U-007-402.8

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INITIAL SCREENING OF ALTERNATIVE FOR OPERABLE UNIT 5 FINAL MARCH 1993

DOE-FN/EPA

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REPORT

INITIAL SCREENING OF ALTERNATIVES FOR OPERABLE UNIT 5

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

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LIST OF ACRONYMS

AEC	U.S. Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
BDAT	best demonstrated available technology
CAA	Clean Air Act
CB	cement-bentonite
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COD	chemical oxygen demand
CRQL	contract required quantitation limit
CSF	cancer slope factor
CWA	Clean Water Act
CWAO	Catalyzed Wet Air Oxidation
DCG	derived concentration guides
DOE	U.S. Department of Energy
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FFCA	Federal Facility Compliance Agreement
FICWD	Federal Interagency Committee for Wetlands Delineation
FS	feasibility study
GAC	granular activated carbon
GMA	Great Miami Aquifer
GPR	ground penetrating radar
HDPE	high density polyethylene
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HSL	hazardous substance list
IRIS	Integrated Risk Information System
ISA	Initial Screening of Alternatives
IT	IT Corporation
K	hydraulic conductivity
LLW	low-level radioactive waste
LSA	low specific activity
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDL	minimum detection limit
MPRSA	Marine Protection Research and Sanctuaries Act
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NLO	National Lead Company of Ohio, Inc.
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NRC	U.S. Nuclear Regulatory Commission

LIST OF ACRONYMS
(Continued)

NTS	Nevada Test Site
O&M	operation and maintenance
ODH	Ohio Department of Health
ODNR	Ohio Department of Natural Resources
ODW	Office of Drinking Water
OEPA	Ohio Environmental Protection Agency
OU	operable unit
OWQS	Ohio Water Quality Standards
ORAU	Oak Ridge Associated Universities
PAH	polycyclic aromatic hydrocarbon
PASA	Production and Additional Suspect Areas
PCB	polychlorinated biphenyl
PCF	plasma centrifugal furnace
PGW	perched groundwater
PMCL	proposed maximum contaminant level
PMCLG	proposed maximum contaminant level goal
PRG	preliminary remediation goal
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
RO	reverse osmosis
ROD	Record of Decision
RSC	relative source contribution
SARA	Superfund Amendments and Reauthorization Act
SB	soil-bentonite
SDWA	Safe Drinking Water Act
SOWC	Southwestern Ohio Water Company
SSOD	storm sewer outfall ditch
SVE	soil vacuum extraction
SVOC	Semivolatile Organic Compound
SWCR	Site-Wide Characterization Report
SWOAPCA	Southwestern Ohio Air Pollution Control Agency
TBC	guidance to be considered
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
THI	target hazard index
THQ	target hazard quotient
TKN	total Kjeldahl nitrigen
TMV	toxicity, mobility, or volume
TOC	total organic carbon

LIST OF ACRONYMS
(Continued)

TON	total organic nitrogen
TOX	total organic halides
TPH	total petroleum hydrocarbons
TR	target risk level
TSCA	Toxic Substances Control Act
TSD	treatment, storage, or disposal
TSP	total suspended particulates
TSS	total suspended solids
UIC	underground injection control
US ACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	underground storage tank
UTL	upper tolerance limit
UV	ultraviolet
VOC	volatile organic compounds
WEMCO	Westinghouse Environmental Management Company of Ohio
WMCO	Westinghouse Materials Company of Ohio

EXECUTIVE SUMMARY

The Feed Materials Production Center, renamed on August 23, 1991 and hereinafter called the Fernald Environmental Management Project (FEMP), is a contractor-operated federal facility for the production of purified uranium metal located on 1050 acres in a rural area approximately 18 miles northwest of downtown Cincinnati, Ohio. Owned by the U.S. Department of Energy (DOE), production operations at the FEMP were suspended in July 1989 and the facility was formally closed in June 1991. On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) was jointly signed by the U.S. Environmental Protection Agency (EPA) and DOE to ensure that human health and environmental impacts associated with the past activities at the FEMP are thoroughly investigated so that appropriate remedial actions can be assessed and implemented. In response to the FFCA, a Remedial Investigation/Feasibility Study (RI/FS) has been initiated to develop these remedial actions.

The 1986 FFCA was amended by a Consent Agreement under Section 120 and 106(a) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Consent Agreement was signed on April 9, 1990 and became effective on June 29, 1990. In 1991, a renegotiation of the Consent Agreement was initiated to establish a revised schedule for cleanup of the FEMP. This Amended Consent Agreement became effective on December 19, 1991.

A technical strategy eventually adopted under the RI/FS was to divide the site into five operable units to facilitate remedial actions. As a result of the renegotiations of the 1991 Amended Consent Agreement, the scope of Operable Unit 5 has been modified. The broad definition of Operable Unit 5 remains unchanged and still includes those environmental media that represent pathways and/or environmental receptors presently or potentially affected by FEMP contaminants. However, soil and perched groundwater previously identified as components of Operable Unit 3 are now included within the scope of Operable Unit 5.

This document presents the initial screening of alternatives (ISA) for Operable Unit 5. Although a previous ISA report for Operable Unit 5 was approved, the rescoping of Operable Unit 5 in the Amended Consent Agreement in 1991 necessitates the preparation of a revised report. The primary objective of this phase of the FS is to develop an appropriate range of waste management options that will be analyzed more fully in the detailed analysis phase of the FS. Appropriate waste management options that ensure the protection of human health and the environment may involve, depending on site-specific circumstances, the complete elimination or destruction of hazardous substances at the site, the reduction of concentrations of hazardous substances to acceptable health-based levels, and prevention of exposure to hazardous substances via engineering or institutional controls, or some combination of the above (EPA 1988a). Alternatives are typically developed concurrently with the RI site characterization, with the results of one influencing the other in an iterative fashion (i.e., RI site

characterization data are used to develop alternatives and screen technologies, whereas the range of alternatives developed guides subsequent site characterization and/or treatability studies).

The results of the screening of alternatives that are presented in this document are limited by several factors. Specifically, this document has been prepared prior to the completion of several RI field activities for Operable Unit 5. While virtually all of the currently available data have been reviewed and evaluated, detailed analysis of the data is still ongoing in conjunction with the RI effort for this operable unit. The baseline risk assessment, which is fundamental to the establishment of cleanup criteria, is also still in progress awaiting the collection, analysis, and validation of the complete RI database.

Since the baseline risk assessment may identify different cleanup criteria for soil and sediment than that used for this initial evaluation and since additional areas or contaminants of concern may be identified during the ongoing RI data development task, the remedial alternatives identified in this screening may require modification as the FS process proceeds. It is unlikely, however, that completion of the risk assessment and RI will negate any of the results of technology and process option identification and evaluation contained in this report. It is also unlikely that substantive changes would be required in remedial alternative components identified in this report. As currently envisioned, any modifications would likely be an expansion or contraction of actual areas/volumes within various media requiring remediation. Any necessary modifications will be addressed and incorporated during the detailed analysis of alternatives and later stages of the FS.

Therefore, the data evaluation completed for this initial screening of alternatives provides an appropriate framework for the development and evaluation of remedial alternatives to address potential contamination problems associated with Operable Unit 5.

In Section 1.0, a description of the site and its operational history is presented, as well as discussions concerning wastes and waste streams generated during the operating phase of the FEMP. The regulatory framework and history of the site are also presented, along with the definition of operable units and Operable Unit 5 in particular.

The important physical properties and characteristics of Operable Unit 5 are discussed in Section 2.0, including information on geology, hydrogeology, hydrology, land use, and ecology of the site and surrounding area.

Section 3.0 presents a summary of federal and state statutes and regulations that might pertain to the FEMP, as well as other environmental guidelines or regulations that should be considered as potentially applicable. Applicable or Relevant and Appropriate Requirements (ARARs) for the remediation of FEMP are then discussed and evaluated. From the ARARs and other criteria,

advisories, and guidance, a set of preliminary remediation goals (PRG) are developed for reach environmental medium.

Section 3.0 also discusses the nature and extent of contamination for the various environmental media within Operable Unit 5. Based on the current site data, uranium is the major contaminant of concern in the groundwater, surface water, soils, and sediments as well as vegetation, benthic macro-invertebrates, and fish.

Several organic contaminants of concern have been detected in the overburden soils, perched groundwater, and isolated portions of regional groundwater. Organic contaminants of greatest concern include tetrachloroethene, trichloroethene, and vinyl chloride. Biological samples collected within Operable Unit 5, including grass, fish, and mammal tissues, were analyzed for semivolatile organic compounds, pesticides, and polychlorinated biphenyls (PCBs). None of these compounds were detected in any of the biological samples.

Section 4.0 discusses the media-specific response actions developed for Operable Unit 5. These response actions are identified for contaminants of concern with emphasis to satisfy the remedial action objectives and to protect human health and the environment. For groundwater (both perched and the Great Miami Aquifer), soils, and sediments, potentially feasible remediation technologies and process options are identified for each of the relevant response actions.

In Section 5.0, the remedial technologies and process options are discussed and an initial screening is performed to eliminate those options which do not appear to be applicable or appropriate for the conditions at the FEMP, based on technical effectiveness or implementability. Costs for each of these technologies and process options are discussed in a qualitative manner. The following technologies and actions for controlling/remediating groundwater contamination were retained for additional review and evaluation after preliminary screening:

- Institutional actions:
  - Groundwater monitoring
  - Deed restrictions
  - Land acquisition

- Groundwater control/containment:
  - Extraction/injection wells (to modify hydraulic gradients)

- Groundwater removal:
  - extraction wells
  - wellpoint system

- Groundwater Treatment:
  - air stripping and carbon adsorption (to remove organics)
  - ion exchange (to remove radionuclides and selected metals)

- reverse osmosis (to remove radionuclides and selected metals)
- precipitation (to remove radionuclides and selected metals)

- Treated Water Disposal:
  - discharge to Great Miami River via the FEMP pipeline currently under construction (Option 1) or discharge to Paddys Run (Option 2)
  - discharge to groundwater via injection wells, with or without gradient control

The following technologies and actions for controlling/remediating contaminated soils and sediments were retained for additional review and evaluation after preliminary screening:

- Institutional actions:
  - Fence site areas
  - Deed restrictions

- Control/containment:
  - Multilayer capping

- Removal:
  - Mechanical excavation

- Treatment:
  - Soil washing
  - Batch vitrification
  - Pozzolanic-based/cement-based stabilization/solidification

- Storage/Disposal:
  - Intermediate storage (on site or off site)
  - Disposal (on site or off site)

In Section 6.0, two sets of remedial action alternatives were developed. Seven alternatives were developed to address the contaminated groundwater utilizing the technologies and process options retained in Section 5.0. For these alternatives, perched water will be remediated in conjunction with regional groundwater.

Eleven alternatives were developed to address the contaminated soils and sediments. The remedial action alternatives for soils and sediments are combined, since the technologies and process options are applicable to each of these media.

