energy Act, but only if it is a mixed waste. The latter act was passed in 1976, along with subsequent amendments in the 1980s, to address a problem of enormous magnitude — how to safely dispose of the huge volumes of municipal and hazardous waste generated nationwide. The goals set by RCRA are:

- To protect human health and the environment,
- To reduce waste and conserve energy and natural resources,
- To reduce or eliminate the generation of hazardous waste as expeditiously as possible, and
- To segregate hazardous materials from Low-Level Radioactive Waste (LLW) and conventional waste streams to minimize generation of mixed radioactive/hazardous waste.

Under the Land Disposal Restriction (LDR) Program, storage of RCRA waste is prohibited unless the accumulation of this waste is necessary to facilitate proper recovery, treatment, or disposal options. At the FEMP, mixed waste is stored onsite because adequate disposal facilities are unavailable. This storage does not meet the requirements of LDRs. However, OEPA recognizes this dilemma and is working on a policy to resolve the problem.

Performing RCRA Closures

If buildings or equipment contaminated with RCRA constituents are to be used again they must be cleaned to more stringent standards as specified by OEPA. This is known as a RCRA closure. The plans detailing tasks and schedules needed to decontaminate these areas are known as RCRA closure plan information and data. Closure plan information and data are prepared to ensure that closure actions are consistent with the RCRA requirements while adhering to the terms of the April 1990 DOE/USEPA Consent Agreement. The major objective to the submittal of closure plan information and data is to ensure efficient integration of all RCRA closure activities with related CERCLA response actions. The following paragraphs describe the RCRA closure plans that the FEMP has completed or submitted to OEPA for their approval in 1991.

The Storage Pad North of Plant 6 held drums of residues and oily sludge created during Plant 6 wastewater treatment. (Plant 6 was built in 1952, and

operations through the years included chemically treating, machining, and inspecting uranium-metal products — see Figure 53.) The wastes stored here were assumed to be hazardous because both 1,1,1–trichloroethane and lead were used in the Plant 6 processes. The presence of 1,1,1–trichloroethane was verified, but analysis could not verify the presence of lead. The FEMP identified the Plant 6 pad as a hazardous waste storage unit in the September 1989 RCRA Part A permit application. The pad must be decontaminated and cleaned because it is no longer in use. Approval of the closure plan information and data were received from OEPA in 1991, and field work on the cleaning of the pad was planned for early 1992.

Bulk Storage Tanks T–5 and T–6 are located in a diked tank storage area west of the Pilot Plant. They contained thorium nitrate solutions from 1969 until about 1980. It is believed that the tanks were empty from 1980 until April 1984. At that time, the tanks were used to store mixed solvent wastes until the tanks were drained in 1989. Approval of the closure plan information and data were received from OEPA, and field work on the cleaning and closure of the unit was planned for early 1992.

Tank 5 is an underground storage tank, installed in 1954 and used through 1986. It is located near Building 31, a vehicle maintenance garage for the site (Figure 53). Waste oils were collected in the floor drains, where the oils were separated from the water; the water flowed to a sanitary sewer while the oils were directed to Tank 5. These wastes varied over the years, and they included hydraulic oil, motor oil, gasoline, diesel fuel, and cleaning solvents such as 1,1,1–trichloroethane. The closure plan information and data were submitted in 1990 to OEPA and gained approval in 1991.

Another closure, the Barium Chloride Waste Salt Treatment Facility, was completed in February 1990. Also, the closure plan information and data for the Trane Thermal Liquid Incinerator were submitted in 1990 and are still waiting for approval.

Underground Storage Tank Investigation

Prior to 1991, ten of the original 13 tanks registered with the Ohio State Fire Marshal were removed from the ground. The FEMP was required to perform these tasks under state regulations since these tanks were permanently out-of-service.

Sampling results confirmed a release of petroleum to the soils from Tank 17, a 200–gallon steel tank which held waste oil from an oil/water separator located under the floor of Building 46 and had been pumped and isolated in 1990. One sample indicated the presence of 1,1,1–trichloroethane in the

water from the separator pit. Throughout 1991, the FEMP remained in negotiation with the Ohio Fire Marshal's Office to close the excavation under CERCLA.

Also in 1991, the FEMP continued negotiations with the Fire Marshal's Office regarding petroleum releases in the plant area. These releases had been identified while removing ten underground storage tanks in 1990.

Conventional Industrial Waste Management

The FEMP also generates nonradioactive wastes normally associated with a large industrial facility, such as boiler plant waste and nonprocess trash from the administrative areas.

The Boiler Plant produces flyash, sludges from boiler water treatment, and runoff from the coal pile. Flyash is taken to the southwest corner of the site and placed on an above-ground pile. The boiler plant water sludges and coal pile runoff are currently drained to a retention pond, and from there the water goes to the General Sump System for treatment.

Another industrial waste is spent lime from the water processing plant. The FEMP produces its own drinking water and process water from three onsite wells. The water treatment process includes a lime-softening step. The spent lime from this process is collected in sludge beds on the western side of the site, and these beds are nearly full. Options are being studied to address this problem.

Pollution Prevention and Waste Minimization

The FEMP is committed to pollution prevention and waste minimization and is supported by the Pollution Prevention and Waste Minimization (PP/WM) Policy Statement which declares the use of the most cost effective and environmentally effective methods to manage and minimize the generation of waste.

In 1991, the FEMP issued the PP/WM Awareness Plan. This plan outlined the program's strategy, objectives, and goals along with the program policy budget, and status. In addition to issuance of this plan, a PP/WM Task Team was formed. The team meets biweekly and is composed of individuals from key organizations onsite. Their combined expertise allows the team to perform comprehensive functions for PP/WM.

The program also performed a Process Waste Assessment (PWA) on the dry compactible waste generated in the controlled area. This assessment was

done to determine if administrative controls could be used to segregate and divert radiologically clean office waste from shipment to NTS and, instead, dispose of it in a sanitary landfill. Evaluations were made and options identified. A pilot project is underway for Building 45 and Receiving to test and monitor the administrative control techniques.

In 1991, the PP/WM Program started a conscious effort to create a sitewide awareness to encourage waste minimization in every task performed. This awareness, coupled with the continued emphasis on PP/WM for EPA and DOE, will enable the program to continue to set goals that achieve actual, measurable reductions in waste generated.

Nonhazardous and noncontaminated wastes generated in the administrative areas, such as paper waste, packaging materials, cafeteria waste, and other noncontaminated wastes are collected in dumpsters free from radioactive contamination and are sent to a local commercial sanitary landfill for offsite disposal.

In 1991, the FEMP began large scale efforts to reduce the amount of this administrative waste sent to local commercial sanitary landfills. Reduction efforts focused on paper, packaging materials, cafeteria waste, and other noncontaminated waste from the administrative areas. These efforts were made by a number of FEMP employees who identified the need to concentrate on the issues of recycling. They formed a Total Quality Recycling Team to investigate the recycling options available to the FEMP, and their activities saved approximately $30,000 in 1991.

This Recycling Team distributed 830 cardboard boxes to personnel in the administrative areas to collect used white paper and computer paper. During 1991, the FEMP collected 19,000 kg (42,000 pounds) of paper for sale to an area firm for recycling. Additional cardboard boxes located around the administrative areas of the site were used to collect aluminum and bimetallic soft drink cans. In 1991, the FEMP donated 1,500 kg (3,400 pounds) of cans to the Crosby Elementary School to fund their Ecology Club and to a local fund raiser for area hospital burn units. Outdated phone books were also collected from employees who received new Cincinnati Bell telephone directories. Approximately 950 kg (2,100 pounds) of old directories were collected and transported to an area grocery store for recycling. Finally, the Recycling Team placed a contract with a vendor to exchange used laserjet cartridges for refurbished units. Two hundred used cartridges were exchanged in 1991.

In addition to Recycling Team initiatives, some onsite departments started their own recycling projects. Personnel in the print shop are turning old

letterhead and other printed material no longer needed into scratch paper pads. The receiving department reuses the styrofoam fillers it receives when mailing shipments from the FEMP. Also, the onsite library has reduced its yearly waste by giving away its outdated books to interested readers instead of throwing them away.

Summary of Waste Management Activities

The FEMP made significant advances in its waste management activities in 1991. During the year, 47,000 DEs of low-level waste were shipped to NTS. Additionally, the NTS renewed its approval for FEMP waste shipments. The final stage of a three-project plan to improve the temporary storage conditions for the thorium inventory was begun in 1991. This plan significantly reduces the potential for any accidental release of thorium through structural failure or a deteriorating container.

The management of the wastes from past activities which are stored in pits, silos, and landfills at the FEMP is described in the next chapter, Remedial Investigation and Feasibility Study (RI/FS).

Remedial Investigation and Feasibility Study

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209

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Remedial Investigation and Feasibility Study

The Remedial Investigation and Feasibility Study (RI/FS) is a comprehensive, long-term environmental investigation currently underway at the FEMP. Its dual purposes are to identify environmental impacts associated with FEMP operations and to develop and evaluate possible solutions. The cleanup of hazardous waste sites in the United States is driven by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). At the Fernald site, the RI/FS began in 1986 and is scheduled to continue through 1998.

Those readers already familiar with the RI/FS process may wish to proceed directly to the section on Operable Unit 1 (see page184). The operable unit sections in this report, however, are only summaries of the RI/FS program's progress through December 31, 1991. See Chapter Three for a more detailed description of the removal actions; for more current and technical information, refer to the Administrative Record at the Public Environmental Information Center, the inventory of documentation for the RI/FS project.

The RI/FS Process

A RI/FS process is designed to investigate the extent of site contamination, risks to health and environment, and best methods for cleaning up a site. The process originates when USEPA receives notification of a potential problem. USEPA initiates a preliminary assessment to determine whether a response is necessary. If a response is needed, it is then decided whether immediate action is required. If immediate action is not warranted, a site investigation is conducted. With the information from the investigation, the site is ranked using a hazard ranking system. A score is allocated based on the types of hazardous materials, the potential pathways to the environment, and other similar criteria. If a score of 28.5 or over is assessed, the site is placed on the National Priority List (NPL) and must then undergo a RI/FS to determine what remedial actions will be taken.

The scope of the RI/FS does not include taking corrective actions; rather, it is an investigation process that results in a proposal for action. Based upon the results of the RI/FS, USEPA will select and the site will implement the most appropriate *remedial actions* to cleanup the site. In contrast to the long-term remedial actions recommended by the RI/FS, *removal actions* are short-term cleanup measures designed to correct problems that are an immediate threat to human health and the environment. Removal actions often develop during the RI/FS to quickly address contamination.

The RI/FS investigation consists of three separate phases that may be simultaneously conducted. Still, no one phase is independent of the others (see Figure 56). These three phases are:

- **Scoping** – Development of the strategy that will be used throughout the process,
- **The Remedial Investigation (RI)** – Characterization of the nature and extent of contamination and of the risks posed to people and the environment, and
- **The Feasibility Study (FS)** – Evaluation of the potential remedial options.

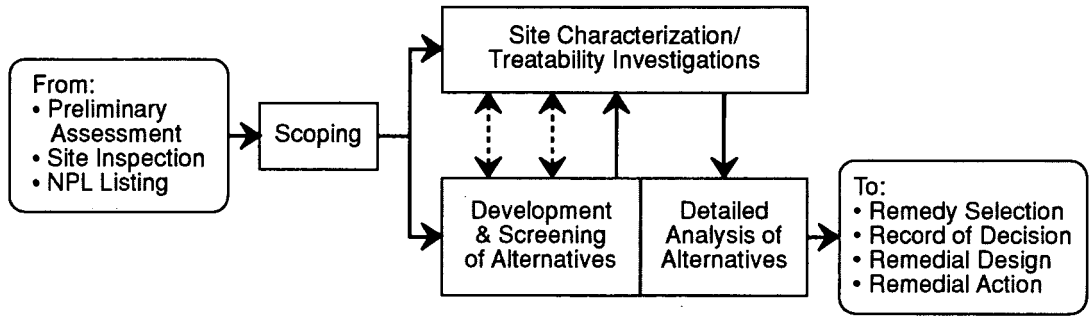
The FEMP as a RI/FS Test Case

The FEMP is one of the first among DOE facilities to undergo a RI/FS process under CERCLA. In many respects, this site is a national test case. One precedent set in the FEMP's RI/FS process was the recognition of USEPA's authority in the regulation of federal facilities.

In July 1986, DOE and USEPA signed a Federal Facility Compliance Agreement (FFCA), addressing impacts to the environment associated with operations at the FEMP. The FFCA's purpose was to ensure that the site would thoroughly investigate those impacts and then implement the appropriate remedial actions. The FEMP agreed to conduct the FFCA investigation as a RI/FS in accordance with the guidelines of CERCLA.

In November of 1989, USEPA and Congress placed the FEMP on the NPL, strengthening USEPA's authority over the cleanup activities. Thus, USEPA plays an active role in determining which remedial actions are chosen for the site. The FFCA was later amended by the June 1990 Consent Agreement between DOE and USEPA to allow RI/FS work (divided into five operable units) to continue. In September of 1991, the Consent Agreement was amended. This amendment redefined OU3 and OU5, established a comprehensive site-wide OU, and extended the OUs' schedules.

Figure 56: The RI/FS Process



Completion of the RI/FS leads to the chain of events that is essential to final site cleanup. These final steps are:

- Remedy selection,
- Record of decision (ROD),
- Remedial design, and
- Remedial action.

Scoping

The scoping phase begins with a site visit. All existing data are evaluated and a conceptual model of the site is developed. To expedite the completion of total site cleanup, sites are often divided into sections called operable units (OUs). The OUs are typically defined such that similar physical properties and geographic orientation can be used to more efficiently manage the RI/FS process. (See Figure 57 on page 182 for Operable Units at the FEMP.) Early in this process, all other Applicable or Relevant and Appropriate Requirements (ARARs) are identified to define cleanup levels and establish criteria on a site specific basis. Examples of ARARs include the Resource Conservation and Recovery Act (RCRA), the Clean Water Act, the Clean Air Act, and State legislation. These ARARs are used to help determine the level of cleanup that must be achieved at a site. With this information, a work plan is prepared.

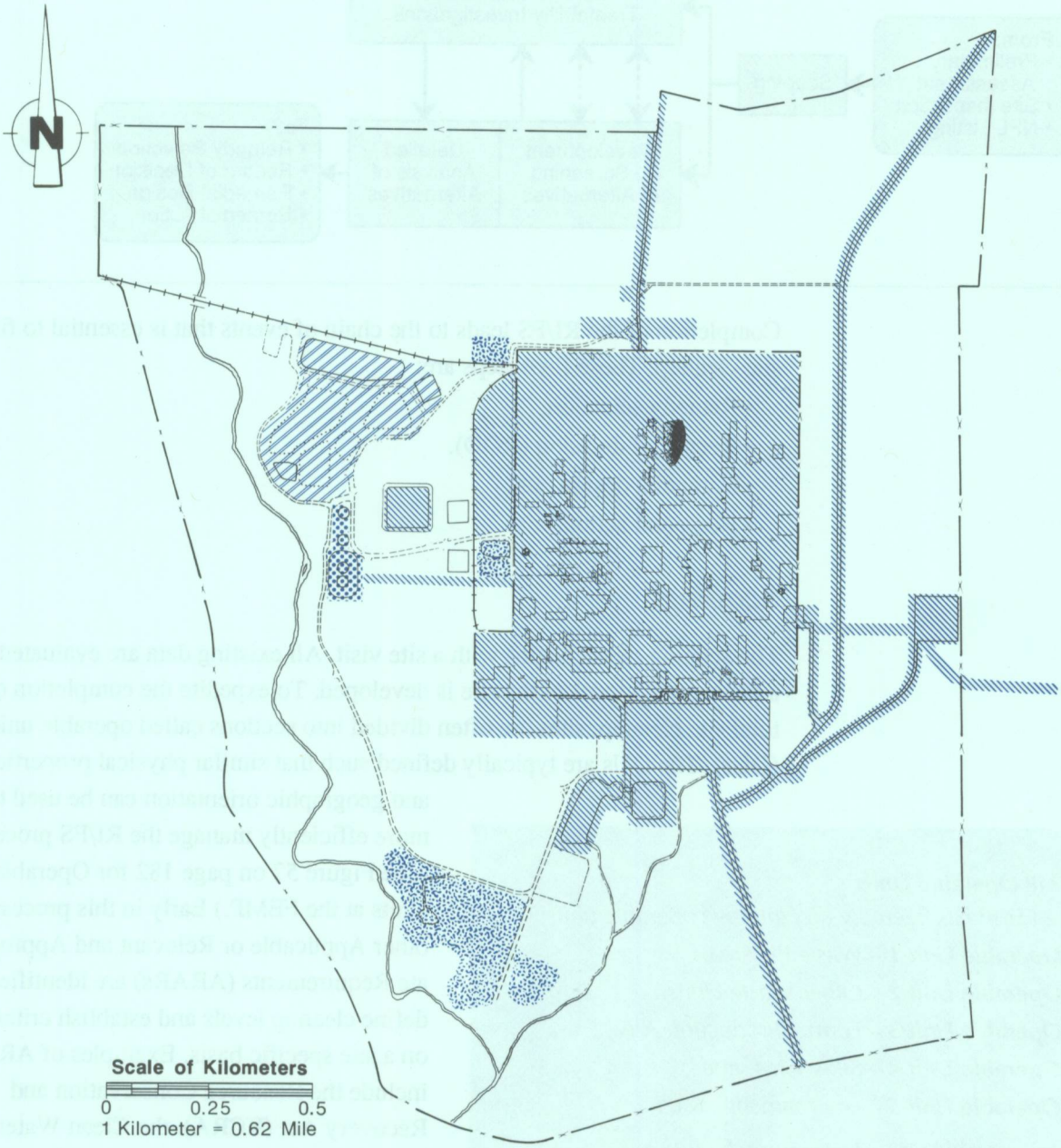
FEMP Operable Units

The FEMP has been divided into five operable units:

- ***Operable Unit 1** – Waste Pit Area,*
- ***Operable Unit 2** – Other Waste Units,*
- ***Operable Unit 3** – Former Production Area,*
- ***Operable Unit 4** – Silos 1 – 4, and*
- ***Operable Unit 5** – Environmental Media.*

Each operable unit has its own schedule and progresses at its own pace. For example, although one OU may be in the latter stages of the RI phase, another OU may still be in the final stages of the scoping phase. Under the 1991 Amended Consent Agreement, a Sitewide Operable Unit (encompassing OU1 through OU5) was established to ensure that actions taken under the individual operable units are protective of human health and the environment on a sitewide basis.