Section 7.0 describes the initial screening of the remedial action alternatives and presents those alternatives selected for detailed evaluation in the next phase of the FS process. The alternatives were qualitatively screened against three general criteria: effectiveness, implementability (technical and administrative feasibility), and cost.

Five groundwater remedial action alternatives were retained for detailed evaluation in the next phase of the FS process:

GW-1: No action

GW-3: Institutional actions, extraction/injection wells, extraction wells and wellpoint system, air stripping, adsorption, ion exchange, surface water discharge (Great Miami River or Paddys Run)

GW-5: Same as GW-3 above, except that treated water would be discharged to reinjection wells

GW-6: Institutional actions, extraction/injection wells, extraction wells and wellpoint system, air stripping, adsorption, precipitation, surface water discharge

GW-7: Same as GW-6 above, except that treated water would be discharged to reinjection wells

For these alternatives (excluding no action), the exact nature of institutional actions is flexible, and the use of extraction/injection wells to control hydraulic gradients is optional. The alternatives listed above will be refined or modified during the later stages of the RI/FS process, as more information becomes available and the technologies have been evaluated in detail.

Nine remedial action alternatives for soil and sediments were retained for detailed evaluation in the next phase of the FS process:

SS-1: No action

SS-2: Institutional actions, excavation, intermediate storage

SS-3: Institutional actions, excavation, disposal (on site or off site)

SS-4: Institutional actions, excavation of sediments, multilayer capping of soils/sediments

SS-6: Institutional actions, excavation, soil washing, disposal of residuals (on site or off site)

SS-7: Institutional actions, excavation, batch vitrification, backfilling of treated residuals

SS-8: Institutional actions, excavation, batch vitrification, disposal (on site or off site)

SS-9: Institutional actions, excavation, soil washing, batch vitrification of residuals, backfilling of vitrified residuals

SS-10: Institutional actions, excavation, soil washing, batch vitrification of residuals, disposal (on site or off site)

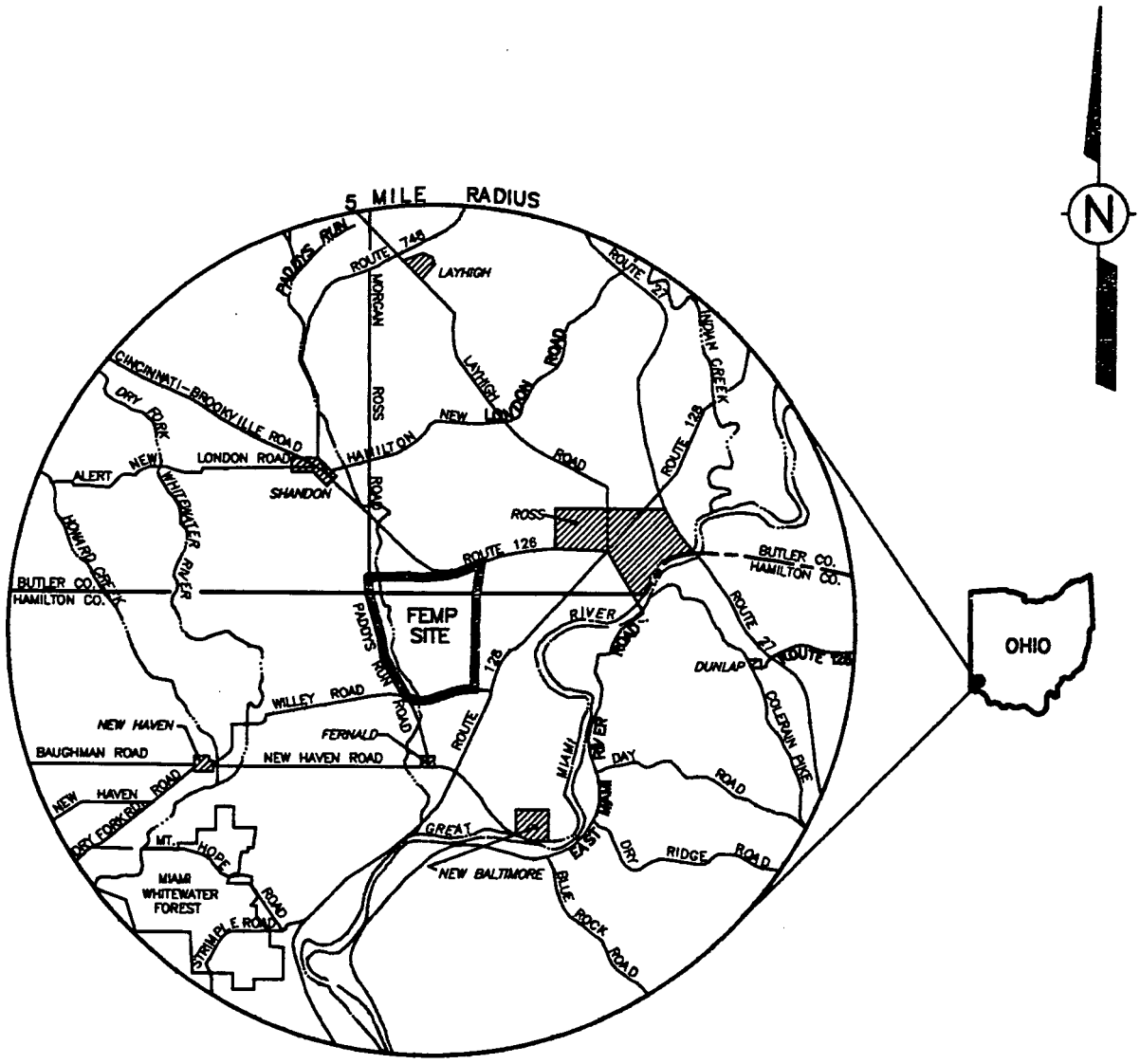
1.0 INTRODUCTION

The Fernald Environmental Management Project (FEMP), formerly known as the Feed Materials Production Center (renamed August 23, 1991), is a contractor-operated federal facility where pure uranium metals were produced for the U.S. Department of Energy (DOE) between 1951 and 1989. The FEMP site is located on 1050 acres in a rural area of Hamilton and Butler Counties, approximately 18 miles northwest of Cincinnati, Ohio. The former production area is limited to an approximate 136-acre tract near the center of the site. The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are all located within a few miles of the site (Figure 1-1).

On March 9, 1985, the U.S. Environmental Protection Agency (EPA) issued a Notice of Noncompliance to the DOE identifying EPA's major concerns over potential environmental impacts associated with the FEMP's past and present operations. Between April 1985 and July 1986, negotiations were held between DOE and EPA representatives to clarify the issues and to identify the steps the DOE proposed to take to achieve and maintain environmental compliance.

On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) pertaining to environmental impacts associated with the FEMP was signed by the DOE and the EPA. The FFCA was entered into pursuant to Executive Order 12088 (43FR47707) to ensure compliance with existing environmental statutes and to implement regulations such as the Clean Air Act, the Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In particular, the FFCA was intended to ensure that environmental impacts associated with past and present activities at the FEMP are thoroughly and adequately investigated so that appropriate remedial action alternatives can be formulated, assessed, and implemented. In response to the FFCA, a Remedial Investigation/Feasibility Study (RI/FS) was initiated pursuant to CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA). All RI/FS activities are being conducted in conformance with the EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988a). In addition, the FEMP was included on the CERCLA National Priority List (NPL) in November 1989.

The 1986 FFCA was amended by a Consent Agreement under Section 120 and 106(a) of CERCLA (Consent Agreement) in order to achieve consistency with the operable unit concept and the commitments of the RI/FS program without modifying the underlying objectives. The Consent Agreement was signed on April 9, 1990 and became effective on June 29, 1990. Under this agreement, the FEMP was divided into five operable units, as defined in the following discussion. This was done in order to allow the remedial action process to proceed to completion for the most well-defined areas at the FEMP, while data collection and analysis continued for other more problematic areas. The Consent Agreement was itself amended the next year to revise the schedules



313327-A101 (ISA) (PGH)

FIGURE 1-1 FEMP FIVE-MILE RADIUS MAP

for the five operable units for completing the RI/FS. This Amended Consent Agreement was signed on September 20, 1991 and became effective on December 20, 1991. Under this amended agreement, the definitions of the operable units were revised and a comprehensive sitewide operable unit was added to evaluate the remedies selected for the five operable units on a sitewide basis.

Within the CERCLA framework, the purpose of the RI is to determine the nature and extent of any release, or threat thereof, of hazardous or radioactive substances and to gather the necessary data to support the evaluation of remedial action alternatives in the FS. The data gathered will be sufficient to determine the risks associated with the site and to support an informed decision regarding the selection of the best remedial action alternative. The RI/FS for the FEMP was designed to address the entire site and to focus on various environmental media that could be potentially impacted by past and present operations at the FEMP.

During the RI/FS process, the RI and FS should be conducted concurrently. Data collected in the RI influence the development of remedial alternatives in the FS, which in turn influences the data needs and the scope of treatability studies and additional field investigations (EPA 1988a). Thus, the FS is generally conducted in phases. The first phase of an FS typically involves the development and screening of remediation alternatives. This report covers this first phase of the FS for Operable Unit 5. As such, this first phase, or initial screening of alternatives (ISA), includes the following steps: (1) identifying remedial action objectives, specifying the contaminants and media of interest, exposure pathways, and preliminary remediation goals; (2) developing general response actions for each medium of interests, defining containment, treatment, pumping, or other actions taken to satisfy the remedial action objects at the site; (3) identifying volumes or areas of media to which general response actions might be applied; (4) identifying and screening the technologies applicable to each general response action to eliminate those that cannot be technically implemented at the site; (5) identifying and evaluating technology process options on the basis of effectiveness, implementability, and relative cost to select a representative process for each technology type retained for further consideration; and (6) assembling the selected representative technologies into alternatives representing a range of treatment and containment combinations as appropriate (EPA 1988a). Alternatives can then be developed to address each contaminated medium, a specific area of a site, or an entire operable unit. For this report, alternatives have been developed that are relevant to two categories of contaminated media: (1) perched and regional groundwater, and (2) soils and stream sediments. During later stages of the FS, alternatives for the entire scope of Operable Unit 5 will be refined in greater detail and evaluated.

1.1 OPERABLE UNIT MANAGEMENT STRATEGY

A Work Plan for the sitewide RI/FS, based on the requirements of the FFCA, was originally submitted to the EPA in December 1986. After a series of technical discussions, the Work Plan was modified

and resubmitted in March 1988 and received EPA approval in May 1988. The Work Plan identified 27 units of the FEMP to be investigated in the RI/FS. Several modifications to the list eventually increased this total to 39 units. Due to the size and complexity of the site, it became apparent that for technical and program management purposes, these 39 units needed to be categorized into manageable groups or operable units for remedial action. The concept of operable units was introduced into the program to accommodate separate schedules for each of the unit groups, thereby allowing the remedial action process to proceed to completion for the most well-defined units while data collection and analysis continued for other operable units. The operable units were first identified in the August 1988 Work Plan for the FS (DOE 1988a). The first document prepared included the six initially identified operable units for the FS and was issued in December 1988. It was the Development of Alternatives for the Feasibility Study, Revision 1, hereinafter referred to as the Development of Alternatives Document (DOE 1988b). Figure 1-2 shows the location of the major features at the FEMP. The six original operable units identified in the Development of Alternatives Document were described as follows:

- Operable Unit 1 - Waste Storage Units
  Pits 1, 2, 3, 4, 5, 6, the Clearwell,
  and the Burn Pit

- Operable Unit 2 - Solid Waste Units
  Lime Sludge Ponds, Fly Ash Piles,
  Sanitary Landfill, South Field

- Operable Unit 3 - Facilities and Suspect Areas
  Production Area Facilities and Suspect Areas,
  Fire Training Area, Incinerator Area,
  Rubble Mounds, Abandoned Drum Locations,
  Area Near Flagpole

- Operable Unit 4 - Special Facilities
  K-65 Silos, Metal Oxides Silo,
  Thorium Inventory

- Operable Unit 5 - Environmental Media
  Soils, On-site Groundwater, Flora and Fauna,
  Regional Aquifer, Ambient Air

- Operable Unit 6 - Surface Water Courses
  Paddys Run, Great Miami River, Storm Sewer Outfall Ditch (SSOD)

Subsequent to the issuance of the Development of Alternatives Document, Operable Units 5 and 6 were reorganized to make (1) all surface waters part of Operable Unit 5 and (2) the South Plume groundwater study area a separate operable unit (a new Operable Unit 6). This decision was triggered by the EPA's request for the DOE to focus a remedial action program on the groundwater outside the

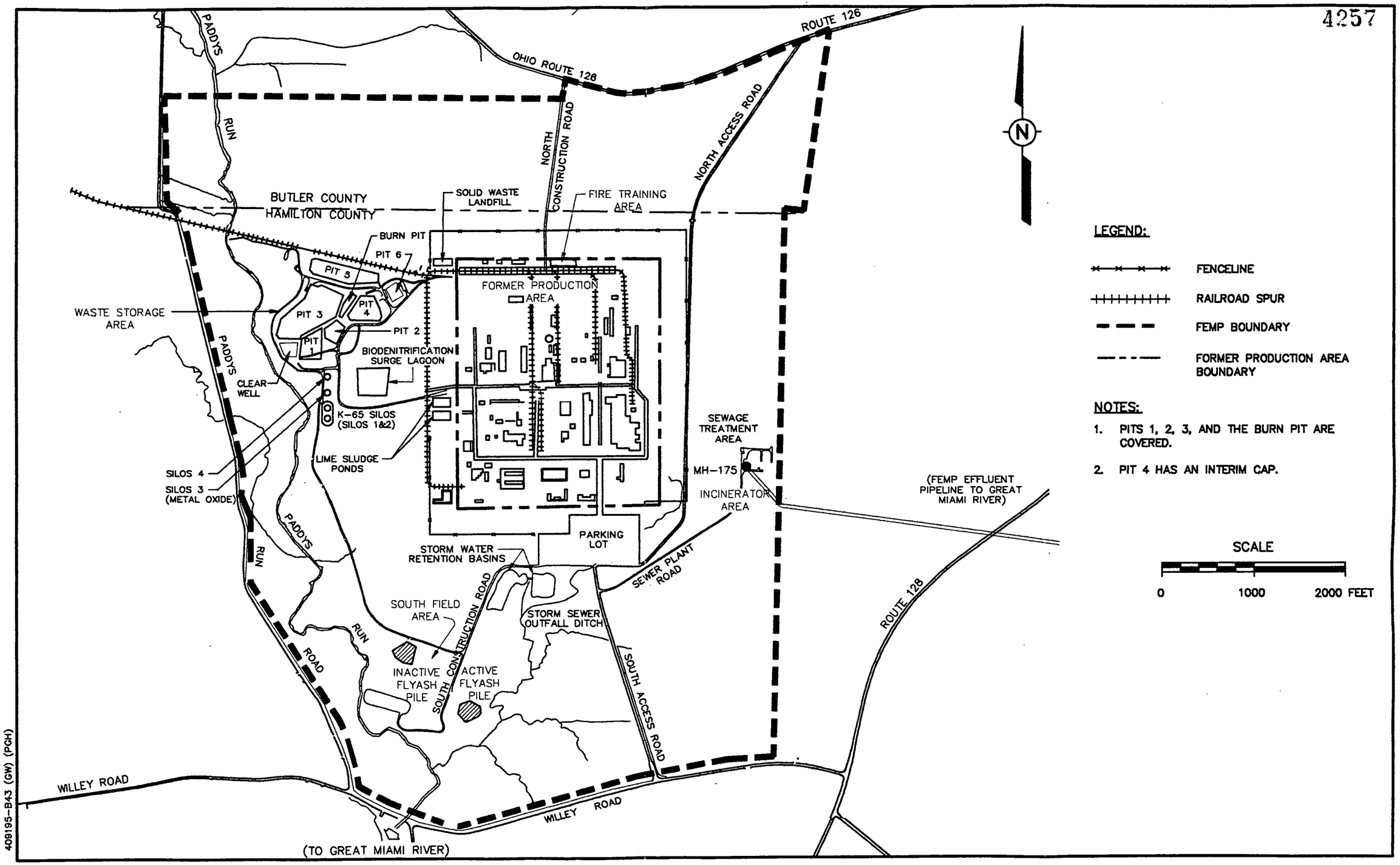


FIGURE 1-2
LOCATION OF MAJOR FEATURES AT THE FEMP

FEMP boundary that had elevated uranium concentrations in an area of the aquifer potentially used for drinking water, agriculture, and industrial manufacturing. This plume was primarily caused by historical releases, and included the areas of the Great Miami Aquifer contained within the southerly groundwater flow regime, both within and outside the FEMP property. After this reorganization, Operable Unit 5 included all other environmental media: surface water, sediments, all groundwater in the regional aquifer (excluding the South Plume), surface and subsurface soils (excluding soils included in the other operable units), flora, and fauna.

During the course of the groundwater investigation conducted as part of the RI/FS program, a potentially important technical shortcoming became apparent in the separation of the South Plume from the rest of the regional aquifer. Data gathered during this investigation indicated that the location of the groundwater flow divide, that initially defined Operable Unit 6 (the South Plume), changes due to the seasonal recharge of Paddys Run. Therefore, the use of the flow divide to differentiate between Operable Units 5 and 6 could lead to significant problems in the FS/Record of Decision (ROD) process and created a need for integration across operable units. In addition, the analysis of complete source-pathway-receptor relationships within the individual operable units was inhibited by a lack of data on the southern portion of the plume, the remaining unknowns related to the South Field near the flow divide, and the contribution of Paddys Run as a source that crosses the groundwater flow divide. For these reasons, the decision was made to deal with the entire regional aquifer within a single operable unit, Operable Unit 5, thus eliminating Operable Unit 6 from the RI/FS process.

The issues of the South Plume concerning the contamination outside the FEMP property were addressed as an accelerated removal action under CERCLA. The Engineering Evaluation/Cost Analysis (EE/CA) document for the South Plume (DOE 1990a) recommended a comprehensive action involving the installation of an alternate water supply to two affected users, installing recovery wells in the southern area of the uranium plume south of the site to intercept and collect the uranium-contaminated plume then discharging the groundwater to the Great Miami River via the effluent line, constructing an interim advanced wastewater treatment system (150 gallons per minute [gpm]) to treat FEMP wastewater, and continued monitoring and institutional controls for the area. These activities will collectively be considered the baseline condition at the FEMP for the purposes of alternative development and evaluation for Operable Unit 5.

Although the 1986 FFCA was amended by the June 1990 Consent Agreement to consolidate the RI/FS work at the FEMP into five operable units (OU), the definitions of these OUs were subsequently revised under the 1991 Amended Consent Agreement and a comprehensive sitewide OU was added.

The five specific OUs are shown and described in Figures 1-3, 1-4, and 1-5. Their revised definitions and that of the comprehensive sitewide OU are presented below:

- Operable Unit 1 - Waste Pits 1-6, the Clearwell, the Burn Pit, berms, liners, and associated contaminated soil within the OU boundary.

- Operable Unit 2 - The active and inactive flyash piles, South Field, the lime sludge ponds, the solid waste landfill, berms, liners, and associated contaminated soil within the OU boundary.

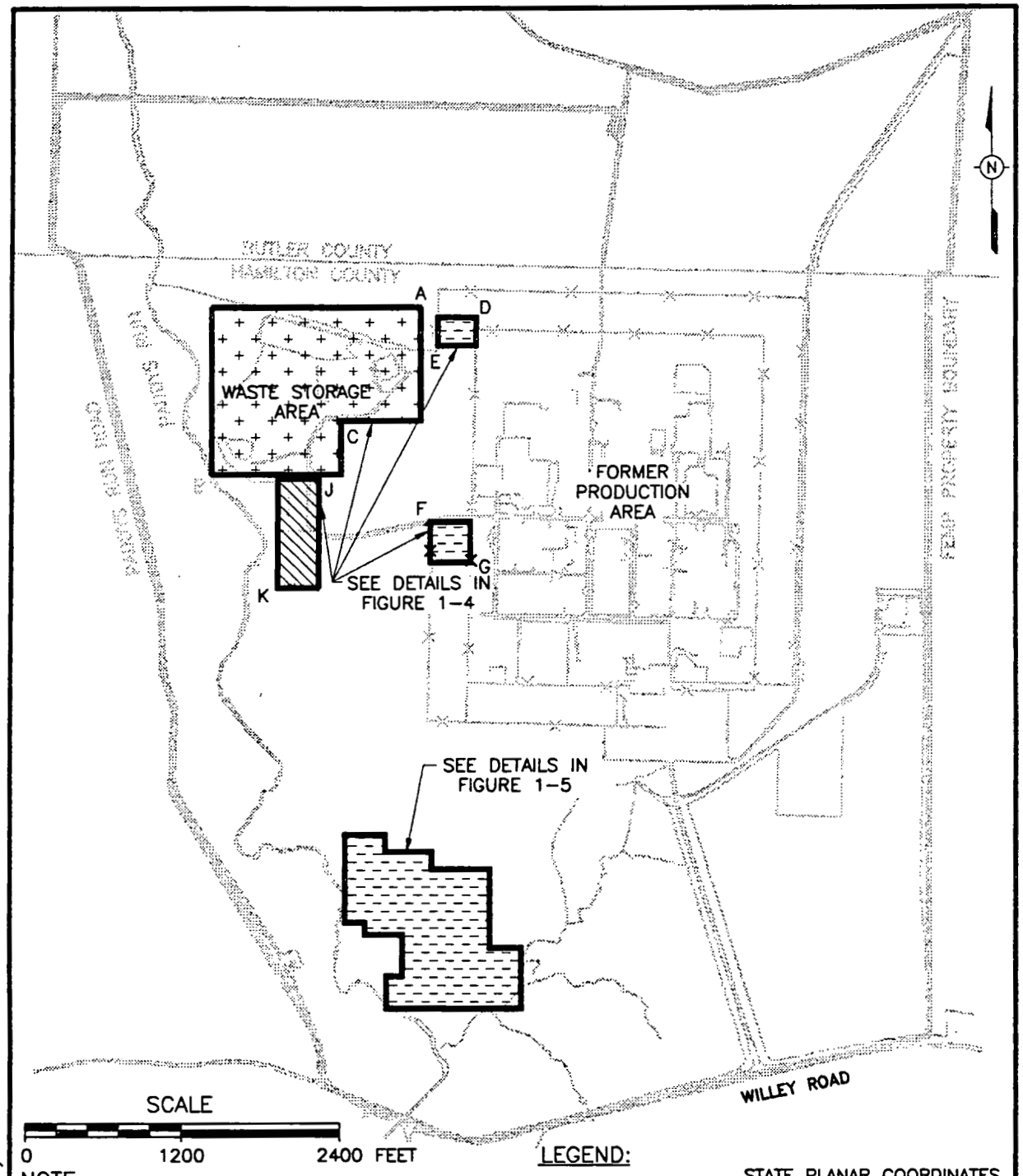
- Operable Unit 3 - The former production area and production associated facilities and equipment (includes all above- and below-grade improvements) including, but not limited to, all structures, equipment, utilities, drums, tanks, solid waste, waste, product, thorium, effluent lines, K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feedstocks, and the coal pile.