Figure 57: FEMP Operable Units



LEGEND

Operable Unit 1
Operable Unit 2
Operable Unit 3
Operable Unit 4
Operable Unit 5 (Not Shown)

1588

Remedial Investigation

The Remedial Investigation (RI) uses the project plan to conduct extensive field investigations. These investigations define the nature and extent of the contamination on site. A Baseline Risk Assessment is also performed. Based upon this information, each operable unit generates an RI report that supports the FS.

> ***Risk Assessment***
> *Risk assessment is a part of each OU's RI report.*
> *The scope is to:*
> - *Identify and assess the toxicity of all radionuclides and chemicals of concern at the site;*
> - *Estimate risks to human health, the environment, and ecological receptors; and*
> - *Support the development of preliminary and final remediation goals.*

Feasibility Study

The Feasibility Study (FS) for each OU describes and compares alternatives for remediation. These alternatives are developed to meet Remedial Action Objectives (RAOs), the cleanup goals set to protect the health of people and the environment.

During the FS, alternatives for long-term remedial action are screened and evaluated based on the following criteria:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume through treatment;
- Short-term effectiveness;
- Implementability;
- Cost;
- State EPA acceptance; and
- Community acceptance.

Working with USEPA, DOE recommends remedial action alternatives for each operable unit. Following the release of the FS reports, State and community acceptance of the recommended alternatives are evaluated. As more data are collected in the RIs, both the remedial goals and the selected alternatives may change. Thus, the RI/FS is an ongoing and complex process.

OU Summaries in this Chapter

The brief data summaries presented here cover the RI/FS through 1991. These summaries and proposals for the OUs are neither interpretations nor descriptions of actions taken; rather, the OU sections that follow summarize the RI/FS program's progress through 1991. Each OU discussion includes the following:

- A description of each operable unit,
- The RI/FS activities that have taken place, and
- The remedial action alternatives.

Operable Unit 1 – Waste Pit Area

Operable Unit 1 (OU1) consists of onsite facilities that were used during uranium production for storage of low-level radioactive waste. The operable unit covers approximately 15 hectares (37 acres) and consists of:

- Waste Pits 1 through 6,
- Waste pit liners,
- Berms,
- Soils within the OU boundary,
- The Clearwell, and
- The Burn Pit.

The immediate surrounding areas affected by these storage facilities are also studied as a part of OU1 (Figure 58).

Description of Operable Unit 1

Waste pits 1 through 6, located west of the former production area, contain a variety of liquid and solid wastes that were generated by the eight separate operations plants at the site. Pits 1 through 4 are covered with earth and pits 5 and 6 are covered with water. The Clearwell was a settling pond, and the Burn Pit contains residue from burned refuse.

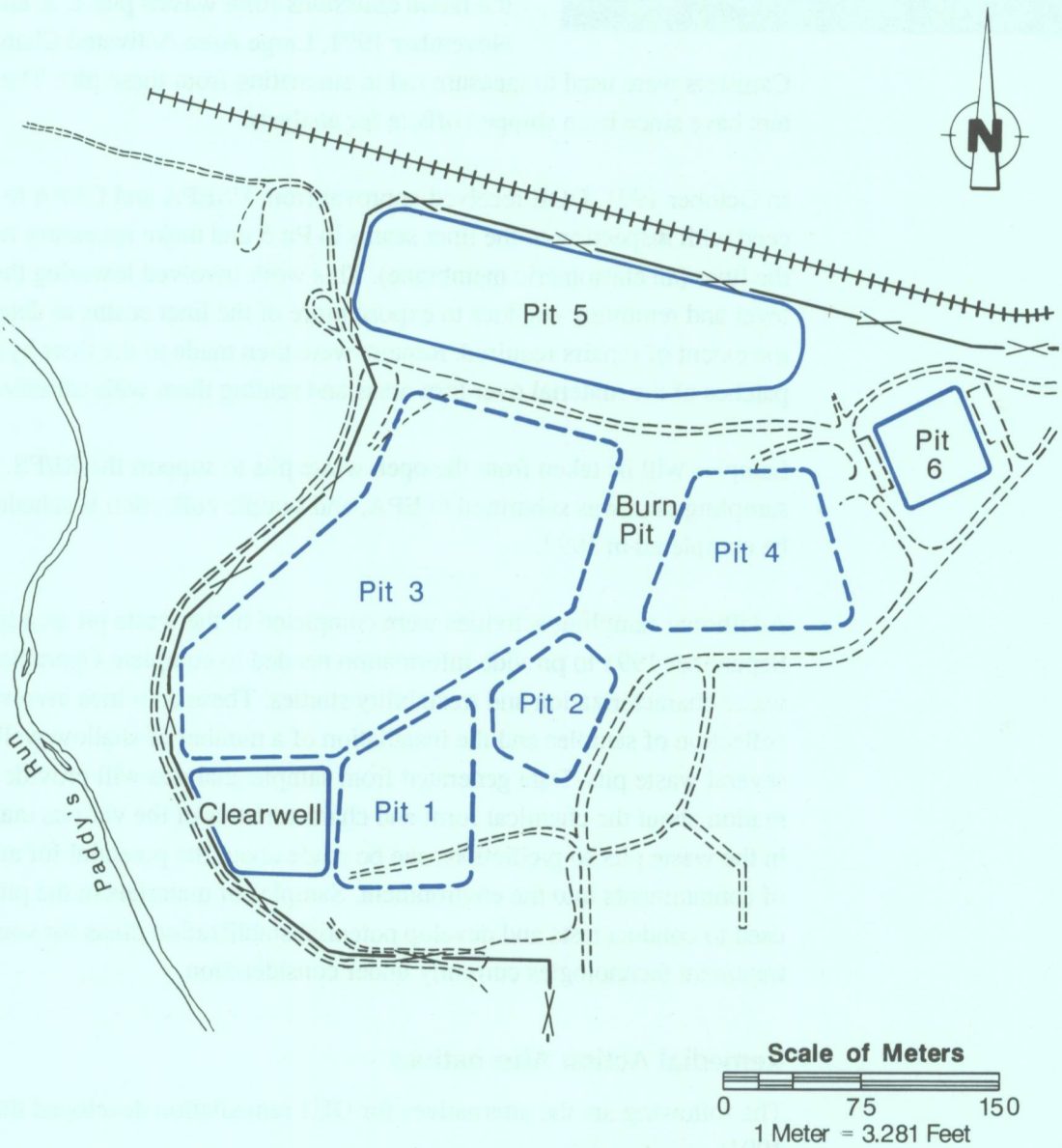
RI/FS Activities

Major activities for OU1 conducted during 1991 were sampling and geotechnical analysis of the pit berm soils; measurement of radon flux from waste pits 1, 2, and 3; repair to the Pit 5 liner; and sampling of the waste pit area to characterize the waste.

Objective
The objective of the RI/FS for OU1 is to stabilize, isolate, or treat the waste and any associated soils to prevent further release or migration of contaminants to the environment.

Regular monitoring of the soil in the berms around Pit 3, Pit 5, and the Clearwell was initiated in August 1991. This monitoring

Figure 58: Operable Unit 1 (OU1)



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Operable Unit 1 consists of the six Waste Storage Pits, the Clearwell and the Burn Pit.

- Fence
- Covered Pit
- Roadway
- Railroad Spur

1588

No-Action Alternative
The process of developing alternatives must always include taking no action as a baseline against which to measure all other alternatives. All the operable unit studies use this analytical tool.

was done to ascertain the berms' strength and to measure any movement or shifting of soils that constitute the berms.

Radon flux measurements were taken to determine the radon emissions from wastes pits 1, 2, and 3. In November 1991, Large Area Activated Charcoal Canisters were used to measure radon emanating from these pits. The canisters have since been shipped offsite for analysis.

In October 1991, DOE received approval from USEPA and OEPA to proceed with inspection of the liner seams in Pit 5 and make necessary repairs to the liner (an elastomeric membrane). This work involved lowering the water level and removing residues to expose more of the liner seams to determine the extent of repairs required. Repairs were then made to the liner by placing patches of the material over torn areas and sealing them with adhesives.

Samples will be taken from the open waste pits to support the RI/FS. The sampling plan was submitted to EPA, and sample collection is scheduled to be completed in 1992.

Additional sampling activities were completed in the waste pit area in September 1991 to provide information needed to complete Operable Unit 1 waste characterization and treatability studies. These activities involved the collection of samples and the installation of a number of shallow wells within several waste pits. Data generated from sample analyses will provide information about the chemical form and characteristics of the various materials in the waste pits so predictions can be made about the potential for migration of contaminants into the environment. Samples of materials in the pits will be used to conduct tests and develop potential stabilization plans for waste treatment technologies currently under consideration.

Remedial Action Alternatives

The following are the alternatives for OU1 remediation developed through 1991:

- No action;
- Nonremoval of wastes, slurry wall, and cap;
- Nonremoval of wastes, physical stabilization, slurry wall, and cap;
- Nonremoval, vitrification, and cap;
- Waste removal, treatment, and on-property disposal;
- Waste removal, treatment, and off-property disposal;
- Waste removal, treatment, on-property disposal, and cap; and
- Waste removal, treatment, on-property disposal, soil treatment, and cap.

Operable Unit 2 – Other Waste Units

Operable Unit 2 (OU2) consists of those facilities used for the storage or disposal of solid wastes from the site operations (see Figure 59 on page 188). These waste units are:

- Inactive Flyash Disposal Area;
- Active Flyash Pile;
- The South Field Disposal Areas;
- North and South Lime Sludge Ponds;
- The Solid Waste Landfill; and
- Berms, liners, and soils within the OU2 boundary.

Description of Operable Unit 2

The waste units in OU2 primarily consist of relatively large volumes of waste with small amounts of hazardous chemicals or radionuclides.

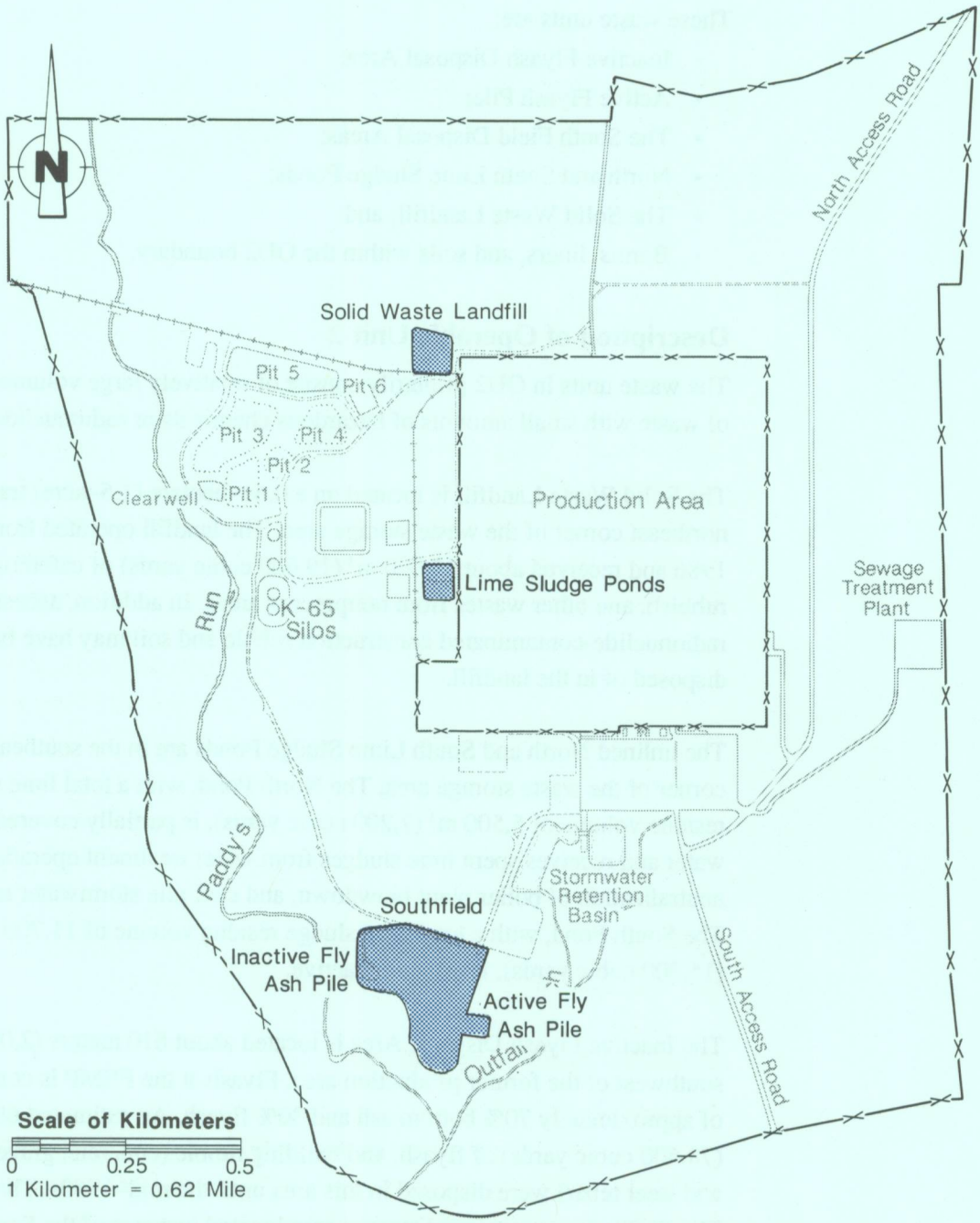
The Solid Waste Landfill is located on a 0.61–hectare (1.5–acre) tract in the northeast corner of the waste storage area. The landfill operated from 1954 to 1986 and received about 15,000 m^3 (19,600 cubic yards) of cafeteria wastes, rubbish, and other wastes from nonprocess areas. In addition, asbestos- and radionuclide-contaminated construction rubble and soil may have been disposed of in the landfill.

The unlined North and South Lime Sludge Ponds are in the southeastern corner of the waste storage area. The North Pond, with a total lime sludge residue volume of 5,500 m^3 (7,200 cubic yards), is partially covered with water and receives spent lime sludges from water treatment operations, the neutralization of boiler plant blowdown, and coal pile stormwater runoff. The South Pond, with a total lime sludge residue volume of 11,700 m^3 (15,300 cubic yards), is dry and inactive.