- Operable Unit 4 - Silos 1, 2, 3, and 4, berms, the decant tank system, and associated contaminated soil within the OU boundary.

- Operable Unit 5 - Perched and regional groundwater, surface water, soils not associated with other OUs, sediments, flora, and fauna.

- Comprehensive Sitewide Operable Unit - An evaluation of the remedies selected for the five operable units, including removal actions, to ensure that they are protective of human health and the environment on a sitewide basis. A sitewide RI/projected residual risk assessment will be developed after the RODs for Operable Units 1 to 5 are finalized. The sitewide RI will incorporate all data collected pursuant to the RIs for Operable Units 1 to 5, including removal actions, and summarize any data collected after finalization of the OU 1-5 RODs. The projected residual risk assessment will document all risks anticipated to remain at the site following the implementation of the response actions embodied in the OU 1-5 RODs and the selected removal actions. If the sitewide RI/projected residual risk assessment indicates that these remedies are protective of human health and the environment on a sitewide basis, then a sitewide FS will not be required. If, however, the selected remedies are not found to be protective, a sitewide FS will be prepared to evaluate additional alternatives or modifications to selected alternatives for the reduction of risk and achievement of protectiveness. In the event that this FS report is necessary, a proposed plan which describes the selected remedial alternative would be developed and published. This would be followed by the submittal of a sitewide ROD.

In accordance with the operable unit management strategy, separate RI/FS reports will be generated for each operable unit. The initial screening of remediation alternatives for Operable Unit 5 is the subject of this report. A previous version of the Operable Unit 5 Initial Screening of Alternatives report was approved in early 1991. However, the 1991 Amended Consent Agreement significantly expanded the definition of OU 5 through the addition of soils and perched groundwater inside the former production area (formerly part of OU 3). This rescoping of OU 5, based on the renegotiated Consent Agreement, requires the preparation of a revised OU 5 Initial Screening of Alternatives report.



NOTE:
OPERABLE UNIT 3 INCLUDES ALL BUILDINGS, PIPELINES, AND ABOVEGROUND STRUCTURES IN THE FORMER PRODUCTION AREA, SEWAGE TREATMENT AREA, FIRE BRIGADE TRAINING AREA, AND WASTE PIT AREA, IN addition TO THE STORM WATER RETENTION BASIN. OPERABLE UNIT 5 INCLUDES GROUNDWATER, SURFACE WATER, SOILS, SEDIMENTS, FLORA AND FAUNA WITHIN THE REGIONAL AREA AS WELL AS THE FORMER PRODUCTION AREA.

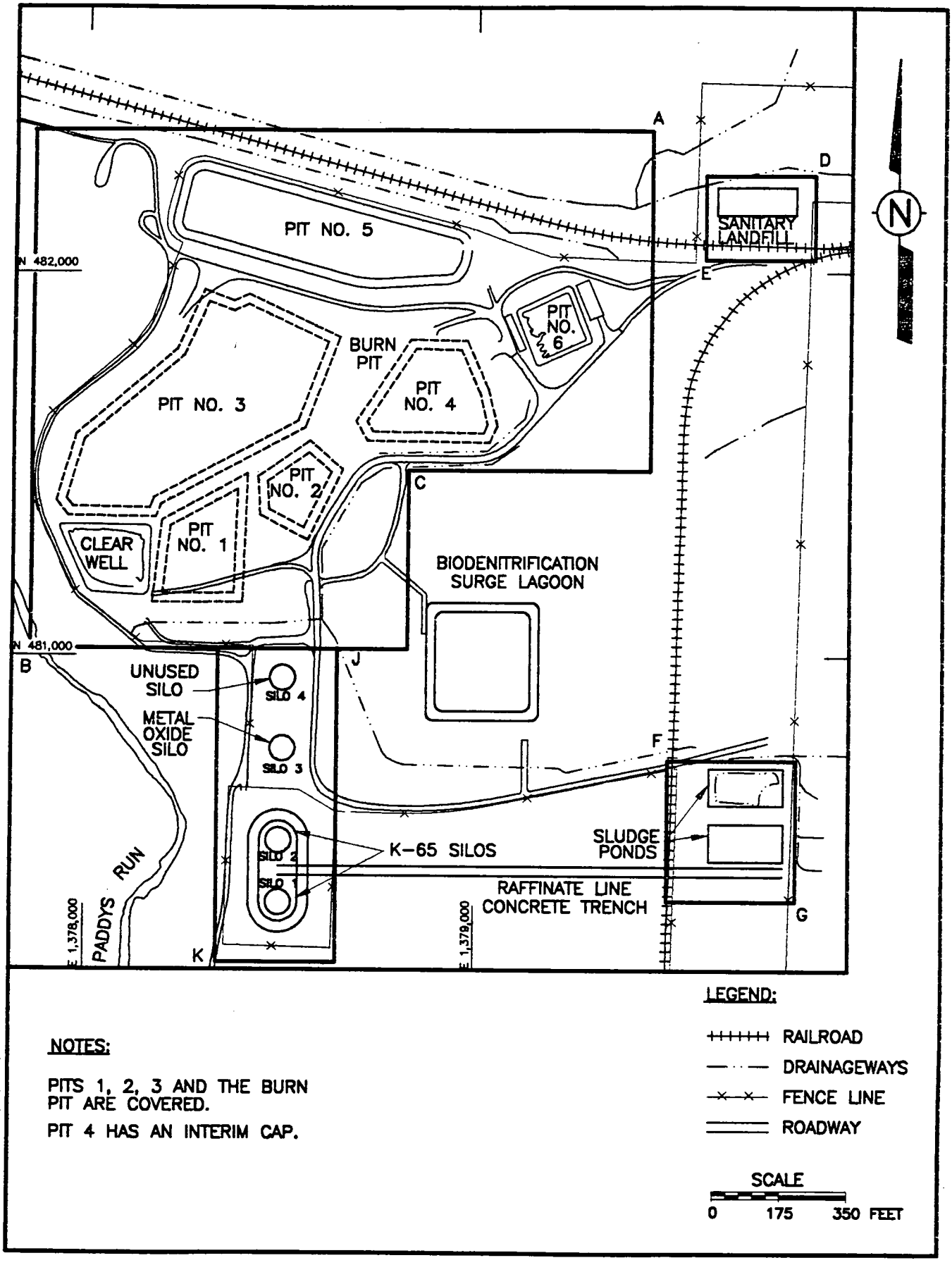
LEGEND:

OPERABLE UNIT 1
OPERABLE UNIT 2
OPERABLE UNIT 4

	STATE PLANAR COORDINATES	
A	N 482,364	E 1,379,432
B	N 481,033	E 1,377,824
C	N 481,499	E 1,378,812
D	N 482,264	E 1,379,849
E	N 482,051	E 1,379,568
F	N 480,756	E 1,379,501
G	N 480,402	E 1,379,819
J	N 481,033	E 1,378.642
K	N 480,222	E 1,378,329

409195-A5 OU5 RI (PGH)

FIGURE 1-3. RI/FS OPERABLE UNITS



NOTES:

PITS 1, 2, 3 AND THE BURN PIT ARE COVERED.

PIT 4 HAS AN INTERIM CAP.

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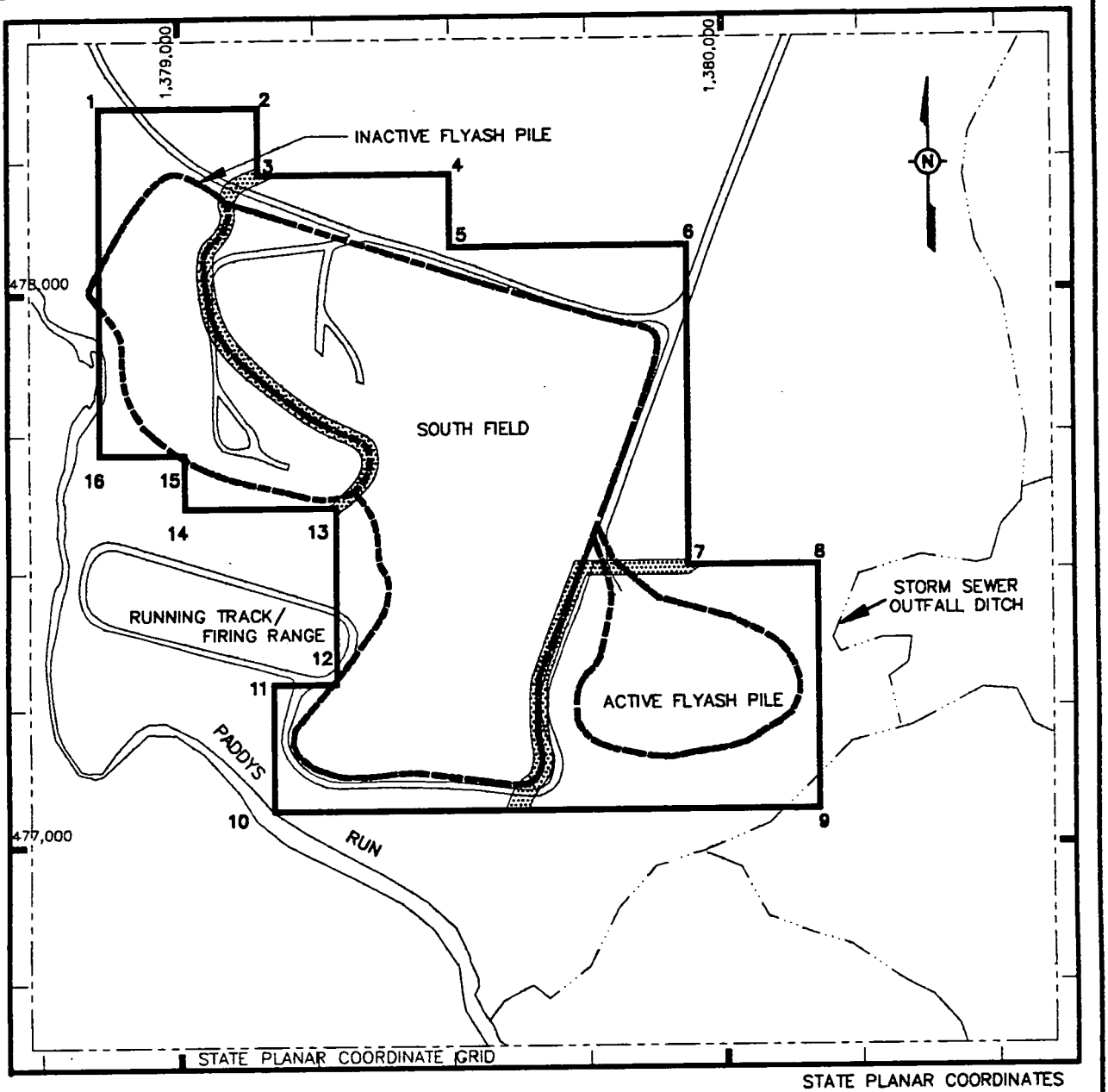
FIGURE 1-4 FEMP WASTE STORAGE AREA



LEGEND:

- FLYASH/SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- OPERABLE UNIT 2 STUDY AREA
- ROADWAY
- DRAINAGEWAY
- EXTENT OF FILL

SCALE

0 125 250 FEET

STATE PLANAR COORDINATES		
1	N478348	E1378859
2	N478348	E1379148
3	N478225	E1379148
4	N478225	E1379500
5	N478091	E1379500
6	N478091	E1379933
7	N477509	E1379933
8	N477509	E1380172
9	N477064	E1380172
10	N477064	E1379174
11	N477295	E1379174
12	N477295	E1379289
13	N477617	E1379289
14	N477617	E1379014
15	N477715	E1379014
16	N477715	E1378859

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FIGURE 1-5. FLYASH/SOUTH FIELD STUDY AREA

1.2 OPERABLE UNIT 5: ENVIRONMENTAL MEDIA

Operable Unit 5 is comprised of the FEMP area environmental media including groundwater, surface water, soil, stream sediments, flora, and fauna. The exception to this definition is soils which underlie Operable Units 1, 2, and 4. These soils are to be characterized, evaluated, and remediated as part of their respective operable units (Figures 1-3, 1-4, and 1-5). The boundary of OU5 is not limited to the FEMP property boundary, but instead is defined by the sampling investigation network and by the extent of contamination originating from the FEMP.

As indicated in the Figure 1-3 footnote, all buildings, building substructures, pipelines, and aboveground structures within the former production area are components of Operable Unit 3, while the soils within the former production area are included in Operable Unit 5.

1.3 TECHNICAL APPROACH AND ORGANIZATION

This ISA document is prepared in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and the EPA's current "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988a). The development and initial screening of alternatives for the Operable Unit 5 FS were accomplished by:

- Developing remedial action objectives to protect human health and the environment
- Developing general response actions to satisfy the remedial action objectives to which the general response actions may apply
- Identifying the volumes and areas of contaminated environmental media
- Identifying and screening technologies and process options for each of the identified general response actions
- Evaluating process options
- Developing and describing remedial action alternatives
- Screening remedial action alternatives
- Selecting specific alternatives for detailed evaluation.

For each media (i.e., perched groundwater, regional aquifer [Great Miami Aquifer], soils, and sediments), potentially feasible remedial technologies and process options have been identified for each of the relevant response actions. These technologies were compiled from various EPA documents as well as other applicable references. Each of these technologies and process options has undergone a refinement of the previously completed screening of technologies and process options in the

"Development of Alternatives" document (DOE 1988b). The goal of the technology screening process is to form a complete set of response actions that are consistent with the remedial action objectives for the operable unit. A set of technology groupings is identified and combined around these general response actions. Each technology type is evaluated on the basis of technical implementability and effectiveness. Using this screening process, certain remedial action options or technology groupings are eliminated from further consideration because they are unable to fulfill the general response objectives for the specific medium in a technically efficient manner. Information regarding site characterization, contaminant types, and contaminant concentrations was used to eliminate technologies and process options that are either not applicable or cannot be effectively implemented at the site. Those remaining technologies are evaluated on the basis of effectiveness, technical implementability, and cost. Technologies retained for further consideration are assembled into a set of alternatives that represent a range of treatment and containment combinations, as appropriate.

The results of the screening of alternatives that are presented in this document are limited by several factors. Specifically, this document is being prepared before the completion of several RI field activities important to Operable Unit 5 that are being conducted in response to the findings of the baseline RI program. While virtually all of the currently available data have been reviewed and preliminarily evaluated, detailed analysis of the data will be conducted and presented in the Operable Unit 5 RI report scheduled for completion in June 1994. The baseline risk assessment, the results of which are fundamental to the establishment of cleanup criteria to support the FS, is also scheduled for completion in June 1994. As a consequence of the currently incomplete risk assessment, sitewide preliminary remediation goals (PRG) were developed using results of the RI/FS investigation presently available (DOE 1992a). The PRGs were developed using Applicable or Relevant and Appropriate Requirements (ARAR) where available, a 10^{-6} risk level in combination with a cancer slope factor (CSF) for carcinogens, or a hazard index (HI) and a reference dose (RfD) for noncarcinogens. These PRGs are intended only as a guide in determining media cleanup levels. Since different cleanup criteria than those used for this initial evaluation may be established as a result of the baseline risk assessment and since additional areas or contaminants of concern may be identified during the ongoing RI studies, the remedial alternatives identified in this screening document may require modification as the FS process proceeds.

The remainder of this chapter provides brief descriptions and summaries of the FEMP site history, a description of the specific activities that occurred in the former production area and suspect areas, and ongoing sampling activities in these areas. The important physical properties and characteristics of the Operable Unit 5 study area are discussed in Section 2.0. Section 3.0 begins with a discussion of the development of ARARs and then follows with a description of PRGs. In addition, a summary of the location and extent of contamination for the environmental media as well as a brief risk analysis of exposure pathways and potential receptors are included in this section. The remedial action objectives

are presented and described in Section 4.0. Since the governing data, such as information on contaminants of concern, the exposure pathways and receptors, and the acceptable contamination levels, are still being developed in ongoing studies, the remedial action objectives and technology combinations are being held flexible enough to accommodate potential changes in cleanup levels, receptors, or contaminants of concern at a later date. Section 4.0 also includes a discussion of the general response actions developed for Operable Unit 5 and the identification and screening of remedial technologies and process options. The process options remaining from the initial screening are then evaluated on the basis of effectiveness, implementability, and cost in Section 5.0 and are assembled into remedial action alternatives in Section 6.0. Section 7.0 describes the initial screening of the remedial action alternatives and presents those alternatives selected for detailed evaluation in the next phase of the FS process, the detailed evaluation of alternatives.

1.4 SITE HISTORY AND OPERATION

This section briefly discusses the historical development and operational history of the FEMP and historical and current waste and effluent management programs.

1.4.1 Operational History

The U.S. Atomic Energy Commission (AEC), predecessor to the DOE, established the FEMP for processing uranium and its compounds from natural uranium ore concentrates and recycled recoverable residues for government needs. This integrated production complex began operations in conformance with AEC orders in the early 1950s. In 1951, the National Lead Company of Ohio (now NLO, Inc.) entered into a contract with the AEC as Operations and Management Contractor. This contractual relationship lasted with the AEC, and eventually the DOE, until January 1, 1986. Westinghouse Materials Company of Ohio (WMCO), a wholly owned subsidiary of Westinghouse Electric Corporation, then assumed management responsibilities of the site operations and facilities for a minimum of five years. In 1991, Westinghouse renamed this subsidiary the Westinghouse Environmental Management Company of Ohio (WEMCO).

A pilot plant was completed in 1951 and was the first operational facility at the FEMP. A metals fabrication plant (Plant 6) began operations in 1952. Another metals production plant (Plant 5), the green salt plant (Plant 4), recovery plant (Plant 8), sampling plant (Plant 1), and the refinery (Plants 2 and 3) began operations in 1953. Plant 7, where uranium hexafluoride (UF_6) was processed, and Plant 9, the special products plant, became operational in 1954. Figure 1-6 illustrates the location of these plants within the former production area. Section 1.5 provides a description of the processes that took place in each of these plants and in other facilities within the former production area.

All plants except the sampling plant and refinery were expanded during the period 1954 to 1956. Production peaked in 1960 at approximately 10,000 metric tons of uranium. Production began