The Inactive Flyash Disposal Area is located about 610 meters (2,000 feet) southwest of the former production area. Flyash at the FEMP is composed of approximately 70% bottom ash and 30% flyash. An estimated 60,000 m^3 (78,500 cubic yards) of flyash, and building rubble (concrete, gravel, asphalt, and steel rebar) were disposed in this area until the mid–1960s. The Active Flyash Pile is an uncovered storage area located just east of the South Field Disposal Area, with an estimated volume of 45,000 m^3 (59,000 cubic yards). Flyash from the coal-fired boiler plant is disposed of in this area. Elevated uranium levels were found in both of these areas.

The South Field Disposal Area is reported to have been used as a disposal site for construction rubble that may have contained low levels of radioactivity. Other wastes may have been deposited here as well, although supporting

Figure 59: Operable Unit 2 (OU2)



LEGEND

- Operable Unit 2
- Covered Pit
- Fence
- Roadway
- Railroad Spur

1588

records are not available. For purposes of the RI/FS, the South Field Disposal Area is said to cover approximately 4.5 hectares (11 acres) with a volume of 83,000 m^3 (109,000 cubic yards) of waste.

RI/FS Activities

To determine whether or not the wastes stored in the OU2 facilities are sources of contamination to the environment, numerous samples were taken during three different investigations. The RI sampling for OU2 has already included the following media:

- Surface water and sediments,
- Surface soils,
- Subsurface soils, and
- Groundwater.

In 1990, however, it became apparent after the first two investigations that additional chemical, radiological, and geotechnical data would be required to complete the OU2 RI. In 1991, a third investigation of OU2 waste areas was undertaken to compensate for the gaps in the existing data. This additional sampling consisted of six borings in the Solid Waste Landfill, four each in the Inactive and Active Flyash Piles and the South Field Disposal Area, and one boring in each of the Lime Sludge Ponds. The additional sampling effort was completed to support waste treatment studies and the ongoing modeling efforts.

Objective
The objective of the RI/FS for OU2 is to mitigate a potential source of contamination resulting from large volumes of waste material that may have been contaminated with small amounts of hazardous chemical and radioactive materials during FEMP operations.

A revised Treatability Study Work Plan was submitted to USEPA in August 1991. Data generated by this study will be used to support OU2 treatment technology selection and remedy implementation. The revised OU2 Initial Screening of Alternatives Document was approved by USEPA in June 1991.

Remedial Action Alternatives

Although the Feasibility Study for OU2 has begun, the Remedial Action Objectives for OU2 are still under review by DOE and USEPA. They will be established during the continuation of the FS. As of 1991, initial screening of FS alternatives for long-term remedial action has identified the following alternatives:

Solid Waste Landfill

- No action,
- Containment (capping),
- Removal and treatment of waste and onsite disposal, and
- Removal and treatment of waste and offsite disposal.

Lime Sludge Ponds

- No action,
- Containment with *in situ* stabilization (capping),
- Removal and treatment of waste and onsite disposal, and
- Removal and treatment of waste and offsite disposal.

Flyash/South Field Disposal Area

- No action,
- Containment (capping),
- Removal and treatment of waste and onsite disposal, and
- Removal and treatment of waste and offsite disposal.

Operable Unit 3 – Former Production Area

All plants and facilities that were involved in producing uranium metal products and in processing thorium for other DOE programs are included in OU3 remediation (Figure 60). The primary contaminant of concern in OU3 is uranium, although thorium and other hazardous materials were also extensively used in these process facilities. The production area and production-associated facilities and equipment (includes all above- and below-grade improvements) are the objects of OU3 cleanup including, but not limited to:

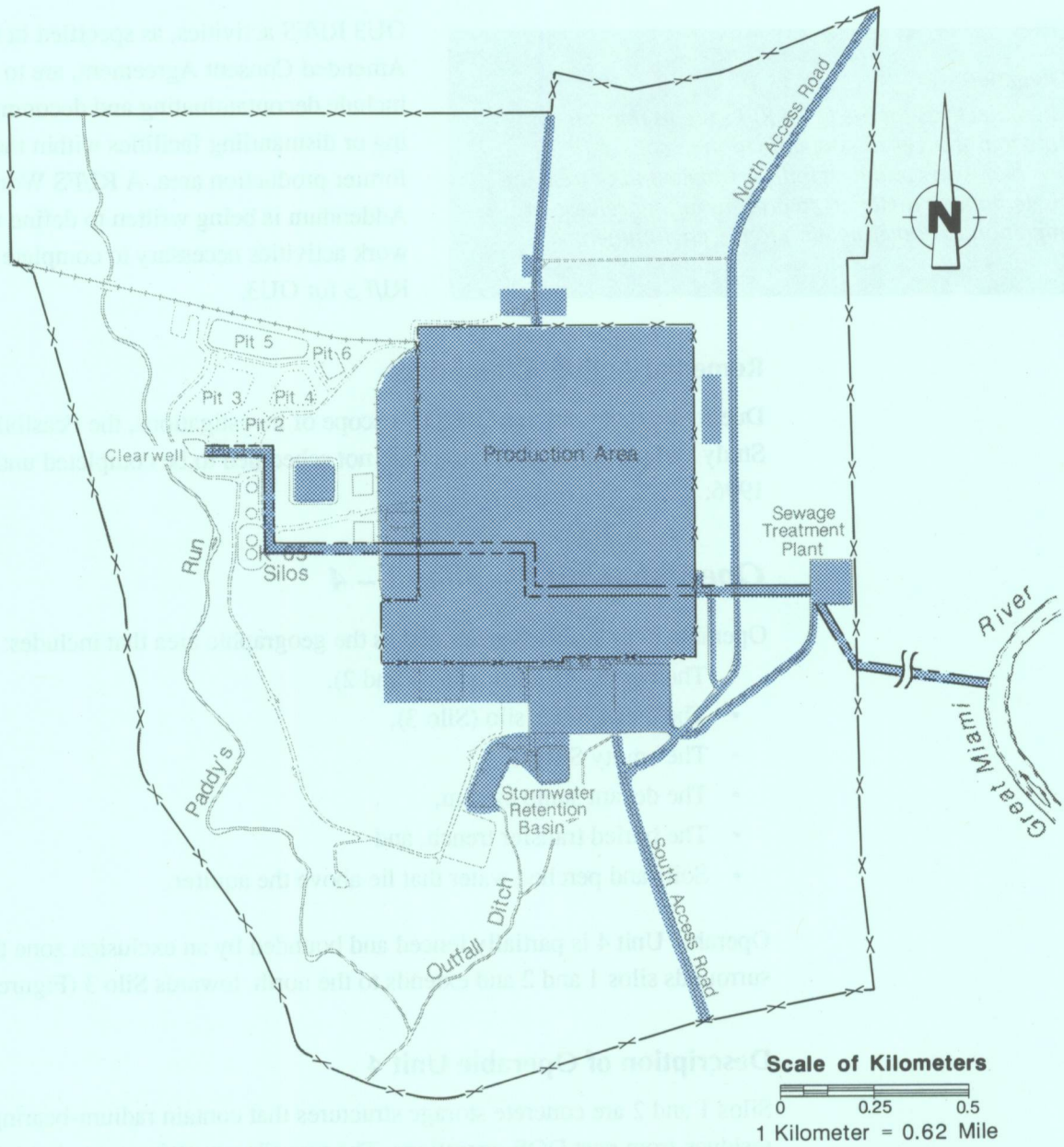
- All structures,
- Utilities,
- Tanks,
- Waste,
- K–65 transfer line,
- Fire training facilities,
- Scrap metal piles,
- Coal pile,
- Equipment,
- Drums,
- Solid waste,
- Effluent lines,
- Wastewater treatment facilities,
- Thorium,
- Feedstocks, and
- Product.

Description of Operable Unit 3

In May 1991, DOE and USEPA entered into negotiations to revise the Consent Agreement. These negotiations included a major revision to the OU3 definition. As a result of these negotiations, an Amended Consent Agreement was drafted and approved in September 1991. This Amended Consent Agreement outlined new schedules for the completion of the RI/FS and included a refined OU3 definition.

The FEMP's original definition for OU3 primarily included the contamination associated with soil, perched groundwater, surface water, and suspect areas in the former production area. The Amended Consent Agreement expanded this definition to include all former process buildings, structures, equipment, drum waste inventories, scrap and rubble piles, product invento-

Figure 60: Operable Unit 3 (OU3)



LEGEND

- Operable Unit 3
- Clearwell to Manhole 175 and Main Effluent Line
- Plant Perimeter
- Production Area Perimeter

1588

ries, roads and railroads, above and below grade piping and utilities, and removed contaminated media of soil and perched groundwater.

RI/FS Activities

Objective
The objectives for the OU3 RI/FS are to mitigate potential sources of contamination to soils and perched water and to stabilize, isolate and/or treat the contaminated materials to prevent further release or migration of contamination to the environment.

OU3 RI/FS activities, as specified in the Amended Consent Agreement, are to include decontaminating and decommissioning or dismantling facilities within the former production area. A RI/FS Work Plan Addendum is being written to define the work activities necessary to complete the RI/FS for OU3.

Remedial Action Alternatives

Due to the redefinition of the OU3 scope of investigations, the Feasibility Study and proposed alternatives are not scheduled to be completed until 1996.

Operable Unit 4 – Silos 1 – 4

Operable Unit 4 (OU4) is defined as the geographic area that includes:

- The two K–65 silos (silos 1 and 2),
- The metal oxide silo (Silo 3),
- The empty Silo 4,
- The decant sump system,
- The buried transfer trench, and
- Soils and perched water that lie above the aquifer.

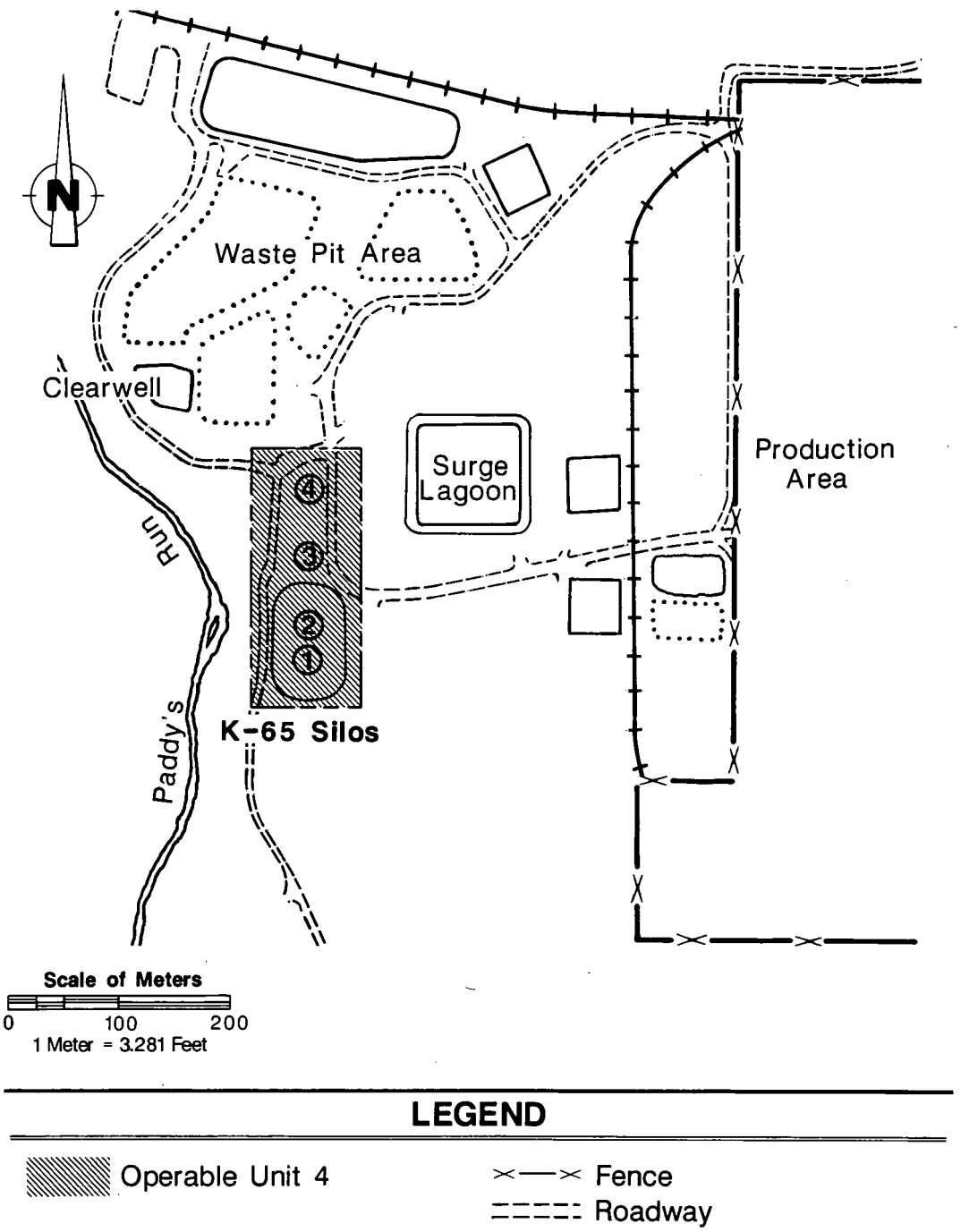
Operable Unit 4 is partially fenced and bounded by an exclusion zone that surrounds silos 1 and 2 and extends to the north, towards Silo 3 (Figure 61).

Description of Operable Unit 4

Silos 1 and 2 are concrete storage structures that contain radium-bearing residues from past DOE operations. The two silos contain approximately 8,800 metric tons (9,700 tons) of residues remaining from the processing of pitchblende, a uranium-rich ore.

Silo 3 received only dry materials. Slurries from refinery operations were dried in a high-temperature evaporator and reduced to a dry waste that was blown into the silo. These wastes were primarily metal oxides.
Silo 4 was never used and, therefore, is not considered to be a past, current, or future source of contaminant release to the environment.

Figure 61: Operable Unit 4 (OU4)



1588

RI/FS Activities

During 1991, OU4 activities included vertical borings into the earthen berms that surround the K–65 silos, low-angle borings to sample underneath the silos, and resampling of the silos' residues.

The four vertical borings into the earthen berms surrounding the K–65 silos were completed in June 1991. Samples were collected from these borings to determine whether measurable quantities of residual materials or radon gas have leaked or diffused through the walls of the silos into the surrounding berms.

> **Objective**
> *The objective of the RI/FS for OU4 is to treat, stabilize, or isolate the silo contents, structures, and affected areas to prevent further release or migration of contaminants to the environment.*

Soil samples from five sub-surface borings beneath the K–65 silos have been acquired, prepared, and transported to an offsite laboratory for analysis. The analysis is being conducted to determine whether residual materials have migrated from the tanks or the associated underdrain system into the underlying soils or perched groundwater. Full chemical and radiological analyses to confirm preliminary findings are currently being evaluated. Preliminary sample analyses indicated that the concentrations of contaminants are for the most part within the natural background range, except for locations where spills might have occurred during the initial filling operations.

Resampling of the contents of silos 1 and 2 was successfully completed in August 1991. This resampling was necessary because material retrieved during previous sampling operations was not representative of the entire silo contents. The amount of material retrieved from the full depth of the silos during resampling operations is adequate to perform planned chemical, radiological, and geotechnical analysis. Sample results will be used to determine appropriate treatment methods for K–65 contents. Analyses results are scheduled to be available from the laboratory in 1992.

In support of the selection of the recommended remedial alternatives, treatability testing per USEPA work plans is being conducted to evaluate stabilization by both cementation and vitrification and chemical separation.

Remedial Action Alternatives

The FEMP identifies and recommends the methods that will be most effective in meeting the Remedial Action Alternatives (RAOs) for OU4 in the FS. Separate remedial alternatives to meet the RAOs have been developed for all components of OU4.

Alternatives for long-term remedial action for OU4 have been evaluated using the following criteria:

- Short-term and long-term protection of public health and the evnironment;
- Reduction in mobility, toxicity, and volume;
- Constructability;
- Reliability;
- Maintenance;
- Agency approvals; and
- Special engineering and equipment.

Below are the *preferred* alternatives currently being considered for long-term remedial action developed for the silos within OU4:

Silos 1 and 2

- In-place stabilization of wastes, cap over the silos;
- Removal and treatment of wastes with either on- or offsite disposal; and
- Removal of wastes and separation of contaminants with either on- or offsite disposal.

Silo 3

- In-place stabilization of wastes, cap over the silo; and
- Removal and treatment of wastes with either on- or offsite disposal.

Silo 4

- Removal of contaminated water, silo demolition, with either on- or offsite disposal; and
- No action.

As more data becomes available through ongoing analysis and treatability studies, both the remediation goals and the alternatives selected to meet those goals may change.

Operable Unit 5 – Environmental Media

The fifth operable unit consists of environmental media that can serve as pathways for transporting contaminants. The environmental media that make up OU5 are:

- Soils,
- Flora and fauna,
- Surface water and sediments, and
- Groundwater (including perched groundwater).

Description of Operable Unit 5

All soils not accounted for in the other operable units are researched as part of this OU. Investigations into the flora and fauna include terrestrial vegetation and animals, aquatic communities in the Great Miami River and Paddy's Run, locally grown produce and crops, and cattle grazing on potentially affected land areas.

Surface water channels included in OU5 are the Great Miami River, Paddy's Run, and the Storm Sewer Outfall Ditch. The river receives the site effluent discharge. Paddy's Run receives natural surface runoff and loses flow to the aquifer through its highly permeable channel bottom. The Storm Sewer Outfall Ditch may receive excess stormwater runoff from the Stormwater Retention Basin, in addition to runoff from the eastern area of the site. As materials suspended in the water settle to the bottom of the stream or river, sediment is formed. This sediment is analyzed to determine any influence from the FEMP.

The groundwater of the Great Miami Aquifer is carefully monitored as part of OU5, because it is a major local water source (see Chapter Six).

RI/FS Activities

In support of RI sampling, the Paddy's Run Seepage Investigation Study is a specific investigation to determine the interaction between Paddy's Run and the aquifer below it. Groundwater flow rates are monitored at wells along the southern stretch of the creek, while Paddy's Run flow rates are measured by a series of stream gauges. Sampling results will show if groundwater flow is being affected by seepage of Paddy's Run water through the creek bed, and these results will be included in the final RI/FS reports.

Objectives
The objectives of the RI/FS for OU5 are to prevent human exposure to contaminated water or other media and to prevent further contamination of area soils, water, flora, sediments, and fauna.

During 1991, the FEMP began to look into the possibility of providing some financial support for a public water supply for those residents and businesses affected by the South Groundwater Contamination Plume. Hamilton County, Ohio is responsible for all aspects of the public water supply; the DOE is proposing to fund its "fair share" of the costs for those areas affected by the South Plume. Planning and evaluation of alternatives will continue in 1992.

In response to a plume of contaminated groundwater extending south of the FEMP, the South Groundwater Contamination Plume Removal Action has been initiated. This removal action is intended to limit access and exposure to this water, protect the groundwater environment, and control further southerly migration of the plume. Included in this removal action is the use

227

of an advanced wastewater treatment facility that will decrease overall uranium discharged to the river.

Also, in order to decrease the amount of uranium released into Paddy's Run from the site, the Collection of Uncontrolled Production Area Runoff Removal Action will be implemented.

Remedial Action Alternatives

The Feasibility Study for OU5 has not yet begun. Much of the data requirements that will govern OU5, such as contaminants of concern, exposure pathways and receptors, and acceptable cleanup levels, are still being defined.

Appendices

4030

FEMP Environmental Monitoring Data for 1991

Numerous sampling and analysis data are required to evaluate compliance with environmental regulations and to obtain accurate indications of the FEMPs operations during 1991. 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 sediments samples. These variations exist because of differences in chemical and physical properties of species in addition to differences in the capabilities of instruments available to measure these properties.

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, 1991

	Units	January	February	March	April	May	June	July	August	September	October	November	December
10 – Meter Wind Speed													
Maximum	kph[a]	19	23	29	24	21	18	15	15	18	18	21	26
Minimum	kph[a]	0.5	0.6	1.0	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.0
60 – Meter Wind Speed													
Maximum	kph[a]	27	39	56	42	35	26	26	26	32	31	40	47
Minimum	kph[a]	0.2	0.2	1.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.1	1.4
Ambient Air Temperature[b]													
Average	°C	– 0.8	2.2	7.1	13	21	23	24	22	18	13	5.2	2.6
Maximum	°C	11	17	24	26	31	33	34	35	33	28	20	18
Minimum	°C	– 15	– 16	– 5.9	– 1.8	5.5	10	12	12	0.5	– 3.0	– 12	– 12
Dew Point [b]													
Average	°C	– 9.8	– 3.8	0.2	6.1	16	16	16	16	12	6.9	– 1.1	– 2.6
Maximum	°C	5.7	9.6	15	17	22	22	23	22	23	17	15	13
Minimum	°C	– 26	– 20	– 10	– 8.4	1.5	5.4	7.8	9.6	– 1.4	– 5.1	– 17	– 17
Precipitation													
Monthly Total	cm[c]	2.3	7.4	14	12	6.4	4.3	3.8	14	8.4	6.4	6.6	11
Daily Maximum	cm[c]	1.0	2.8	4.8	3.8	2.0	1.0	1.5	3.3	4.8	1.5	1.8	4.8

(a) To convert wind speed from kilometers per hour (kph) to miles per hour (mph) divide by 1.6093.

(b) Ambient air temperature and dew point measured at the 10–meter level.

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

TABLE 2: Uranium in Air, 1991

Sampling [a] Location	Number of Samples	Concentration ($pCi/m^3 \times 10^{-6}$) Minimum	Maximum	Average	Percent of Standard[b] Minimum	Maximum	Average
Fenceline							
AMS 1	51	0	630	150	0	0.63	0.15
AMS 2	52	10	610	170	0.0010	0.61	0.17
AMS 3	52	21	650	240	0.0021	0.65	0.24
AMS 4	52	0	1,300	120	0	1.3	0.12
AMS 5	52	0	210	60	0	0.21	0.060
AMS 6	52	0	320	90	0	0.32	0.090
AMS 7	52	0	230	60	0	0.23	0.060
Onsite							
AMS 8	52	0	1,300	350	0	1.3	0.35
AMS 9	52	65	10,000	2,200	0.065	10	2.2

(a) See Figure 21 for locations.

(b) Standard is $100,000 \times 10^{-6}$ pCi/m^3, as listed in DOE Order 5400.5.

TABLE 3: Uranium in Grass and Soil, 1991

Sampling Location[a]	Distance from Center of FEMP (km)	Grass Uranium Concentration (pCi/g dry)[b,c]	Soil Uranium Concentration (pCi/g dry)[b,c] 0 – 5 cm	Soil Uranium Concentration (pCi/g dry)[b,c] 5 – 10 cm
Onsite				
9	0.10	0.16 ± 0.03	11 ± 1.8	22 ± 3.6
8	0.15	0.17 ± 0.07	28 ± 4.3	22 ± 3.3
Fenceline				
1	0.16	0.095 ± 0.020	11 ± 1.6	8.5 ± 1.3
3	0.16	0.041 ± 0.014	6.4 ± 1.0	43 ± 6.5
4	0.49	0.22 ± 0.07	7.2 ± 1.1	4.8 ± 0.7
6	0.63	0.095 ± 0.034	1.7 ± 0.3	3.0 ± 0.5
5	0.64	0.28 ± 0.07	4.4 ± 0.7	9.7 ± 1.6
2	1.1	0.074 ± 0.027	10 ± 1.6	14 ± 2.2
7	1.3	0.15 ± 0.03	0.74 ± 0.14	0.95 ± 0.20
Offsite				
30	1.3	0.020 ± 0.014	14 ± 2.4	8.0 ± 1.3
31	1.9	0.034 ± 0.007	4.5 ± 0.74	4.5 ± 0.68
15	1.9	0.068 ± 0.020	3.9 ± 0.61	1.7 ± 0.27
12	2.2	0.088 ± 0.041	0.54 ± 0.07	0.88 ± 0.14
24	2.4	0.14 ± 0.02	4.1 ± 0.61	2.2 ± 0.34
10	2.6	0.047 ± 0.020	0.41 ± 0.07	0.81 ± 0.14
25	2.7	0.034 ± 0.020	1.3 ± 0.20	4.3 ± 0.68
11	3.7	0.027 ± 0.020	0.88 ± 0.14	0.54 ± 0.07
17	3.7	0.095 ± 0.020	1.5 ± 0.27	1.4 ± 0.20
20	3.7	0.095 ± 0.014	0.74 ± 0.14	1.1 ± 0.20
34	3.8	0.034 ± 0.014	2.3 ± 0.34	2.1 ± 0.34
21	3.9	0.081 ± 0.014	0.95 ± 0.14	1.1 ± 0.20
13	4.2	0.32 ± 0.07	4.9 ± 0.81	14 ± 2.2
33	4.2	0.68 ± 0.14	3.1 ± 0.47	2.3 ± 0.34
23	4.3	0.027 ± 0.014	2.7 ± 0.47	1.6 ± 0.27
22	5.0	0.027 ± 0.014	1.5 ± 0.27	1.1 ± 0.20
18	5.1	0.041 ± 0.020	1.3 ± 0.20	1.2 ± 0.20
14	5.4	0.14 ± 0.02	1.1 ± 0.14	2.2 ± 0.34
19	8.8	0.020 ± 0.014	1.4 ± 0.27	1.4 ± 0.20
29	24	0.10 ± 0.03	3.8 ± 0.61	1.6 ± 0.27
28	40	0.16 ± 0.04	1.1 ± 0.20	1.6 ± 0.27

(a) Locations (see Figure 24) are listed in order of increasing distance from the center of the FEMP production area (Plant 4).

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

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

TABLE 4: Uranium in Produce and Soil, 1991

Sampling Location[a]	Distance from Center of FEMP(km)[a]	Concentration pCi/g[b,c]
Soil		
14	1.4	2.1 ± 0.34
19	1.4	3.2 ± 0.54
19	1.4	2.0 ± 0.34
15	1.5	1.1 ± 0.14
24	1.6	1.4 ± 0.2
24	1.6	1.7 ± 0.06
1	1.6	3.9 ± 0.61
9	1.6	Not Sampled
23	1.7	1.6 ± 0.05
23	1.7	2.0 ± 0.06
4	1.9	Not Sampled
18	1.9	2.0 ± 0.34
18	1.9	1.6 ± 0.06
6	2.0	1.6 ± 0.27
20	2.1	2.1 ± 0.07
20	2.1	1.8 ± 0.06
21	2.4	3.2 ± 0.11
21	2.4	1.4 ± 0.04
5	2.9	0.74 ± 0.14
5	2.9	1.4 ± 0.20
3	3.2	3.6 ± 0.54
12	3.6	2.2 ± 0.34
13	3.8	1.6 ± 0.27
10	4.0	1.4 ± 0.27
2	4.6	1.7 ± 0.27
7	4.9	1.5 ± 0.27
8	11	2.0 ± 0.14
17	16	0.88 ± 0.14
11	24	0.81 ± 0.14
16	30	1.4 ± 0.2
22	42	0.95 ± 0.02
22	42	1.4 ± 0.03

Sampling Location[a]	Concentration pCi/g[b,c]
Tomatoes	
15	0.27 ± 0.07
1	0.27 ± 0.07
6	0.067 ± 0.068
3	0.20 ± 0.07
12	0.34 ± 0.07
13	0.14 ± 0.07
10	0.14 ± 0.07
2	0.14 ± 0.07
7	0.14 ± 0.07
8	0.41 ± 0.07
11	0.41 ± 0.07
16	0.61 ± 0.07
Green (G) & Red (R) Peppers	
15(G)	0.34 ± 0.07
1(R)	0.20 ± 0.07
5(G)	0.27 ± 0.07
5(R)	0.27 ± 0.07
12(G)	0.20 ± 0.07
10(R)	0.068 ± 0.068
2(G)	0.27 ± 0.07
8(G)	0.20 ± 0.07
16(G)	0.27 ± 0.07

Sampling Location[a]	Concentration pCi/g[b,c]
Potatoes (P), Carrots (C), Beets (B), Onions (O), and Radish (R)	
15 (R)	1.6 ± 0.27
15 (O)	2.5 ± 0.41
1 (C)	0.34 ± 0.07
1 (B)	1.2 ± 0.20
12 (P)	0.20 ± 0.07
13 (P)	0.34 ± 0.07
7 (P)	0.54 ± 0.07
7 (O)	0.41 ± 0.07
8 (P)	0.20 ± 0.07
8 (O)	0.20 ± 0.07
17 (P)	0.14 ± 0.07
16 (C)	1.2 ± 0.20
Soybeans	
19	0.21 ± 0.01
24	< 0.0047
23	< 0.13
18	< 0.030
20	< 0.027
21	< 0.042
22	1.2 ± 0.05

Sampling Location[a]	Concentration pCi/g[b,c]
Cabbage	
6	0.27 ± 0.07
12	0.14 ± 0.07
8	0.27 ± 0.07
16	0.20 ± 0.07
Eggplant (E), Green Beans (G), Pumpkins (P), Lima Beans (L), and Squash (S)	
5(E)	0.14 ± 0.07
5(G)	0.20 ± 0.07
12(S)	0.14 ± 0.07
13(P)	0.34 ± 0.07
10(L)	0.27 ± 0.07
10(S)	0.41 ± 0.07
10(P)	0.34 ± 0.07
7(L)	0.14 ± 0.07
7(S)	0.27 ± 0.07
8(E)	0.27 ± 0.07
8(S)	0.34 ± 0.07
8(S)	0.20 ± 0.07
8(G)	0.27 ± 0.07
17(G)	0.27 ± 0.07

TABLE 4: Uranium in Produce and Soil, 1991

Sampling Location[a]	Concentration pCi/g[b,c]
Corn	
19	0.27 ± 0.07
24	0.14 ± 0.07
23	< 0.28
4	0.14 ± 0.07
4	0.34 ± 0.07
18	0.14 ± 0.07
6	0.27 ± 0.07
20	< 0.020
21	< 0.012
3	0.41 ± 0.07
12	0.14 ± 0.07
13	0.34 ± 0.07
10	0.20 ± 0.07
17	0.20 ± 0.07
17	0.20 ± 0.07
22	< 0.013
Apples	
14	0.20 ± 0.07
9	0.20 ± 0.07
13	0.14 ± 0.07
7	0.47 ± 0.07
17	0.20 ± 0.07
11	0.14 ± 0.07
16	0.27 ± 0.07

(a) Locations (see Figure 26) are listed in order of increasing distance from the center of the FEMP production area (Plant 4).

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

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

TABLE 5: Uranium in Milk, 1991

Concentration of Total Uranium

Month	Local Dairy (pCi/L)[a]	Background Dairy[b]	QC Spike Recovery (pCi/L)[a] Background Dairy [b]	
			Expected	Measured
January	0.048 ± 0.005	0.065 ± 0.001	5.0	1.6
February	0.029 ± 0.038	0.052 ± 0.006	100	74
March	0.067 ± 0.007	0.043 ± 0.005	50	41
April	0.068 ± 0.007	0.11 ± 0.01	24	16
May	0.035 ± 0.004	0.60 ± 0.07	10	6.9

Concentration of Uranium–238[c]

Month	Local Dairy (pCi/L)[a]	Background Dairy[b]	QC Spike Recovery (pCi/L)[a] Background Dairy [b]		QC Spike Recovery (pCi/L)[a] Local Dairy	
			Expected	Measured	Expected	Measured
June	0.012 ± 0.028	0.033 ± 0.039	0.85	0.84	0.85	1.0
July	0.015 ± 0.064	0.007 ± 0.022	0.85	0.71	0.85	0.42
August	< 0.048	0.013 ± 0.031	0.85	0.97	0.85	1.2
September	0.052 ± 0.038	0.021 ± 0.025	0.85	1.3	0.85	0.80
October	0.015 ± 0.022	< 0.030	0.85	1.1	0.85	1.3
November	0.012 ± 0.029	< 0.032	0.85	0.74	0.85	0.95
December	0.009 ± 0.013	0.029 ± 0.031	0.85	0.60	0.85	0.73

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

(b) Background dairy is about 37 km (23 miles) west-south-west (WSW) of the FEMP.

(c) The total uranium radioactivity is about twice this amount because naturally occurring uranium typically contains equal amounts of uranium–238 and uranium–234 radioactivity.