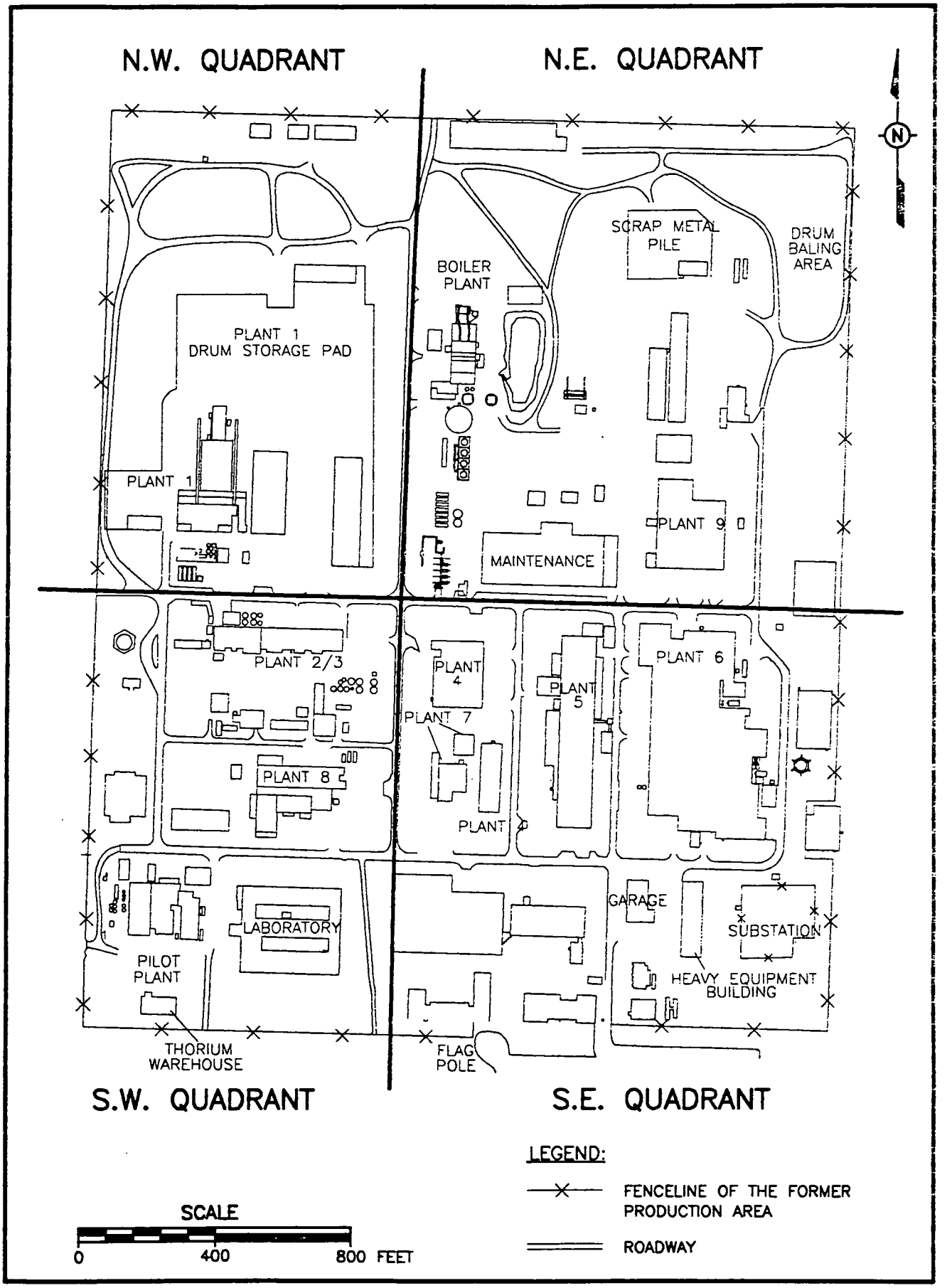

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FIGURE 1-6 FORMER PRODUCTION AREA QUADRANT MAP OF THE FEMP

declining in 1964 and reached a low in 1975 of about 1230 metric tons of uranium. During the 1970s, consideration was given to closing the FEMP; therefore, capital improvements and staffing were reduced. The staffing level, which peaked at 2891 in 1956, slowly declined from 662 in 1972 to 538 in 1979. Beginning in 1981, production levels significantly increased along with a rapid increase in staff in many areas. A major facilities restoration program followed. Production operations ceased in the summer of 1989 and plant resources were focused on a cleanup program. In June 1991, the FEMP was officially closed as a federal production facility; however, the environmental studies and cleanup activities continue.

A variety of chemical and metallurgical processes were used at the FEMP to manufacture uranium products. During the manufacturing process, high-quality uranium compounds were introduced into the FEMP processes at several points. Impure starting materials were dissolved in nitric acid and the uranium was purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating converted the nitrate solution to uranium trioxide (UO_3) powder. This compound was reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal was produced by reacting UF_4 and magnesium metal in a refractory-lined vessel. This primary uranium metal was then remelted with scrap uranium metal to yield a purified uranium ingot. Various uranium metal working processes also existed.

From 1953 to 1955, the FEMP refinery processed pitchblende ore from the Belgian Congo. Pitchblende ore contains all the progeny of the uranium decay chains and is particularly high in radium content due to high uranium assay. No chemical separation or purification was performed on the ore prior to arrival at the FEMP. Beginning in 1956, the refinery feedstock consisted of uranium concentrates (yellowcake) from Canada and the United States (U.S.). Canadian concentrates were not processed after 1960. In the production of these concentrates, most of the uranium progeny had been removed. However, radium-226 (Ra-226) remained in the yellowcake in amounts that varied with the process. The Canadian yellowcake contained higher levels of thorium-230 than yellowcake from the U.S. sources. Small amounts of thorium were produced at the FEMP on several occasions from 1954 through 1975. Thorium operations were performed in the metals fabrication plant, the recovery plant, the special products plant, and the pilot plant. The FEMP currently serves as the thorium repository for the DOE and maintains long-term storage facilities for a variety of thorium materials.

1.4.2 Waste and Effluent Management

Waste and effluent management practices at the FEMP played a significant role in determining the nature and extent of contamination at the site and the potential for future contamination events. Before 1984, solid and slurried wastes from the FEMP processes were disposed of in the on-property waste storage area (Figure 1-4). This area, which is located west of the former production facilities, includes six low-level radioactive waste storage pits; two earthen-bermed concrete silos containing

K-65 residues which are high-specific activity, radium-bearing residues resulting from the pitchblende refining process; one silo containing metal oxides and one currently unused concrete silo; two lime sludge ponds; and a solid waste landfill.

Additional waste materials associated with uranium metals production are presently stored on property in steel drums awaiting further processing or off-site disposal at approved facilities. These wastes include oils, sludges, contaminated combustibles, filter cake, off-specification UF_4 or thorium tetrafluoride (ThF_4), and reject UO_3. The drums, which sit on various pads and in warehouses, are inspected weekly. Contents of deteriorated drums are repackaged. Other wastes include spent degreasing solvents and material contaminated with polychlorinated biphenyls (PCB). These wastes are contained in drums and stored on concrete pads.

Two flyash piles are located approximately 3000 feet south-southeast of the waste storage area (Figure 1-2). One pile remains active for the disposal of flyash from the FEMP coal-fired boiler plant. An area between and adjacent to the flyash areas, known as South Field, is believed to be the disposal site for construction debris and possibly other types of solid wastes from the FEMP operations. The waste storage area is addressed under Operable Units 1, 2, and 4.

Surface water runoff from the waste storage area, flyash piles, and other affected areas within the western portion of the FEMP enters Paddys Run, a tributary of the Great Miami River. Paddys Run originates just north of the FEMP and flows south-southeast along the western edge of the site (Figure 1-1). Sections of Paddys Run are usually dry during the summer and autumn months. The surface water runoff entering Paddys Run from the waste storage area has been addressed as a removal action in 1991. The EE/CA for Waste Pit Area storm water runoff control (DOE 1990b) recommends the collection and treatment of runoff from this area.

Liquid wastes generated from FEMP process operations are sent to a general plant sump for sampling and analysis, prior to treatment and/or release to the Great Miami River through the main effluent line (Figure 1-2). The main effluent line to the Great Miami River is a permitted discharge for wastewater from the FEMP. The discharge is regulated by a National Pollutant Discharge Elimination System (NPDES) permit and DOE Order 5400.5 (DOE 1990a). Compliance monitoring is performed at Manhole 175 as the effluent leaves the property boundary.

Storm water runoff from the former production area is collected in storm water retention basins, located on the south side of the former production area, to allow for solids settling prior to the water being analyzed and released to the Great Miami River through the main effluent line (Figure 1-2). Two 700 gpm pumps have been installed at the storm water retention basins to reduce occurrences of overflow events. However, if the retention basins do overflow during an extreme storm event, storm

water is discharged through the SSOD to Paddys Run. Evaluation of the impacts associated with surface water discharges from the FEMP, including overflows from the storm water retention basins, are being evaluated within the environmental assessment being conducted for incorporation into the Operable Unit 5 RI report.

1.5 FORMER PRODUCTION AREA OVERVIEW AND DESCRIPTION

The majority of soils and perched groundwater within Operable Unit 5 that contain constituents above their PRG levels is located within the former production area. In addition to the nine specialized production plants within the former production area, a number of other buildings on site housed support operations. Each of these facilities had a distinct purpose, resulting in significant differences in the process operations, chemical forms, and types of individual conveyance, storage, and containment units associated with each of the facilities. To better focus the investigation of this complex production network into a manageable technical framework, the former production area has been separated into four quadrants (Figure 1-6) which include the distinct groupings of facilities and operations.

1.5.1 Southeast Quadrant

The southeast quadrant (Figure 1-7) includes Plants 4 through 7, the main electrical substation, and the garage/heavy equipment building. Uranium tetrafluoride (green salt) was produced from uranium trioxide through a reduction-hydrofluorination process at Plant 4, the green salt plant. The depleted green salt was blended and packaged for transportation to the metals production plant. Black uranium oxide was also reprocessed at Plant 4 to enhance its reactivity for other processing.

At Plant 5, the metals production plant, uranium tetrafluoride was reduced with magnesium in an electrical resistance furnace to produce high-purity uranium metal derbies. Some derbies were remelted in vacuum induction furnaces, molded into ingots, and cropped into billets before transportation to Plant 6, the metals fabrication plant, or Plant 9, the special products plant. Other derbies were shipped directly to various DOE sites.

Uranium metal billets were heat treated at Plant 6, the metals fabrication plant, to improve their strength and grain structure in preparation for extrusion into tubes which occurred off property. Extruded tubes of uranium were cut into blanks, heat treated, and machined into finished elements for inspection and shipment to other DOE production sites. Resultant chips and lathe turnings were crushed, pickled, briquetted, and recycled to the casting operations in Plant 5. Flat ingots were surface machined and inspected.

Plant 7, the hexafluoride reduction plant, was designed for the conversion of uranium hexafluoride to uranium tetrafluoride in a gas-gas reaction. It was used for this purpose until it was shut down in