TABLE 6: Radionuclides Discharged to the Great Miami River, 1991

Radionuclide [a]	Total Curies 1990	Total Curies 1991	1991 Average Concentration (pCi/L)[b,c]	Standard[d] pCi/L	Percent of Standard[e]
Actinium – 227	< 0.00098	< 0.00013	< 0.16	10	< 1.6
Cesium – 137	< 0.011	< 0.0011	< 4.0	3,000	< 0.1
Potassium – 40	< 0.16	< 0.071	< 86	7,000	< 1.2
Neptunium – 237	< 0.0002	0.0016	1.9	30	6.3
Lead – 210 [f]	< 0.0083	< 0.0026	< 3.1	30	<10.33
Plutonium – 238	< 0.000098	< 0.000082	< 0.10	40	< 0.2
Plutonium – 239/240	< 0.00012	< 0.000041	< 0.05	30	< 0.2
Radium – 226	< 0.0048	< 0.0026	< 3.1	100	< 3.1
Radium – 228	< 0.010	< 0.0030	< 3.7	100	< 3.7
Ruthenium – 106	< 0.088	< 0.0098	< 36	6,000	< 0.6
Strontium – 90	0.00039	< 0.00071	< 2.7	1,000	< 0.27
Technetium – 99	< 1.7	< 1.6	< 2,000	100,000	< 2.0
Thorium – 228	< 0.00027	< 0.00011	<0.13	400	< 0.03
Thorium – 230	0.00069	0.00046	0.56	300	0.2
Thorium – 232	< 0.0005	< 0.000050	< 0.06	50	< 0.1
Thorium – 234[g]	0.26	0.22	270	10,000	2.67
Uranium – 234	0.18	0.17	210	500	42.2
Uranium – 235	0.011	0.0084	10	600	1.7
Uranium – 236	0.0068	0.0061	7.4	500	1.5
Uranium – 238	0.26	0.22	270	600	44.6
					Total: < 122.6

(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.

(b) Averages are flow-weighted.

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

(d) As stated in DOE Draft Order 5400.5.

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

(f) Calculated value based on radioactive decay equilibrium with Radium-226.

(g) Calculated value based on radioactive decay equilibrium with Uranium-238.

TABLE 7: Radionuclides in Surface Water, 1991

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	52	0.74	1.5	1.1	550	0.14	0.27	0.19
Downstream of Effluent Line	W3	52	0.81	1.9	1.2	550	0.15	0.34	0.22
Downstream of Effluent Line	W4	52	0.88	1.8	1.3	550	0.16	0.32	0.23
Radium – 226[d]									
Upstream of Effluent Line	W1	12	< 0.1	0.1	< 0.1	100	< 0.1	0.1	< 0.1
Downstream of Effluent Line	W3	12	< 0.1	0.1	< 0.1	100	< 0.1	0.1	< 0.1
Downstream of Effluent Line	W4	12	< 0.1	0.1	< 0.1	100	< 0.1	0.1	< 0.1
Radium – 228[d]									
Upstream of Effluent Line	W1	12	< 0.1	0.2	0.1	100	< 0.1	0.2	0.1
Downstream of Effluent Line	W3	12	< 0.1	0.1	< 0.1	100	< 0.1	0.1	< 0.1
Downstream of Effluent Line	W4	12	< 0.1	0.2	0.1	100	< 0.1	0.2	0.1
Strontium – 90[d]									
Upstream of Effluent Line	W1	2	< 1.3	1.7	—	1,000	< 0.13	0.17	—
Downstream of Effluent Line	W3	2	< 1.2	< 1.4	—	1,000	< 0.12	< 0.14	—
Downstream of Effluent Line	W4	2	< 1.2	< 1.3	—	1,000	< 0.12	< 0.13	—
Cesium – 137[d]									
Upstream of Effluent Line	W1	2	< 4.1	< 5.3	—	3,000	< 0.14	< 0.18	—
Downstream of Effluent Line	W3	2	< 3.6	< 3.7	—	3,000	< 0.12	< 0.12	—
Downstream of Effluent Line	W4	2	< 3.5	< 4.0	—	3,000	< 0.12	< 0.13	—
Technetium – 99[d]									
Upstream of Effluent Line	W1	2	< 7.7	< 7.9	—	100,000	< 0.0077	< 0.079	—
Downstream of Effluent Line	W3	2	< 7.7	< 7.8	—	100,000	< 0.0077	< 0.078	—
Downstream of Effluent Line	W4	2	< 7.7	< 7.8	—	100,000	< 0.0077	< 0.078	—

TABLE 7: Radionuclides in Surface Water, 1991

Parameter	Sampling Location[a]	Number of Samples	Concentration (pCi/L)[b] Minimum	Maximum	Average	Standards (pCi/L)[c]	Percent of Standard Minimum	Maximum	Average
Paddy's Run									
Total Uranium									
Upstream of FEMP	W5	47	0.41	1.6	0.78	550	0.07	0.28	0.14
Onsite	W9	40	0.47	5.3	1.5	550	0.09	0.97	0.27
Onsite	W-10 US	25	0.95	850	2.8 [e]	550	0.17	150	0.52 [e]
	W10	25	1.0	1,100	3.4 [e]	550	0.18	210	0.63 [e]
	W-10 DD	26	45	770	340	550	8.1	140	62
	W-10 DS	25	1.1	290	8.1 [e]	550	0.21	53	1.5 [e]
Onsite	W11	24	2.5	11	5.7	550	0.46	2.1	1.0
Downstream of FEMP	W7	22	2.3	9.5	5.0	550	0.42	1.72	0.92
Downstream of FEMP	W8	50	1.1	8.1	3.9	550	0.20	1.47	0.70
Radium – 226[d]									
Upstream of FEMP	W5	6	< 0.1	< 0.1	< 0.1	100	< 0.1	< 0.1	< 0.1
Downstream of FEMP	W7	6	< 0.1	0.1	< 0.1	100	< 0.1	0.1	< 0.1
Downstream of FEMP	W8	6	< 0.1	0.1	< 0.1	100	< 0.1	0.1	< 0.1
Radium – 228[d]									
Upstream of FEMP	W5	6	< 0.1	0.1	< 0.1	100	< 0.1	0.1	< 0.1
Downstream of FEMP	W7	6	< 0.1	0.2	0.1	100	< 0.1	0.2	0.1
Downstream of FEMP	W8	6	< 0.1	0.2	0.1	100	< 0.1	0.2	0.1

(a) See Figure 32 for sampling locations.

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

(c) Standards as listed in DOE Order 5400.5. The standards are based on drinking 730 liters (about 200 gallons) of water per year. The FEMP compares data from the Great Miami River and Paddy's 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, W7, and W8; and
- two-month composites of weekly samples from W5.

Semiannual composites were used for those isotopes where two samples are recorded.

(e) Represents the median value.

TABLE 8: Radioisotopes in Great Miami River, Paddy's Run and Storm Sewer Outfall Ditch Sediments, 1991[a]

Radionuclide	Number of Samples	Concentration (pCi/g dry)[b] Minimum	Maximum	Maximum to Minimum Ratio	Average for all Samples
Paddy's Run Background (North of S.R. 126)					
Radium – 226	4	0.60	0.65	1.1	0.64
Thorium – 228	4	0.67	1.1	1.6	0.83
Thorium – 230	4	0.81	1.5	1.8	1.1
Thorium – 232	4	0.67	1.1	1.6	0.83
Total Uranium	4	0.41	1.4	3.5	0.79
Paddy's Run North of the Storm Sewer Outfall Ditch					
Radium – 226	12	0.40	0.90	2.3	0.63
Thorium – 228	10	0.34	1.0	3.0	0.66
Thorium – 230	10	0.46	1.2	2.7	0.73
Thorium – 232	10	0.34	1.0	3.0	0.66
Total Uranium	12	0.61	3.7	6.0	1.4
Storm Sewer Outfall Ditch					
Radium – 226	8	0.50	1.3	2.6	0.72
Thorium – 228	5	0.60	0.83	1.4	0.75
Thorium – 230	5	0.80	1.4	1.7	1.1
Thorium – 232	5	0.60	0.83	1.4	0.75
Total Uranium	8	0.41	3.4	8.3	1.8
Paddy's Run South of Storm Sewer Outfall Ditch					
Total Uranium	12	0.61	2.5	4.1	1.2
Great Miami River North of the Effluent Line					
Total Uranium	2	0.68	1.8	2.6	1.2
Great Miami River at the Effluent Line					
Total Uranium	1	—	—	1.0	1.1
Great Miami River South of the Effluent Line, and North of Paddy's Run					
Total Uranium	4	0.74	1.6	2.1	1.1
Great Miami River South of Paddy's Run					
Total Uranium	2	0.54	1.4	2.6	0.98

(a) See Figure 34 for sampling locations.

(b) Multiply pCi/g by 0.037 to obtain Bq/g.

TABLE 9: Uranium Concentrations in Fish from the Great Miami River, 1991

Sampling Location[a]	Family[b]	Number of Samples	Concentration (pCi/g dry)[c,d] Minimum	Maximum	Average
1 Upstream of the Hamilton Dam (River Mile 38)	1	5	0.0020	0.018	0.0060
	2	11	0.0020	0.0095	0.0043
	3	4	0.0041	0.0055	0.0048
	4	5	0.0025	0.0043	0.0035
	5	0	—	—	—
	Summary	**25**	**0.0020**	**0.018**	**0.0046**
2 Upstream of the Effluent Line (River Mile 28)	1	6	0.0029	0.0051	0.0038
	2	0	—	—	—
	3	9	0.0034	0.10	0.015
	4	26	0.0029	0.033	0.0095
	5	3	0.0032	0.015	0.0075
	Summary	**44**	**0.0029**	**0.10**	**0.0097**
3 At the Effluent Line (River Mile 24)	1	5	0.0032	0.027	0.016
	2	0	—	—	—
	3	8	0.0022	0.0052	0.0041
	4	8	0.0016	0.0088	0.0058
	5	5	0.0058	0.030	0.019
	Summary	**26**	**0.0016**	**0.030**	**0.0097**
4 At Confluence of Paddy's Run and River (River Mile 19)	1	3	0.0032	0.012	0.0069
	2	0	—	—	—
	3	4	0.0048	0.0088	0.0059
	4	6	0.0033	0.0074	0.0052
	5	1	0.0030	0.0030	0.0030
	Summary	**14**	**0.0030**	**0.012**	**0.0056**

(a) See Figure 35 for sampling locations.

(b) Family:
1 = Cyprinidae (carp, minnow, and shiner)
2 = Catastomidae (carpsucker, redhorse, hogsucker, quillback, and black buffalo)
3 = Centrarchidae, Serranidae, Percidae, and Lepisosteidae (bass, sunfish, drum, sauger, darter, crappie, and gar)
4 = Clupeidae (gizzard shad)
5 = Ictaluridae (catfish)

(c) All concentrations in dry weight.

(d) Multiply by 0.037 to obtain Bq/g (dry weight).

TABLE 10: NPDES Data, 1991

Sampling Location and Parameter	Units	Monitoring Requirements	Daily Monitoring Results Minimum	Maximum	Average[a]	Permit Limits[b] Daily Maximum	Monthly Average	Percent Compliance[c]
Discharge 001 (MH175 to Great Miami)								
Flow Rate	MGD	Continuous	0.13	1.5	0.60	NA	NA	NA
pH	S.U.	Continuous	4.0	9.3	NA	Range = 6.5 to 9.0		100.0[d]
Dissolved Oxygen	mg/L	Weekly/Grab	6.0	11	8.6	Minimum = 5.0		100.0
Suspended Solids	mg/L	Wk/24hr Comp	< 2.0	15	< 5.0	45	30	100.0
Oil & Grease	mg/L	Weekly/Grab	< 5.0	< 5.0	< 5.0	15	15	100.0
Cyanide	mg/L	Weekly/Grab	< 0.005	0.006	< 0.005	0.076	0.036	100.0
Copper	µg/L	Wk/24hr Comp	< 14	26	< 15	94	23	100.0
Silver	µg/L	Wk/24hr Comp	< 3.0	< 10	< 6.2	26	12	100.0
BOD-C	mg/L	Wk/24hr Comp	0.02	4.6	2.1	30	20	100.0
Lead	µg/L	Wk/24hr Comp	< 3.0	21	< 5.8	780	60	100.0
Suspended Solids	kg/day	Wk/24hr Comp	< 1.3	60	< 13	150	99	100.0
Oil & Grease	kg/day	Weekly/Grab	< 3.4	27	< 12	50	50	100.0
Cyanide	kg/day	Weekly/Grab	< 0.0034	0.027	< 0.013	0.25	0.12	100.0
Copper	kg/day	Wk/24hr Comp	< 0.0094	0.087	< 0.036	0.31	0.077	100.0
Silver	kg/day	Wk/24hr Comp	< 0.0028	0.049	< 0.015	0.086	0.40	100.0
BOD-C	kg/day	Wk/24hr Comp	0.028	24	52	99	66	100.0
Lead	kg/day	Wk/24hr Comp	< 0.0023	0.043	< 0.014	2.6	0.20	100.0
							Percent Compliance	**100.0**
Discharge 002 (Spillway to Paddy's Run)								
Flow Rate	MGD	Estimate	The Stormwater Retention Basin did not overflow during 1991.			NA	NA	NA
pH	S.U.	Event/Grab				Range = 6.5 to 9.0		100.0
Suspended Solids	mg/L	Event/Comp				100	NA	100.0
Chromium (total)	µg/L	Event/Comp				4,000	NA	100.0
Chromium (+6)	µg/L	Event/Comp				19	NA	100.0
Oil & Grease	mg/L	Event/Grab				15	NA	100.0
Copper	µg/L	Event/Comp				45	NA	100.0
Nickel	µg/L	Event/Comp				3,100	NA	100.0
Silver	µg/L	Event/Comp				11.6	NA	100.0
							Percent Compliance	**100.0**

TABLE 10: NPDES Data, 1991

Sampling Location and Parameter	Units	Monitoring Requirements	Daily Monitoring Results Minimum	Maximum	Average[a]	Permit Limits[b] Daily Maximum	Monthly Average	Percent Compliance[c]
Discharge 601 (Sewage Treatment Plant)								
Flow Rate	MGD	Continuous	0.020	0.31	0.15	NA	NA	NA
pH	S.U.	Continuous	6.7	8.4	NA	Range = 6.5 to 9.0		100.0
Suspended Solids	mg/L	Wk/24hr Comp	< 2.0	9.0	< 3.0	40	20	100.0
Chromium (total)	µg/L	Wk/24hr Comp	< 6.0	23	< 6.3	32	13	100.0
Fecal Coliform[e]	#Col/100 ml	Wk/24hr Comp	1.0	1,500	41	2,000	1,000	100.0
Fluoride	mg/L	Wk/24hr Comp	0.2	0.9	0.3	5.1	2.3	100.0
Copper	µg/L	Wk/24hr Comp	< 14	26	< 15	110	53	100.0
Nickel	µg/L	Wk/24hr Comp	< 9.0	25	< 14	49	32	100.0
BOD-5	mg/L	Wk/24hr Comp	0.20	7.2	3.0	40	20	100.0
Suspended Solids	kg/day	Wk/24hr Comp	< 0.19	5.4	< 1.5	19	9.5	100.0
Chromium (total)	kg/day	Wk/24hr Comp	< 0.0006	0.011	< 0.0036	0.015	0.006	100.0
Fluoride[f]	kg/day	Wk/24hr Comp	0.039	0.45	0.18	2.4	1.1	100.0
Copper	kg/day	Wk/24hr Comp	< 0.0013	0.018	< 0.0084	0.053	0.025	100.0
Nickel	kg/day	Wk/24hr Comp	< 0.0009	0.017	< 0.0078	0.023	0.015	100.0
BOD-5	kg/day	Wk/24hr Comp	0.14	5.3	1.9	19	9.5	100.0
							Percent Compliance	**100.0**
Discharge 602 (General Sump)								
Flow Rate	MGD	Continuous	0.020	0.16	0.051	NA	NA	NA
pH	S.U.	Weekly/Grab	6.1	8.5	NA	Range = 6.5 to 9.0		97.9
Chromium (total)	µg/L	Wk/24hr Comp	< 6.0	6.0	< 6.0	54	41	100.0
Chromium (+6)	µg/L	Wk/24hr Comp	< 6.0	< 6.0	< 6.0	17	12	100.0
Copper	µg/L	Wk/24hr Comp	< 14	35	< 15	110	66	100.0
Nickel	µg/L	Wk/24hr Comp	< 9.0	170	< 21	170	91	98.3
Chromium (total)	kg/day	Wk/24hr Comp	< 0.0009	0.0027	< 0.0011	0.013	0.010	100.0
Chromium (+6)	kg/day	Wk/24hr Comp	< 0.0009	0.0027	< 0.0011	0.004	0.003	100.0
Copper	kg/day	Wk/24hr Comp	< 0.0020	0.0074	< 0.0026	0.027	0.016	100.0
Nickel	kg/day	Wk/24hr Comp	< 0.0014	0.025	< 0.0038	0.040	0.022	100.0
							Percent Compliance	**99.6**
Discharge 604 (Lift Station)								
Flow Rate	MGD	Continuous	0.009	0.41	0.10	NA	NA	NA
pH	S.U.	Continuous	6.8	9.0	NA	Range 6.5 to 9.0		100.0
Suspended Solids	mg/L	Wk/24hr Comp	< 2.0	7.0	< 3.0	100	30	100.0
Oil & Grease	mg/L	Weekly/Grab	< 5.0	< 5.0	< 5.0	15	15	100.0
							Percent Compliance	**100.0**

TABLE 10: NPDES Data, 1991

Sampling Location and Parameter	Units	Monitoring Requirements	Daily Monitoring Results Minimum	Maximum	Average[a]	Permit Limits[b] Daily Maximum	Monthly Average	Percent Compliance[c]
Discharge 605 (Bioreactor)								
Flow Rate	MGD	Continuous	0.001	0.24	0.10	NA	NA	NA
pH	S.U.	Continuous	6.6	8.5	NA	Range = 6.5 to 9.0		100.0
Suspended Solids	mg/L	Wk/24hr Comp	< 2.0	25	7.0	45	30	100.0
Nitrate-Nitrogen	mg/L	Wk/24hr Comp	0.10	3.4	1.2	150	73	100.0
Chromium (total)	µg/L	Wk/24hr Comp	< 6.0	22	< 7.4	27	12	100.0
Fluoride[f]	mg/L	Wk/24hr Comp	2.7	6.8	3.7	4.5	1.3	75.0
Copper	µg/L	Wk/24hr Comp	< 14	22	< 15	90	45	100.0
Nickel	µg/L	Wk/24hr Comp	11	27	< 17	42	29	100.0
BOD-5	mg/L	Wk/24hr Comp	2.3	44	9.8	45	30	98.3
Suspended Solids	kg/day	Wk/24hr Comp	< 0.30	12	< 2.4	38	26	100.0
Nitrate-Nitrogen	kg/day	Wk/24hr Comp	0.043	2.6	0.44	120	62	100.0
Chromium (total)	kg/day	Wk/24hr Comp	< 0.0009	0.011	< 0.0027	0.023	0.010	100.0
Fluoride [f]	kg/day	Wk/24hr Comp	0.33	3.0	1.6	3.8	1.1	84.4
Copper	kg/day	Wk/24hr Comp	< 0.0013	0.012	< 0.0052	0.077	0.039	100.0
Nickel	kg/day	Wk/24hr Comp	0.0016	0.015	0.0062	0.036	0.025	100.0
BOD-5	kg/day	Wk/24hr Comp	0.34	25	3.7	38	26	100.0
							Percent Compliance	**99.0**
Discharge 606 (Retention Basin)								
Flow Rate	MGD	Continuous	0.047	0.86	0.56	NA	NA	NA
pH	S.U.	Continuous	6.6	9.3	NA	Range = 6.5 to 9.0		99.3
							Percent Compliance	**99.3**

(a) Flow-weighted daily averages are shown as less than (<) if more than one quarter of the values were less than the detection limit.

(b) Values have been rounded for consistency of data presentation.

(c) Percent compliance is determined by comparing the noncompliance with the compliance opportunities.

(d) Individual excursions of less than one hour and the sum of all excursions totalling less than 7.26 hours a month are not noncompliances.

(e) Geometric mean.

(f) Effluent limitation and monitoring requirement deleted effective 7/15/91.

TABLE 11: Anions in Surface Water, 1991

Parameter	Sampling Location[a]	Number of Samples	Concentration (mg/L) Minimum	Maximum	Average	Standards (mg/L)	Percent of Standard[b] Minimum	Maximum	Average
Great Miami River									
Fluoride									
Upstream of Effluent Line	W1	52	0.2	1.0	0.48	1.8	11	56	27
Downstream of Effluent Line	W3	51	0.2	1.0	0.48	1.8	11	56	27
Downstream of Effluent Line	W4	52	0.3	1.0	0.46	1.8	17	56	26
Nitrate-Nitrogen									
Upstream of Effluent Line	W1	49	1.0	< 5.0	3.9	10	10	50	39
Downstream of Effluent Line	W3	49	1.0	< 5.0	3.9	10	10	50	39
Downstream of Effluent Line	W4	48	1.0	< 5.0	3.7	10	10	50	38
Paddy's Run									
Fluoride									
Upstream of FEMP	W5	14	0.2	0.5	0.29	1.8	11	56	16
Onsite	W9	11	0.2	0.7	0.28	1.8	11	39	16
Onsite	W10	7	0.2	0.9	0.35	1.8	11	50	19
Onsite	W11	7	0.2	0.5	0.25	1.8	11	28	14
Downstream of FEMP	W7	6	0.2	0.7	0.29	1.8	11	39	16
Downstream of FEMP	W8	12	0.1	0.9	0.23	1.8	5.6	50	13
Nitrate-Nitrogen									
Upstream of FEMP	W5	13	< 1.0	5.0	3.2	10	10	50	32
Onsite	W9	10	1.0	5.0	3.5	10	10	50	35
Onsite	W10	6	1.0	5.0	3.0	10	10	50	30
Onsite	W11	6	1.0	5.0	3.1	10	10	50	31
Downstream of FEMP	W7	5	1.4	5.0	2.7	10	14	50	27
Downstream of FEMP	W8	11	< 1.0	5.0	2.8	10	10	50	28

(a) See Figure 32 for sampling locations.

(b) Neither the Great Miami River (sampling locations W1, W3, and W4) nor Paddy's Run (sampling locations W5, W7, W8, W9, W10, and W11) are designated as a public water supply (OEPA Regulations, Vol. 1, 3745-1-21). Nevertheless, the FEMP compares the surface water data to public use standards published by OEPA (3745-1-07).

TABLE 12: pH Values for Surface Water, 1991

Parameter	Sampling Location[a]	Number of Samples	pH Value Minimum	pH Value Maximum	pH Value Average	Number of Values Outside Acceptable Range[b]
Great Miami River						
Upstream of Effluent Line	W1	52	7.7	8.8	8.3	0
Downstream of Effluent Line	W3	51	7.6	9.0	8.3	0
Downstream of Effluent Line	W4	52	7.6	9.0	8.3	0
Paddy's Run						
Upstream of FEMP	W5	47	7.5	8.2	7.8	0
Onsite	W9	40	7.4	8.3	7.9	0
Onsite	W10	25	7.4	8.4	7.9	0
Onsite	W11	23	7.4	8.3	7.9	0
Downstream of FEMP	W7	23	7.4	8.2	8.0	0
Downstream of FEMP	W8	49	7.4	8.0	7.7	0

(a) See Figure 32 for sampling locations.

(b) Acceptable range, as defined in OEPA Regulation 3745-1-21, is 6.5 – 9.0.

TABLE 13: Uranium in Private Wells, 1991

Well Number[a]	Number of Samples	Concentration (pCi/L)[b] Minimum	Maximum	Average	Percent of Standard[c] Minimum	Maximum	Average
1	11	0.07	0.54	0.20	0.3	2.5	0.9
3	12	0.14	0.61	0.20	0.6	2.8	0.9
4	12	0.74	1.6	1.2	3.4	7.3	5.5
5	11	0.88	1.4	1.2	4.0	6.4	5.5
7	12	0.61	1.4	1.0	2.8	6.4	4.6
8	12	0.34	0.74	0.54	1.6	3.4	2.5
9	12	0.81	1.5	1.0	3.7	6.8	4.6
10	12	0.27	0.54	0.41	1.2	2.5	1.9
11	12	0.74	2.0	1.4	3.4	9.1	6.4
12[d]	11	81	130	110	370	590	500
13[d]	38	1.2	9.5	3.5	5.5	43	16
14	12	0.88	1.8	1.2	4.0	8.2	5.5
15[d]	12	140	210	170	640	950	770
16	11	0.27	0.88	0.54	1.2	4.0	2.5
17[d]	11	19	36	27	86	160	120
18	12	0.14	0.41	0.27	0.6	1.9	1.2
19	12	0.07	0.20	0.14	0.3	0.9	0.6
21	12	0.20	0.41	0.27	0.9	1.9	1.2
22	12	0.47	0.81	0.68	2.1	3.7	3.1
23	12	0.41	0.68	0.54	1.9	3.1	2.5
24	12	0.27	0.68	0.41	1.2	3.1	1.9
25	4	0.14	0.34	0.27	0.6	1.5	1.2
26	12	0.07	0.20	0.14	0.3	0.9	0.6
27	12	0.27	0.68	0.47	1.2	3.1	2.1
28	4	0.41	1.0	0.61	1.9	4.6	2.8
29	12	1.0	1.9	1.4	4.6	8.6	6.4
30	4	0.27	0.61	0.34	1.2	2.8	1.5
32	12	0.07	0.27	0.14	0.3	1.2	0.6
33	6	0.20	0.34	0.27	0.9	1.5	1.2
34[d]	7	1.6	2.4	2.1	7.3	11	9.5
35	12	1.1	1.5	1.3	5.0	6.8	5.9
36	10	0.41	1.0	0.68	1.7	4.5	3.1
37	1	–	–	0.95	–	–	4.3
38	5	0.07	0.20	0.14	0.3	0.9	0.6
39[d]	16	1.4	5.3	3.6	6.4	24	16
40[d]	13	1.8	3.5	2.4	8.2	16	11
41	11	0.27	0.61	0.41	1.2	2.8	1.9

(a) See Figure 36 for well locations. Wells are numbered in order of first time sampled.

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

(c) Guideline of 22 pCi/L (33 ppb) as listed in DOE Order 5400.5.

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

TABLE 14: Comprehensive Groundwater Samples with Uranium Concentrations above DOE Guidelines, 1991

Well[a]	Location	Sample Date	Concentration (pCi/L)[b,c]	Concentration (ppb)
1019	Pit 4	June 4	510	760
1021	Pit 4	June 4	650	1,000
1022	Pit 4	June 3	1,200	1,800
1027	Pit 6	May 13	140	200
1027	Pit 6	July 2	160	230
1027	Pit 6	October 9	88	130
1082	Pit 6	May 15	360	530
1082	Pit 6	July 10	450	660
1082	Pit 6	October 21	450	660
1083	Pit 6	May 21	55	82
1083	Pit 6	July 9	53	79
1083	Pit 6	October 22	49	72
1085	Production Area	September 4	2,900	4,300
1643	Pit 4	July 23	150	220
1643	Pit 4	October 23	120	180
1644	Pit 4	July 23	160	230
1644	Pit 4	October 23	120	180
1645	Pit 4	July 23	29	43
1646	Pit 4	July 24	1,200	1,800
1646	Pit 4	October 23	470	690
2015	South Plume, Onsite	September 24	110	170
2015	South Plume, Onsite	October 31	120	170
2106	SSOD	November 7	34	50
2125	South Plume, Offsite	December 11	27	40
2545	South Plume, Offsite	August 27	29	43
2624	South Plume, Offsite	August 28	100	150
2626	South Plume, Offsite	August 28	39	57
3013	Production Area	May 22	430	630
3013	Production Area	July 2	780	1,200
3013	Production Area	October 7	880	1,300
3019	Pit 4	May 9	1,000	1,500
3019	Pit 4	July 1	960	1,400
3019	Pit 4	October 15	840	1,200
3069	South Plume, Onsite	November 13	28	41
3084	Pit 5	May 13	170	250
3084	Pit 5	July 11	7,200	11,000
3084	Pit 5	October 8	6,200	9,200
4013	Production Area	May 22	30	44

(a) See figures 40 through 43 for well locations.

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

(c) Guideline of 22 pCi/L as listed in DOE Order 5400.5.

TABLE 15: Metals in Private Wells, 1991

Metals Listed in Primary Drinking Water Regulations

Well Number[a]	Concentration (mg/L) Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver
1	< 0.010	0.38	< 0.005	< 0.010	0.0060	< 0.0050	< 0.010
3	0.016	0.48	< 0.005	< 0.010	0.0032	< 0.0050	< 0.010
4	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
5	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
7	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
8	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
9	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
10	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
11	< 0.010	< 0.20	0.020	< 0.010	< 0.0030	< 0.0050	< 0.010
12	< 0.010	< 0.20	< 0.005	< 0.010	0.010	< 0.0050	< 0.010
13	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
14	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
15	< 0.010	< 0.20	< 0.005	< 0.010	0.0041	< 0.0050	< 0.010
16	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
17	< 0.010	< 0.20	< 0.005	< 0.010	0.0048	< 0.0050	< 0.010
18	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
19	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
21	< 0.010	< 0.20	< 0.005	< 0.010	0.0033	< 0.0050	< 0.010
22	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
23	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
24	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
25	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
26	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
27	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
28	< 0.010	< 0.20	< 0.005	< 0.010	0.0076	< 0.0050	< 0.010
29	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
30	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
32	0.020	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
33	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	0.031
35	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
36	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
37	< 0.010	< 0.20	< 0.005	< 0.010	0.0067	< 0.0050	< 0.010
38	< 0.010	< 0.20	< 0.005	0.022	< 0.0030	< 0.0050	< 0.010
41	< 0.010	< 0.20	< 0.005	< 0.010	< 0.0030	< 0.0050	< 0.010
Primary Standard[b]	**0.05**	**1.0**	**0.01**	**0.5**	**0.05**	**0.01**	**0.05**

(a) See Figure 36 for well locations. Samples were taken during the month of July.

(b) USEPA drinking water regulations (taken from 40 CFR Part 141, National Interim Primary Drinking Water Regulations – Subpart B – Maximum Contaminant Levels, July, 1984, and from CFR Part 143, National Secondary Drinking Water Regulations – Section 143.3 – Secondary Maximum Contaminant Levels).

TABLE 15: Metals in Private Wells, 1991

Metals Listed in Secondary Drinking Water Regulations

Well Number[a]	Concentration (mg/L) Copper	Iron	Manganese	Zinc
1	< 0.025	3.4	0.020	0.045
3	< 0.025	3.7	0.022	0.030
4	< 0.025	< 0.10	< 0.015	0.12
5	< 0.025	0.17	< 0.015	0.040
7	< 0.025	3.5	0.16	0.033
8	< 0.025	< 0.10	0.25	0.029
9	< 0.025	< 0.10	0.10	0.044
10	< 0.025	2.4	0.24	0.094
11	0.031	< 0.10	< 0.015	0.19
12	0.036	0.70	0.037	0.78
13	< 0.025	< 0.10	0.028	< 0.020
14	< 0.025	0.75	0.35	0.022
15	< 0.025	< 0.10	< 0.015	32
16	< 0.025	1.7	0.34	0.024
17	0.057	16	0.40	0.021
18	< 0.025	2.8	0.23	< 0.020
19	< 0.025	1.5	0.30	0.030
21	< 0.025	1.8	0.25	0.067
22	< 0.025	< 0.10	0.049	0.035
23	0.028	0.18	0.080	0.025
24	< 0.025	< 0.10	0.040	0.046
25	< 0.025	< 0.10	< 0.015	< 0.020
26	< 0.025	4.5	0.31	0.064
27	0.10	0.14	< 0.015	0.10
28	< 0.025	0.24	0.079	0.022
29	< 0.025	0.78	0.057	0.023
30	0.030	< 0.10	< 0.015	0.027
32	< 0.025	1.4	0.49	< 0.020
33	0.048	< 0.10	< 0.015	< 0.020
35	< 0.025	< 0.10	< 0.015	0.026
36	0.034	< 0.10	< 0.015	0.067
37	< 0.025	0.21	< 0.015	< 0.020
38	0.033	1.8	0.082	0.19
41	< 0.025	0.16	0.13	0.033
Secondary Standard[b]	**1.0**	**0.3**	**0.05**	**5.0**