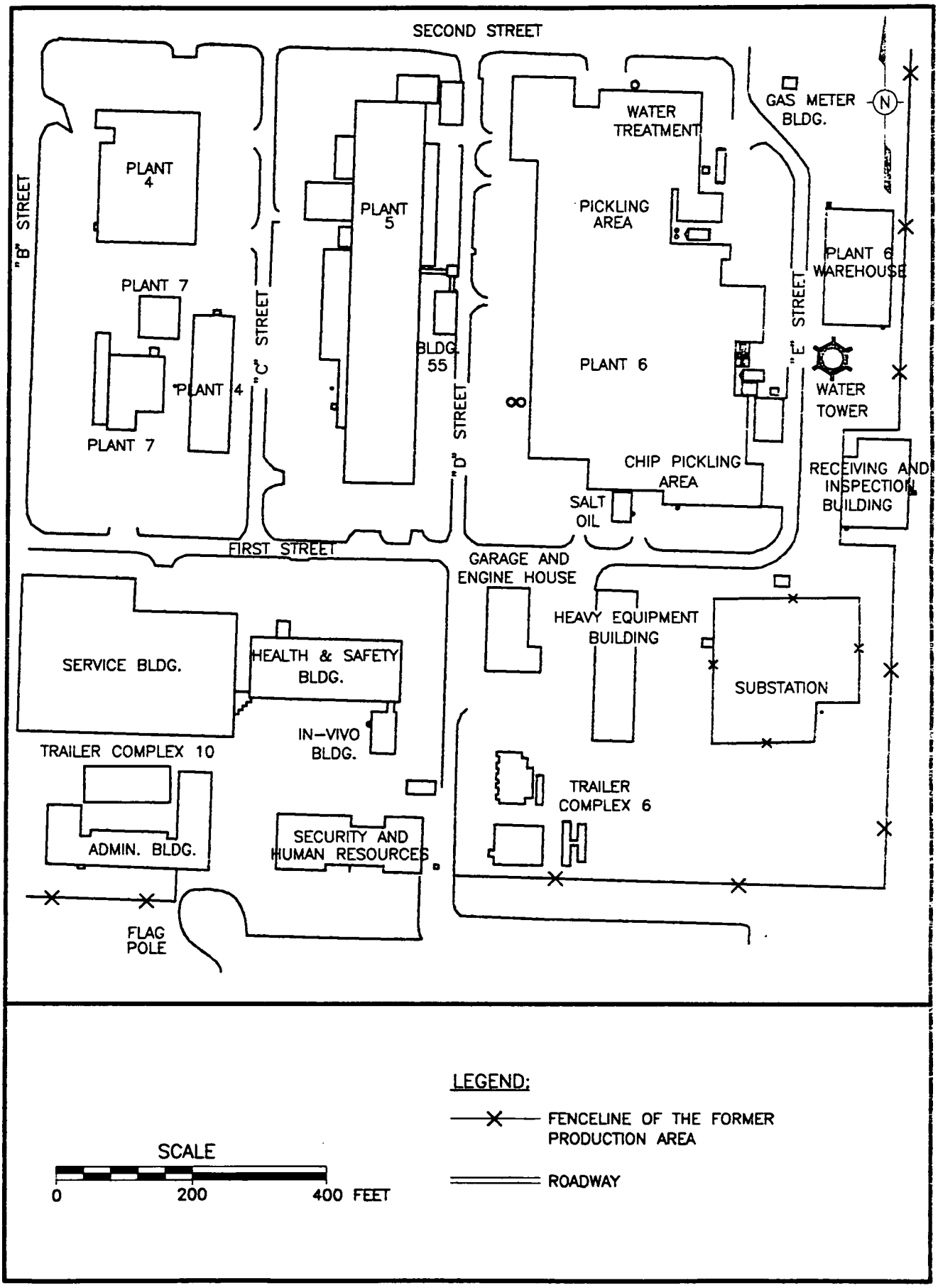

FIGURE 1-7 SOUTHEAST QUADRANT OF THE FORMER PRODUCTION AREA

1956. It is currently classified as a surplus facility, and has been used as a storage warehouse principally for drums of uranium tetrafluoride and a few drums of residue from Plant 4.

The southeast quadrant also includes the main electrical substation, the garage, the truck weigh station, a water tower, a new warehouse, a new receiving/inspection building, the service building, the health and safety building, and the heavy equipment building. None of these facilities are production process operation or uranium handling facilities, and there are currently no production wastes stored or located in them.

1.5.2 Southwest Quadrant

Within the southwest quadrant (Figure 1-8), there are three general types of facilities: operating plants, storage areas, and support areas. Plant 2/3, the refinery, was a large-scale chemical operation plant in which the following processes occurred: digesting enriched uranium scrap residues in nitric acid to produce a uranyl nitrate feed solution, solvent extraction and purification using kerosene-tributyl phosphate, concentration of the purified uranyl nitrate solution by evaporation, and thermal denitrification to uranium trioxide. Nitrogen oxides released during the dissolution and denitrification steps were converted to nitric acid and reused in the process.

At Plant 8, the recovery plant, enriched residues and scrap generated on site or received from off-site facilities were processed to remove moisture, oil, graphite, and other impurities before being sent to Plant 2/3 for uranium extraction. In addition, Plant 8 was also the facility where large volumes of low-level radioactive waste slurries were filtered, residues were dried in the plant's furnaces, materials were milled and sorted, and thorium processing was performed.

The pilot plant is the original FEMP process facility where many of the FEMP processes were tested before scaling up for actual production. Portions of the pilot plant were extensively refurbished for the production of uranium tetrafluoride from uranium hexafluoride.

The FEMP hazardous waste, bulk storage tank facility is also located in a portion of the pilot plant tank farm. The facility consists of two empty 10,000-gallon tanks that previously contained spent degreasing solvents.

Other key facilities in this quadrant are:

- Metal dissolver building
- Plant 2/3 maintenance building
- Control building

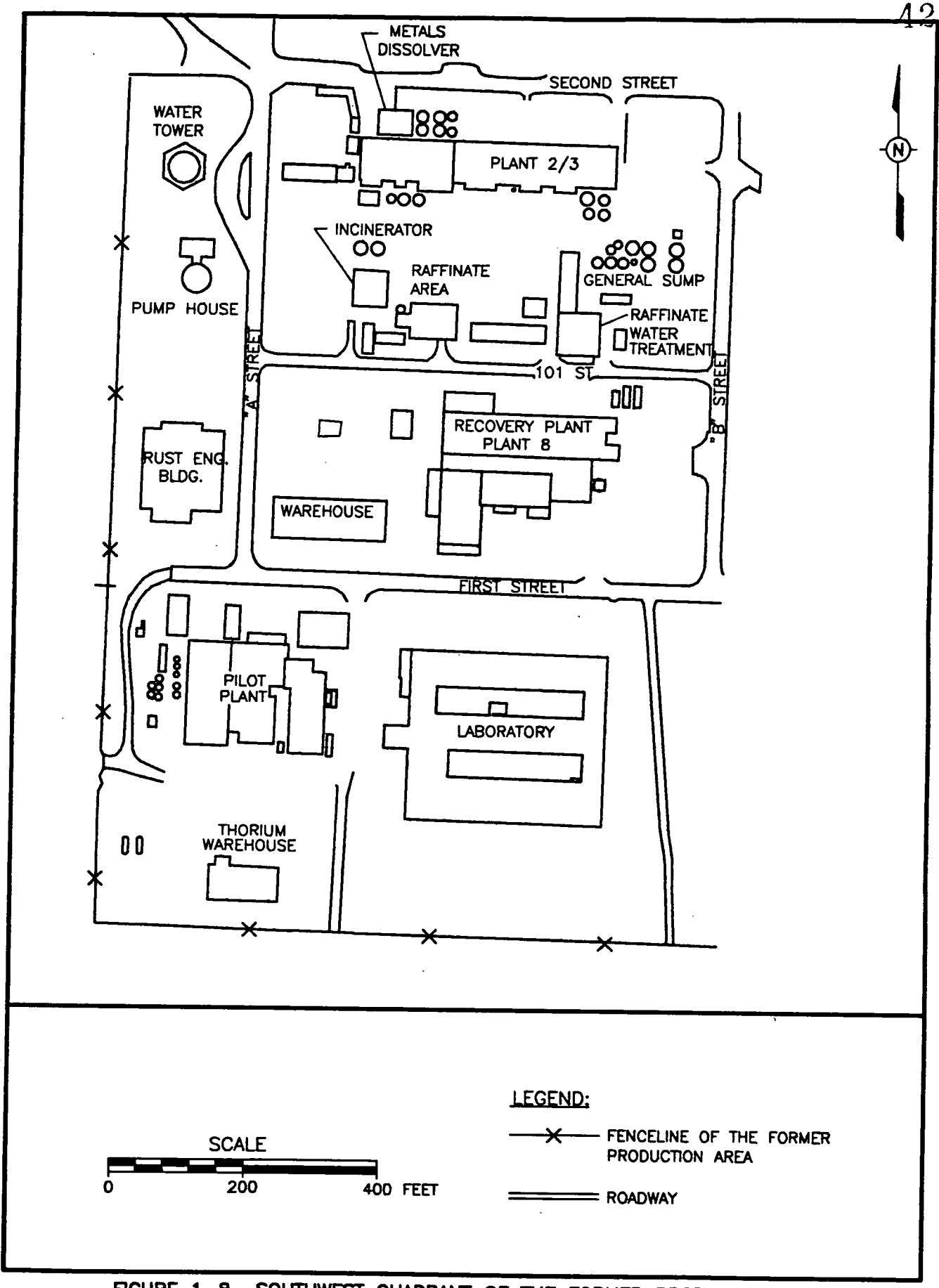

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FIGURE 1-8 SOUTHWEST QUADRANT OF THE FORMER PRODUCTION AREA

- Hot raffinate building
- Storage building
- Refinery sump
- General sump
- Green salt warehouse
- Former waste solvent drum storage site immediately west of the laboratory
- Pilot plant/ammonia tank farm
- Underground tanks, drum storage area immediately south of the Pilot Plant main building
- Hydrogen fluoride/hydrofluoric acid tank
- Pilot plant/thorium warehouse and radiographic facility
- Uranium hexafluoride/uranium tetrafluoride reduction area
- Ammonia dissociator building
- Argon tank
- Laboratory
- Incinerator plant
- Areas containing aboveground tanks and sumps
- Biodenitrification building.

1.5.3 Northeast Quadrant

The northeast quadrant (Figure 1-9) contains a wide variety of facilities and storage pad areas, including the metal scrap pile, the former drum baling area, the graphite furnace/oil burner area, the special products plant (Plant 9), the maintenance building, the boiler plant, the tank farm, the decontamination and decommissioning building, and various warehouses.

The decontamination and decommissioning building and pad areas were used primarily for decontamination and disposal activities. Materials were cleaned and reused, or salvaged if possible, with some having been placed on the metal scrap pile which primarily consists of ferrous material, with some aluminum, copper, brass, and nickel. Within the drum baling area are various discarded