Metals Not Listed in Drinking Water Regulations

Well Number[a]	Concentration (mg/L) Calcium	Magnesium	Nickel	Potassium	Sodium
1	73	22	< 0.040	< 5.0	17
3	79	22	< 0.040	< 5.0	29
4	98	40	< 0.040	< 5.0	28
5	120	40	< 0.040	< 5.0	26
7	110	30	< 0.040	< 5.0	7.6
8	94	26	< 0.040	< 5.0	14
9	31	9.3	< 0.040	< 5.0	9.8
10	100	24	< 0.040	< 5.0	9.6
11	110	29	< 0.040	< 5.0	88
12	77	18	< 0.040	< 5.0	11
13	96	25	< 0.040	< 5.0	13
14	100	26	< 0.040	< 5.0	17
15	40	9.0	< 0.040	< 5.0	6.2
16	100	26	< 0.040	< 5.0	31
17	95	22	< 0.040	< 5.0	13
18	97	23	< 0.040	< 5.0	8.9
19	65	24	< 0.040	71	32
21	100	23	< 0.040	< 5.0	9.6
22	82	22	< 0.040	< 5.0	13
23	84	26	< 0.040	< 5.0	< 5.0
24	55	15	< 0.040	< 5.0	< 5.0
25	78	32	< 0.040	< 5.0	22
26	88	23	< 0.040	< 5.0	8.5
27	89	20	< 0.040	< 5.0	17
28	83	24	< 0.040	< 5.0	< 5.0
29	21	6.0	< 0.040	< 5.0	< 5.0
30	70	19	< 0.040	< 5.0	11
32	87	32	< 0.040	42	12
33	46	13	< 0.040	< 5.0	8.8
35	110	29	< 0.040	< 5.0	18
36	120	24	< 0.040	< 5.0	14
37	54	22	< 0.040	< 5.0	6.7
38	16	< 5.0	< 0.040	< 5.0	10
41	91	28	< 0.040	< 5.0	9.4

TABLE 16: Nonradioactive Substances above Primary Drinking Water Standards, 1991

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Arsenic	1021 Waste Pits	February 20	0.069	0.05
Arsenic	1021 Waste Pits	June 4	0.059	0.05
Arsenic	1021 Waste Pits	June 4	0.057[c]	0.05
Arsenic	1038 Waste Pits	February 11	0.082	0.05
Arsenic	1644 Waste Pits	July 23	0.17	0.05
Arsenic	1644 Waste Pits	October 23	0.3	0.05
Arsenic	1644 Waste Pits	July 23	0.11[c]	0.05
Arsenic	1644 Waste Pits	October 23	0.25[c]	0.05
Arsenic	2024 North of Waste Pits	October 1	0.058	0.05
Arsenic	2027 Waste Pits	May 9	0.58	0.05
Arsenic	2128 Paddy's Run Road Site	March 7	0.053	0.05
Arsenic	2129 Paddy's Run Road Site	March 7	0.27	0.05
Arsenic	3066 NW Corner of FEMP	May 29	0.063	0.05
Arsenic	3066 NW Corner of FEMP	July 17	0.057	0.05
Arsenic	3066 NW Corner of FEMP	May 29	0.12[c]	0.05
Barium	1021 Waste Pits	February 20	2.1	1.0
Barium	1021 Waste Pits	June 4	1.6	1.0
Cadmium	2118 Production Area	December 9	0.07[c]	0.01
Fluoride	1644 Waste Pits	July 23	8.1	4.0
Fluoride	1644 Waste Pits	October 23	7.2	4.0
Fluoride	2118 Production Area	December 9	5.4	4.0
Lead	1021 Waste Pits	February 20	0.067	0.05
Lead	1021 Waste Pits	June 4	0.071	0.05
Lead	1038 Waste Pits	May 16	0.063	0.05
Lead	1038 Waste Pits	October 8	0.061	0.05
Lead	1110 Production Area	March 13	0.067	0.05

TABLE 16: Nonradioactive Substances above Primary Drinking Water Standards, 1991

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Nitrate	1025 Waste Pits	February 12	160	10
Nitrate	1025 Waste Pits	May 21	130	10
Nitrate	1025 Waste Pits	July 11	140	10
Nitrate	1025 Waste Pits	October 9	16	10
Nitrate	1031 Waste Pits	February 12	11	10
Nitrate	1054 Production Area	March 20	13	10
Nitrate	1081 Waste Pits	February 6	11	10
Nitrate	1081 Waste Pits	May 15	11	10
Nitrate	1081 Waste Pits	July 10	10	10
Nitrate	2019 Waste Pits	February 4	30	10
Nitrate	2019 Waste Pits	May 9	35	10
Nitrate	2019 Waste Pits	July 1	21	10
Nitrate	2019 Waste Pits	October 23	36	10
Nitrate	2021 Waste Pits	February 20	11	10
Nitrate	2021 Waste Pits	May 29	11	10
Nitrate	2021 Waste Pits	October 16	27	10
Nitrate	2022 Waste Pits	December 9	41	10
Nitrate	2084 Waste Pits	February 5	11	10
Nitrate	2084 Waste Pits	May 13	19	10
Nitrate	2118 Production Area	December 9	17	10
Nitrate	2643 Waste Pits	February 27	78	10
Nitrate	2643 Waste Pits	July 18	100	10
Nitrate	2643 Waste Pits	October 21	24	10
Nitrate	2649 Waste Pits	February 14	62	10
Nitrate	2649 Waste Pits	July 30	110	10
Nitrate	2649 Waste Pits	October 23	64	10
Selenium	2118 Production Area	December 9	0.066[c]	0.01
Silver	3005 Waste Pits	February 21	0.071	0.05
Vinyl Chloride	1031 Pit 1	February 12	0.0065	0.002
Vinyl Chloride	1031 Pit 1	May 28	0.007	0.002
Vinyl Chloride	1031 Pit 1	July 30	< 0.005	0.002
Vinyl Chloride	1031 Pit 1	October 23	< 0.005	0.002
Vinyl Chloride	2649 Waste Pits	July 30	< 0.005	0.002

(a) See Figures 40 through 43 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.

(c) Substance was dissolved in water, not measured as a particle.

TABLE 17: Summary of Radiation Dose Due to 1991 Emissions[a]

Type of Dose	Committed Effective Dose[b]	Standard[c]	Percent of Standard
I. Individual	**mrem[d]**	**mrem[d]**	
A. Maximum individual dose from air emissions, excluding radon[e]	0.3	10	3.0
B. Ingestion[f]			
Produce (141 kg/year or 311 pounds/year)	< 0.1	100	< 0.1
Great Miami River Water (2 L/day or 0.5 gallons/day)	0.01	100	0.01
Great Miami River Fish (4.4 kg/year or 10 pounds/year)	< 0.01	100	< 0.01
Offsite Well Water[g] Well 15 (2 L/day or 0.5 gallons/day)	26	4.0	650
C. Direct External[h]	8.8	100	8.8
D. Radon Maximum dose to public at FEMP fenceline 8,760 hrs/year	93	— (i)	
II. 80 km (50 miles) Population Dose[e]	**person-rem**		
Total committed dose equivalent for 2,600,000 people living within 80 km (50 miles)	1.2	— (i)	
III. Other Background Sources of Dose[j]			
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		
B. Medical diagnosis[k]	50		
C. Consumer products	10		
D. Atmospheric weapons tests	4.6		
E. Well water in FEMP area	0.3		

(a) Including dose from all radionuclides listed in Table 18.

(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. 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) See Table 23 for inhalation dose estimates at all air monitoring stations.

(f) Dose based on environmental measurements according to ICRP 26/30 methodology. ICRP 26/30 based on 50– year committed dose conversion factors.

(g) Well 15 contained the highest average concentration of uranium measured offsite in 1991. Dose calculations based on maximum hypothetical dose from drinking this water. This well is no longer a source of drinking water.

(h) Whole body dose calculated from measured exposure rate at nearest residence west of the K-65 silos, using environmental thermoluminescent dosimeters.

(i) There are no applicable standards.

(j) From NCRP-93, "Ionizing Radiation Exposure of the Population of the United States."

(k) Medical dose estimates are population averages and will not necessarily be applicable to each individual.

TABLE 18: Estimated Airborne Emissions for FEMP, 1991

Radionuclide	Total Curies	Measured Curies[a]	Estimated Curies[b]	
			Waste Pits[c]	Remaining Sources[d]
Uranium – 234	0.0000954	0.000000207	0.0000309	0.0000643
Uranium – 235	0.00000469	0.0000000109	0.00000127	0.0000034
Uranium – 236	0.00000569	0.00000000804	0.00000319	0.0000025
Uranium – 238	0.0000652	0.000000231	0.0000232	0.0000718
Strontium – 90	0.000000671	0.00000000122	0.000000291	0.000000379
Technetium – 99	0.0000544	0.0000000256	0.0000464	0.00000795
Ruthenium – 106	0.00000148	0.00000000475	0.00	0.00000148
Cesium – 137	0.00000205	0.00000000356	0.000000945	0.0000011
Barium – 137m	0.00000205	0.00000000356	0.000000945	0.0000011
Radium – 226	0.0000201	0.000000000147	0.0000201	0.0000000456
Radium – 228	0.00000266	0.000000000589	0.00000248	0.000000183
Thorium – 228	0.00000531	0.00000000622	0.00000319	0.00000193
Thorium – 230	0.000365	0.0000000183	0.000359	0.000000568
Thorium – 232	0.00000278	0.000000000977	0.00000248	0.0000000304
Thorium – 234	0.000308	0.000000914	0.0000233	0.000284
Protactinium – 234m	0.000308	0.00000000914	0.0000233	0.000284
Neptunium – 237	0.000000395	0.0000000000742	0.000000372	0.000000023
Plutonium – 238	0.00000010	0.000000000088	0.0000000728	0.0000000273
Plutonium – 239	0.000000272	0.000000000581	0.000000091	0.000000181
Plutonium – 240	0.000000137	0.000000000148	0.000000091	0.0000000461
Plutonium – 241	0.00000129	0.00000000217	0.000000616	0.000000673
Plutonium – 242	0.0000000000132	0.0000000000000319	0.00000000000322	0.0000000000099

(a) Measured emissions include two monitored stacks (dust collectors) that operated during 1991. They are measured by single-point continuous isokinetic samplers.

(b) There were no nonroutine releases during 1991.

(c) Fugitive emissions from the waste pits.

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

TABLE 19: Estimated Population Distribution within 80 km (50 miles) of the FEMP, 1991[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	7	64	77	108	125	1,008	16,676	7,161	16,737	12,369
NNE	5	57	65	111	300	13,702	7,595	8,288	31,333	78,291
NE	8	206	120	129	317	38,550	45,545	96,440	189,514	317,133
ENE	16	106	2,714	5	47	31,258	17,295	31,720	13,520	25,702
E	24	62	119	89	235	34,442	53,951	39,591	17,675	10,403
ESE	16	68	137	206	292	38,965	160,794	72,536	24,073	13,277
SE	8	69	107	153	192	52,064	273,363	94,394	26,815	15,853
SSE	15	67	88	256	591	20,714	218,659	55,517	9,311	8,685
S	8	69	97	384	620	8,376	32,804	34,309	9,475	9,575
SSW	9	77	154	290	354	4,814	9,492	7,718	6,022	9,695
SW	9	85	143	129	130	1,171	15,147	10,752	3,708	4,916
WSW	17	84	142	216	296	7,081	3,749	7,092	7,243	5,908
W	9	79	135	215	270	2,488	3,650	10,355	5,805	16,385
WNW	8	66	102	161	213	1,596	4,242	6,469	4,255	12,060
NW	12	63	99	154	219	1,091	1,398	3,222	26,366	9,417
NNW	17	64	102	186	316	1,538	12,963	4,921	48,181	13,725
Total	188	1,286	4,401	2,792	4,517	258,858	877,323	490,485	440,033	563,394
Total for all sectors: 2,643,277										

(a) Based on an extrapolation from 1980 census data by Geographic Data Systems Section, Computing and Telecommunications Division at Oak Ridge National Laboratory, May 1989.

Table 20: Estimated Committed Effective Doses at Air Monitoring Stations, 1991

AMS[a]	50 Year Dose Commitment, mrem[b] 1990	1991	Percent of Standard[c]
1	0.2	0.1	0.1
2	0.2	0.2	0.2
3	0.3	0.2	0.2
4	0.1	0.1	0.1
5	0.1	0.1	0.1
6	0.2	0.1	0.1
7	0.2	<0.1	<0.1
8	0.7	0.3	__(d)
9	1.0	1.6	__(d)

(a) Doses at offsite AMSs were not calculated because of delays in receiving data from the contract laboratory.

(b) The effective dose is the weighted sum of doses delivered to the individual organs of the body. Values reported in this table are based on concentrations of radionuclides measured in the air sampled by the various air monitoring stations. These values are very conservative since "less than detectable" concentrations were not subtracted.

(c) Standard is 100 mrem for all pathways, as noted in DOE Order 5400.5.

(d) Onsite AMS; standards for dose to public not applicable.

TABLE 21: Direct Radiation Dose, 1991

Sampling Location[a]	Dose Rate (µrem/hr) Minimum	Maximum	Average[b]
Fenceline			
AMS 1	7.1	8.1	7.6
AMS 2	7.5	8.5	7.9
AMS 3	6.8	7.7	7.2
AMS 4	7.2	8.2	7.7
AMS 5	6.9	7.7	7.3
AMS 6	11	13	12
AMS 7	6.7	8.0	7.1
Onsite			
AMS 8	6.7	7.8	7.2
AMS 9	9.1	10	9.7
Offsite			
AMS 10	5.5	6.2	5.7
AMS 11	6.8	7.5	7.0
AMS 12	6.4	7.0	6.7
AMS 13	6.2	6.6	6.3
BKGD[c]	6.1	6.9	6.5

(a) See Figure 21 for locations.

(b) Average dose rate is calculated from four quarterly measurements.

(c) Background is average of measurements at four locations between 10 and 40 km (6 and 25 miles) from the FEMP.

257

TABLE 22: Radon in Air, 1991

Fenceline Locations[a]	Concentration (pCi/L)[b] 1991	1990
AMS1	0.8	0.4
AMS2	0.7	0.6
AMS4	1.2	0.4
AMS6	0.6	0.6
AMS7	1.2	0.5
FEMP A	1.1	1.1
FEMP B	1.3	0.7
FEMP C	0.9	0.5
FEMP D	1.0	0.5
FEMP E	0.9	0.7
FEMP F	0.4	0.5
FEMP G	0.7	0.8
FEMP H	1.5	1.5
FEMP I	0.6	1.1
FEMP J	0.8	1.2
FEMP K	1.0	0.7
FEMP L	0.6	0.6
FEMP M	0.8	0.7
FEMP N	1.5	0.8
FEMP O	0.8	0.7
FEMP P	0.6	0.9

Background Locations[a]	Concentration (pCi/L)[b] 1991	1990
BKGD 1	0.5	0.4
BKGD 2	0.6	0.4
AMS 15	0.6	0.6
AMS 16	0.6	0.6

Other Locations	Concentration (pCi/L)[b] 1991	1990
AMS 8	0.6	0.5
AMS 9	0.6	0.8
AMS 10	0.8	0.5
AMS 11	1.0	0.6
AMS 12	0.6	0.7
AMS 13	0.6	0.7
RES 1	1.2	0.8
RES 2	1.5	0.9
RES 3	1.4	0.8

(a) See Figure 48 and 21 for locations.

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

(c) DOE guideline is 3.0 pCi/L as stated in DOE Order 5400.5.

Summary: 1991 & 1990 Results

Average Fenceline Concentration Minus Average Background Concentration Equals Average Net Concentration

Fenceline (All Locations)	Concentration (pCi/L)[b] 1991	1990
Average	0.90	0.75
Std. Dev.	± 0.30	± 0.27

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Background (4 Locations)	Concentration (pCi/L)[b] 1991	1990
Average	0.59	0.52
Std. Dev.	± 0.05	± 0.07

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Net Concentration at the Fenceline[c]	Concentration (pCi/L)[b] 1991	1990
Average	0.31	0.23
Std. Dev.	± 0.30	± 0.28

TABLE 23: DOE Quality Assessment Program for Environmental Radionuclide Analyses FEMP Laboratories Performance Results, 1991

Sample Type	Sample Number	Units	Uranium Values		Ratio
			FEMP Laboratories	EML[a]	FEMP Value/EML Value
Water	91–03	µg/L	0.0174	0.0172	1.01
Water	91–09	µg/L	0.0432	0.0370	1.17
Air Filter	91–03	µg/Filter	0.073	0.070	1.06
Air Filter	91–03	µg/Filter	0.078	0.070	1.11
Air Filter	91–09	µg/Filter	4.1	3.08	1.33
Air Filter	91–09	µg/Filter	4.30	3.08	1.40
Soil	91–03	µg/g	1.94	2.34	0.83

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

TABLE 24: USEPA Quality Assurance Program for Waste Water Analyses FEMP Laboratories Performance Evaluation, 1991 [a]

Parameter	Units	Values FEMP Laboratories	True[b]	USEPA Acceptance Limits[c]	USEPA Performance Evaluation[d]
Chromium	mg/L	78.0	74.0	56.7 – 90.2	ACCEPTABLE
Copper	mg/L	40.5	43.0	34.9 – 50.2	ACCEPTABLE
Lead	mg/L	327	320	271 – 369	ACCEPTABLE
Nickel	mg/L	1,566	1,600	1,420 – 1,770	ACCEPTABLE
pH	Standard	8.78	8.80	8.46 – 9.24	ACCEPTABLE
Total Suspended Solids	µg/L	59.0	63.3	46.1 – 67.2	ACCEPTABLE
Oil & Grease	µg/L	13.8	13.0	6.48 – 17.7	ACCEPTABLE
Ammonia - Nitrogen	µg/L	17.6	18.0	14.4 – 21.3	ACCEPTABLE
Nitrate - Nitrogen	µg/L	8.7	8.0	6.47 – 9.52	ACCEPTABLE
Carbonaceous BOD	µg/L	33.2	25.5	4.04 – 47.1	ACCEPTABLE
5 Day BOD	µg/L	32.3	30.0	15.8 – 44.2	ACCEPTABLE
Total Cyanide	µg/L	0.014	0.020	DL – 0.035	ACCEPTABLE

(a) USEPA Discharge Monitoring Report (DMR) Quality Assurance (QA) Program. The FEMP, along with all other National Pollutant Discharge Elimination Systems (NPDES) permit holders, is required to participate in these annual laboratory performance evaluation studies (Section 308 [a] of the Clean Water Act).

(b) Actual parameter concentrations established by USEPA based on theoretical calculations or a reference value when necessary.

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

(d) USEPA DMR–QA Study Number 010 conducted during 1990.

TABLE 25: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1991 Summary of Performance of FEMP Laboratories

Parameter	Units	Number of Analyses	Range of True Values	Percent Recovery[a] Min.	Max.	Avg.	Standard Deviations from Mean[b] Min.	Max.	Avg.	Percentage Acceptable[c]
Ammonia-Nitrogen	mg/L	22	0.15 – 3.40	29	105	80	0.06	4.17	0.20	77
Biochemical Oxygen Demand	mg/L	22	16.3 – 209	55	156	99	0.10	2.68	0.96	95
Calcium	mg/L	20	2.52 – 29.3	73	120	99	0.002	2.31	0.18	100
Chloride	mg/L	24	18.9 – 142	84	117	96	0.004	3.09	0.26	92
Fluoride	mg/L	22	1.22 – 8.41	99	109	101	0.002	0.96	0.36	100
Magnesium	mg/L	20	1.64 – 10.5	78	126	95	0.003	5.99	0.89	90
Nitrate-Nitrogen	mg/L	16	0.25 – 1.78	88	109	100	0.08	1.18	0.41	100
Oil & Grease	mg/L	24	5.01 – 43.3	30	194	88	0.013	4.84	1.11	92
Potassium	mg/L	20	5.74 – 20.0	76	150	106	0.03	6.03	1.05	85
Sodium	mg/L	20	21.6 – 91.5	87	137	105	0.05	4.55	0.92	95
Sulfate	mg/L	24	0.75 – 75.0	2.7	133	83	1.01	5.38	1.03	67
Total Suspneded Solids	mg/L	24	25.5 – 476	54	110	97	0.27	5.11	1.04	96
pH	standard	23	4.22 – 11.3	97	103	99	0.39	1.15	0.62	100
Arsenic	µg/L	21	12.4 – 413	86	120	107	0.11	2.18	0.36	100
Barium	µg/L	20	216 – 1,944	103	117	107	0.40	3.30	0.56	90
Cadium	µg/L	20	21.5 – 273	102	126	114	0.39	4.70	1.80	85
Chromium (Total)	µg/L	20	25.0 – 265	89	115	104	0.09	2.00	0.51	100
Chromium (Hexavalent)	µg/L	18	0.02 – 0.43	76	1040	95	0.08	78.6	0.70	90
Copper	µg/L	18	22.1 – 275	94	111	106	0.06	1.22	0.55	100
Iron	µg/L	20	25.3 – 653	95	161	113	0.05	7.68	1.51	90
Lead	µg/L	22	27.3 – 476	91	119	104	0.13	2.61	0.79	100
Managenese	µg/L	20	33.6 – 264	72	113	104	0.005	3.35	1.25	90
Nickel	µg/L	18	22.7 – 285	92	115	109	0.007	2.27	0.96	100
Selenium	µg/L	20	11.0 – 13.5	90	112	99	0.01	1.02	0.27	100
Silver	µg/L	17	12.3 – 350	66	114	94	0.14	2.15	0.42	94
Uranium	µg/L	66	50.1 – 1,341	82	176	101	0.04	5.38	0.84	83
Zinc	µg/L	18	18.9 – 186	83	197	108	0.02	6.03	0.97	83

(a) Percent recovery is the FEMP measured value divided by the true parameter concentration multiplied by 100.

(b) The standard deviation indicates the closeness of the FEMP measurement result to the mean value reported by Analytical Products Group, Inc., which conducts the testing program. The standard deviation would be 0.00 if the FEMP result and 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 FEMP measurement results for each parameter which met the USEPA "Acceptable" criteria of being within 2.58 standard deviations of the mean value.

TABLE 26: FEMP – ODH Uranium Sampling Comparison, 1990
Surface Water Sampling Locations

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] FEMP	ODH	Equivalent Results
W1	January 30	1.351	1.6 ± 0.65	YES
W1	March 5	1.554	2.0 ± 0.7	YES
W1	March 28	1.757	0.8 ± 0.5	NO
W1	April 25	1.216	1.0 ± 0.57	YES
W1	May 23	1.284	1.6 ± 0.6	YES
W1	June 27	1.149	0.9 ± 0.4	YES
W1	July 18	1.081	1.2 ± 0.6	YES
W1	August 29	1.014	0.6 ± 0.4	YES
W1	September 26	1.149	0.5 ± 0.4	NO
W1	October 24	1.081	0.84 ± 0.5	YES
W1	November 21	1.216	1.8 ± 0.6	YES
W3	January 30	1.554	2.0 ± 0.7	YES
W3	March 5	1.757	2.5 ± 0.8	YES
W3	March 28	1.351	1.5 ± 0.6	YES
W3	April 25	1.419	1.8 ± 0.71	YES
W3	May 23	1.284	2.0 ± 0.7	YES
W3	June 27	1.216	1.0 ± 0.5	YES
W3	July 18	1.149	< 1.0	YES
W3	August 29	1.554	1.4 ± 0.5	YES
W3	September 26	1.419	0.9 ± 0.5	YES
W3	October 24	1.351	0.73 ± 0.5	YES
W3	November 21	1.419	1.69 ± 0.6	YES
W3	December 19	0.878	0.5 ± 0.5	YES
W4	January 30	1.757	0.9 ± 0.4	NO
W4	March 28	1.351	1.4 ± 0.6	YES
W4	April 25	1.419	2.0 ± 0.7	YES
W4	May 23	1.419	1.0 ± 0.6	YES
W4	June 27	1.216	1.1 ± 0.5	YES
W4	July 18	1.081	8.0 ± 0.4	NO
W4	August 29	1.014	2.0 ± 0.6	YES
W4	September 26	1.419	0.8 ± 0.5	YES
W4	October 24	1.351	1.0 ± 1.0	YES
W4	November 21	1.284	2.0 ± 0.6	YES
W4	December 19	0.811	1.0 ± 0.4	YES

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] FEMP	ODH	Equivalent Results
W7	January 30	5.000	2.3 ± 1.1	NO
W7	March 28	5.541	3.0 ± 0.8	NO
W7	April 25	4.257	5.2 ± 1.0	YES
W7	May 23	5.743	7.0 ± 1.0	YES
W7	August 29	10.81	6.3 ± 1.0	NO
W7	October 24	5.203	5.0 ± 2.0	YES
W7	December 19	4.865	3.5 ± 1.4	YES
W8	June 27	3.514	2.0 ± 0.7	NO
W8	July 18	2.973	< 1.0	NO
W8	September 26	2.500	1.7 ± 0.6	YES
W8	November 12	2.906	2.8 ± 0.8	YES
W8	December 19	4.595	3.0 ± 1.3	YES
W9	January 30	2.162	1.6 ± 0.63	YES
W9	March 28	1.351	1.5 ± 0.6	YES
W9	April 25	1.081	1.4 ± 0.63	YES
W9	May 23	1.284	1.4 ± 0.7	YES
W9	June 27	0.878	0.9 ± 0.4	YES
W9	July 18	1.824	1.89 ± 0.7	YES
W9	August 29	1.351	0.6 ± 0.4	NO
W9	September 26	1.216	0.9 ± 0.5	YES
W9	October 24	1.960	2.0 ± 1.0	YES
W9	November 21	1.622	1.2 ± 0.5	YES
W9	December 19	1.554	1.5 ± 0.9	YES

263

TABLE 26: FEMP – ODH Uranium Sampling Comparison, 1990 Ground Water Sampling Locations

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] FEMP	ODH	Equivalent Results
Well 1	July 18	0.1	1.3 ± 0.3	NO
Well 3	March 5	0.2	< 1.0	YES
Well 4	January 30	1.4	1.3 ± 0.5	YES
Well 4	March 28	1.6	2.2 ± 0.7	YES
Well 4	April 25	1.4	3.0 ± 0.8	NO
Well 4	May 23	1.6	0.7 ± 0.4	NO
Well 4	June 27	1.1	1.2 ± 0.6	YES
Well 4	July 18	1.1	2.0 ± 3.0	YES
Well 4	August 29	1.1	2.3 ± 0.7	NO
Well 4	September 26	1.2	1.3 ± 0.5	YES
Well 4	October 24	1.3	2.7 ± 0.7	NO
Well 4	November 21	1.4	1.8 ± 1.0	YES
Well 4	December 19	1.2	1.4 ± 0.9	YES
Well 4	June 27	1.4	0.9 ± 0.5	YES
Well 4	January 30	1.0	1.5 ± 0.5	YES
Well 4	March 5	1.1	1.0 ± 0.5	YES
Well 4	March 28	1.0	1.4 ± 0.9	YES
Well 4	April 25	1.0	1.0 ± 0.6	YES
Well 4	May 23	1.0	1.2 ± 0.6	YES
Well 5	June 27	0.9	1.0 ± 0.5	YES
Well 14	July 18	1.0	3.4 ± 0.8	NO
Well 14	August 29	1.0	1.0 ± 0.5	YES
Well 14	September 26	0.9	1.0 ± 0.4	YES
Well 14	October 24	1.1	1.0 ± 1.0	YES
Well 14	November 21	1.1	0.9 ± 0.4	YES
Well 14	December 19	1.0	1.4 ± 0.9	YES
Well 15 [c]	January 30	180	92 ± 4.0	NO
Well 15 [c]	March 5	180	190 ± 6.0	NO
Well 15 [c]	March 28	190	180 ± 6.0	NO
Well 15 [c]	April 25	170	220 ± 67.0	YES
Well 15 [c]	May 23	160	190 ± 6.0	NO
Well 15 [c]	June 27	180	43 ± 3.0	NO
Well 15 [c]	July 18	180	77 ± 2.0	NO
Well 15 [c]	August 29	180	230 ± 3.2	NO
Well 15 [c]	September 26	200	220 ± 5.6	NO
Well 15 [c]	October 24	220	169 ± 10.0	NO
Well 15 [c]	November 21	190	142 ± 5.3	NO
Well 15 [c]	December 19	180	170 ± 5.9	NO
Well 16	March 28	0.47	0.46 ± 0.5	YES
Well 18	January 30	0.3	0.42 ± 0.42	YES
Well 18	August 29	0.2	< 1.0	YES
Well 19	January 30	0.2	0.16 ± 0.4	YES
Well 19	March 5	0.1	0.05 ± 0.3	YES
Well 19	March 28	0.1	< 1.0	YES
Well 19	April 25	0.2	< 3.0	YES
Well 19	May 23	0.2	< 1.0	YES
Well 19	June 27	0.1	0.52 ± 0.3	YES
Well 19	July 18	0.1	1.3 ± 0.3	YES
Well 19	August 29	0.1	0.1 ± 2.0	YES
Well 19	September 26	0.1	< 1.0	YES
Well 19	October 24	0.1	< 1.0	YES
Well 19	November 21	0.1	< 1.0	YES
Well 19	December 19	0.1	0.2 ± 0.2	YES
Well 21	November 21	0.2	0.3 ± 0.3	YES
Well 23	September 26	0.5	1.0 ± 0.4	YES
Well 24	December 19	0.3	0.5 ± 0.3	YES
Well 34 [c]	April 25	2.9	4.0 ± 0.9	YES
Well 34 [c]	May 23	2.8	3.0 ± 0.81	YES
Well 38	October 24	0.1	0.4 ± 0.3	YES
		Percent equivalent for all measurements		77

(a) See Figures 29 and 38 for locations.

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

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

Chemical Release Information for 1991

Among the information presented in the ASER for the FEMP are estimates on both radiological and nonradiological emissions to the environment. The information in this appendix includes chemical release estimates from the Superfund Amendments and Reauthorization Act of 1986 (SARA) 313 report for 1991 and a summary of emissions from the FEMP Boiler Plant during 1991. This summary includes the chemical name, type and quantity of release, major release sources, and the basis of estimate.

To estimate releases, the FEMP used a method that followed guidelines defined by SARA 313. These estimates do not reflect actual measured emissions. Rather, the FEMP estimated releases through material balance calculation, monitoring data, or engineering calculations. In cases where quantitative monitoring data, inventory estimates, or emission factors were not readily available, release estimates were based on best engineering judgments. Information obtained from air permits, rate of operation, quantities used, and known treatment efficiencies were used to estimate quantities released into the environment. Typically, assumptions based on best engineering judgment were required in order to perform the calculations when all variables were not known.

Calculations for Boiler Plant emissions were based on published AP–42 emission factors and coal use and analysis records for the FEMP during 1991.

The SARA 313 chemicals included in this addendum 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.

FEMP Chemical Release Information for 1991

Section One: Summary of SARA 313 Report

Chemical Name	Type of Release	Quantity Released (lb/kg)	Release Sources	Basis of Estimate
Hydrochloric Acid	Air: fugitive	8/4	Ancillary Uses[a]	Best Engineering Judgment
	Air: point source	47/21	Coincidental Manufacturing	Published Emission Factors
Methanol	Air: fugitive	350/159	Chemical Processing Aid	Published Emission Factors
	Air: point source	270/123	Chemical Processing Aid	Published Emission Factors
	Water: Great Miami River	150/68	Chemical Processing Aid	Best Engineering Judgment
Sulfuric Acid	None	N/A	Ancillary Use[b]	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	36,100/16,410	Fossil Fuels Combustion	Stack Testing
Sulfur Dioxide	Air: stack emissions	900,000/410,000	Fossil Fuels Combustion	AP–42 Emission Factors[c]
Nitrogen Oxide	Air: stack emissions	340,000/154,000	Fossil Fuels Combustion	AP–42 Emission Factors
Carbon Monoxide	Air: stack emissions	120,000/55,000	Fossil Fuels Combustion	AP–42 Emission Factors
Non-methane Volatile Organic Compounds	Air: stack emissions	1,703/766	Fossil Fuels Combustion	AP–42 Emission Factors

(a) Chemical processing aid to decontaminate equipment and materials. The waste HCL is pH neutralized and released to the general sump.

(b) Chemical processing aid during pH adjustment and regeneration of ion exchangers.

(c) Calculations were based on AP–42 emission factors and 1991 FEMP coal use and analysis records.

FEMP Source Reduction Information for 1991

Section One: Summary of SARA 313 Report

Chemical Name	Type of Treatment	Quantity (lb/kg)	Treatment Method	Basis of Estimate
Hydrochloric Acid	Treated onsite	0/0	N/A	N/A
Methanol	Treated onsite	1,200/545	Biological-Aerobic	Best Engineering Judgment
Sulfuric Acid	Treated onsite	0/0	N/A	N/A

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Glossary of Terms

Activity the rate of disintegration, expressed as disintegrations per second (Becquerels) or in units of Curies (one Curie = 3.7×10^{10} Becquerels).

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

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).

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, they are 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 Guide 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.

Fugitive Dust dust that did not flow through a production stack. This includes materials such as dust from the waste storage areas, 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 and whose 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 collective dose to a population group. For example, a dose of one rem to ten people results in a collective dose of ten person-rem.

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

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

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

Radioisotope a radioactive isotope.

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

Radioactive Emissions releases of radioactive materials to the environment.

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

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

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

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

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

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.

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