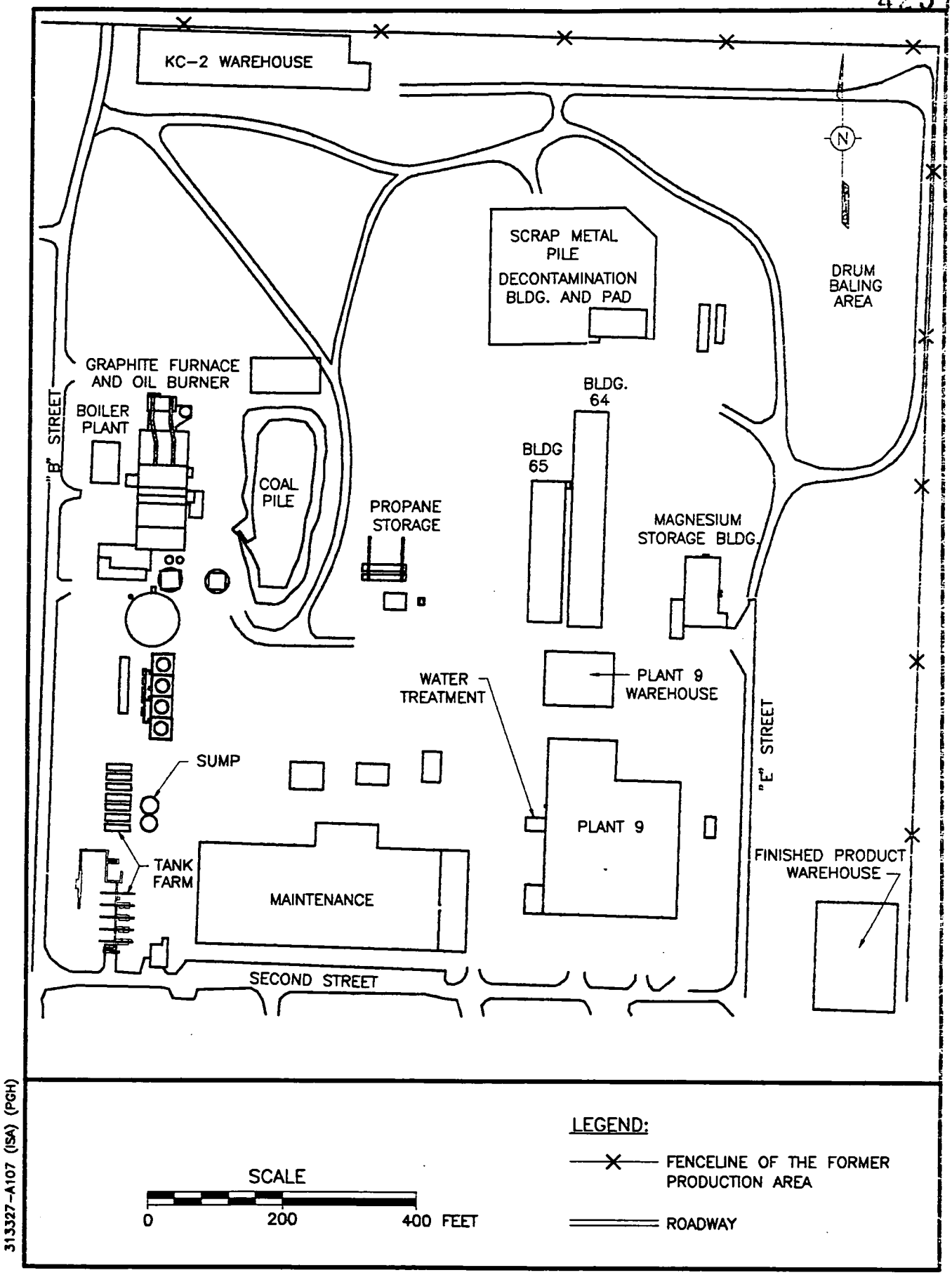


FIGURE 1-9 NORTHEAST QUADRANT OF THE FORMER PRODUCTION AREA

scraps, materials, abandoned vehicles and equipment. The abandoned graphite furnace and oil burner were used to incinerate scrap graphite and contaminated liquid organics.

The maintenance building includes various nonprocess, storage, and support areas. In addition to the maintenance craft shops, this building housed the plant storage and receiving area. Drummed solvents, lubricants, and gas cylinders are stored on a pad located north of the maintenance building.

The boiler plant area includes all equipment and distribution systems for the "process fluids" for the site, including sanitary, process, and cooling water; plant and instrumentation air; fuel gas; and steam. Compressed air was used for running instruments and processes in the plant. Fuel gas was used in the various plant furnaces. Steam is primarily used for heating, but also powers the backup turbines in case of a power failure. These turbines serve as an emergency backup system for pumping water throughout the plant. Water is pumped from sumps, tanks, and other retainers to the general sump and the wastewater treatment plant.

Plant 9, the special products plant, had the following functions: machining uranium metal ingots for off-site extrusion, casting derbies into large-diameter ingots, and chemically decladding copper layers from nonirradiated uranium fuel cores. These functions were also conducted in Plants 5 and 6; however, the resulting ingots were smaller than those produced in Plant 9. Plant 9 operations evolved over the years due to program changes to directly support the FEMP operations.

The tank farm originally consisted of 16 aboveground and buried storage tanks that contained ammonia, ammonium hydroxide, anhydrous hydrogen fluoride, hydrofluoric acid, potassium fluoride, kerosene, nitric acid, hydrochloric acid, calcium fluoride, potassium hydroxide, and tributyl phosphate.

The original tank farm was expanded in the 1960s with several modifications thereafter until 1985, when a major renovation was started. The tanks were modified to hold hydrofluoric acid, but are presently empty.

1.5.4 Northwest Quadrant

The facilities within the northwest quadrant (Figure 1-10) are principally used for warehousing and storage. Plant 1, the sampling plant, and the Plant 1 drum storage pad are the principal facilities in this quadrant. In addition, the northwest quadrant contains two large metal scrap piles, the shot blaster area, a storage area for drummed thorium, and a large rubble mound near Third Street, which consists of discarded construction rubble materials.

At one time, the activities in the northwest quadrant included storage of approximately 68,000 drums and containers of thorium and uranium residue. However, due to major drum relocation activities, the

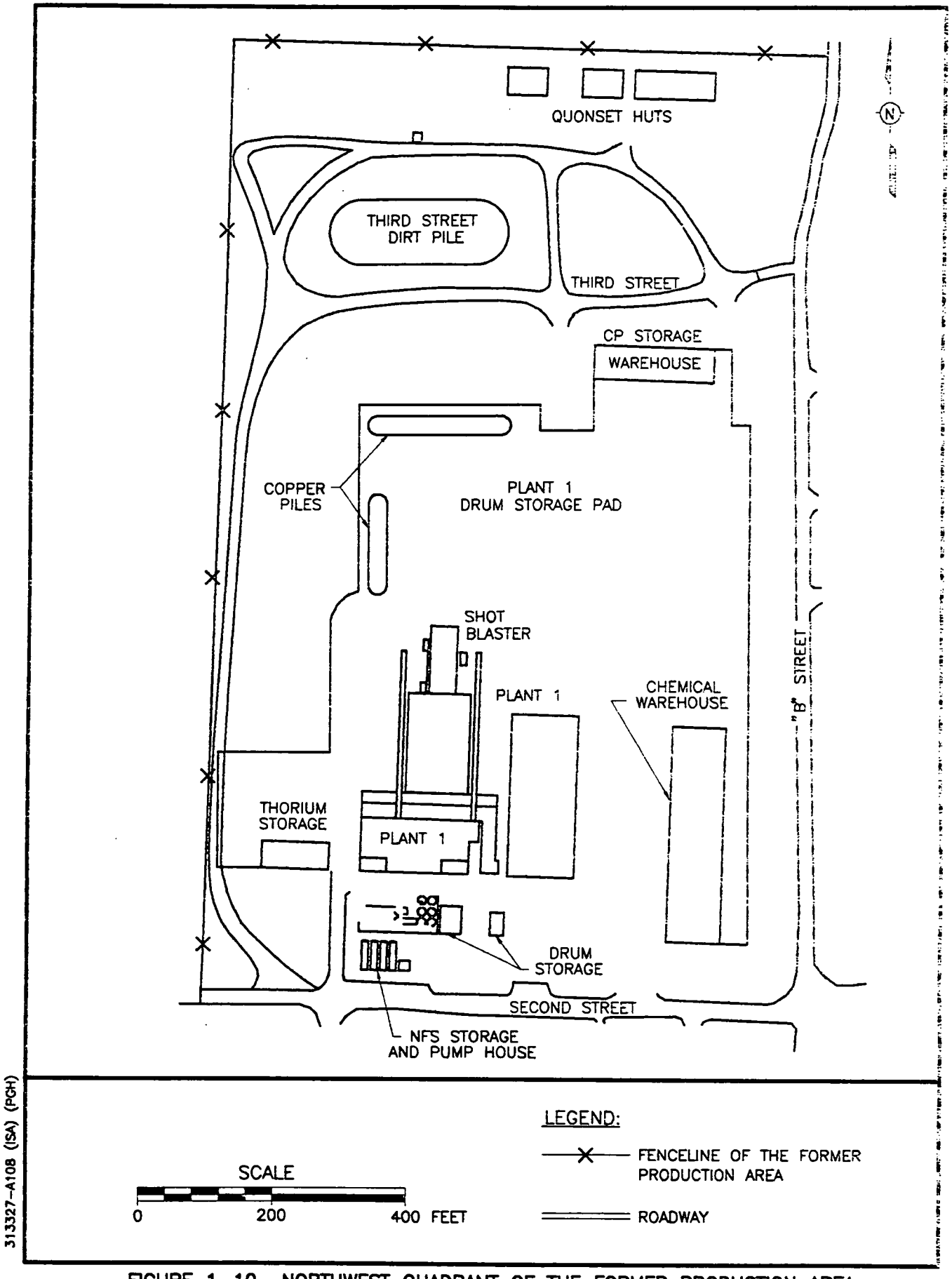


FIGURE 1-10 NORTHWEST QUADRANT OF THE FORMER PRODUCTION AREA

number of drums in a given area was subject to considerable variation. A database is maintained that records the waste characteristics and location of drummed materials at the site. This inventory of drums and other containers was completed by the end of September 1992. All movement of these inventoried wasted containers are documented. Prior activities included:

- Shipping, receiving, storing, milling, and classifying depleted, normal, and enriched uranium materials
- Reconditioning of steel drums and baling of deteriorated drums for salvage
- Opening nonirradiated fuel pins containing enriched uranium dioxide pellets
- Sampling and analyzing incoming materials and storing residues and other materials awaiting off-site shipment.

The potential contaminants resulting from all of these processes are included in Table 1-1 (Former Production Area Potential Contaminants by Location) and are listed by location within the former production area. This listing only includes major processing locations and storage pads.

Solid waste materials associated with uranium metals production are presently stored on property in steel drums awaiting further processing or off-site disposal at approved facilities. These wastes include oils, sludges, contaminated combustibles, filter cake, off-specification UF_4 or thorium tetrafluoride (ThF_4), and reject UO_3 (Table 1-1). The drums are located on various pads and in warehouses and are inspected weekly. Contents of deteriorated drums are repackaged. Other wastes stored in drums on contained surfaces include spent degreasing solvents, material contaminated with PCBs, and other types of material listed in Table 1-1.

1.6 SUSPECT AREAS

Suspect areas are those areas (1) within the FEMP property boundary, but outside the former production area, and (2) suspected or identified through field testing as having constituents above their PRG levels due to past activities. Specifically, these areas are: the north flagpole area, two rubble mounds, a suspected rubble mound, the K-65 slurry line, the main effluent line, the Clearwell line, the sewage treatment plant/incinerator area, and the fire training area (Figure 1-11). While the facilities, equipment, and utilities associated with these areas are components of Operable Unit 3, the contaminated environmental media are components of Operable Unit 5.

An area around the south flagpole in front of the current administration building was identified as the burial site of a large tank or vault containing radioactive wastes. A geophysical survey was conducted in the area, but no anomalous results were indicated. Further review of records revealed a second,

TABLE 1-1
FORMER PRODUCTION AREA POTENTIAL CONTAMINANTS BY LOCATION

Preparation Plant (Plant 1A)
Americium-241
Cesium-137
Ore and ore concentrates[a]
Radium-226
Thorium
Thorium oxalate
Uranium (up to 20% enriched)

Uranium octo-oxide
Uranium tetrafluoride
Uranium trioxide

Ammonia
Arsenic
Cadmium
Chromium
Hydrofluoric acid
Lead
Magnesium fluoride
Sodium hydroxide

Carbon tetrachloride
Chlordane
Chloroform
1,2-Dichloroethane
1,1-Dichloroethylene
Perchloroethylene
1,1,1-Trichloroethane
Trichloroethylene

Halon 1301
Solvent residues[b]
Still bottoms
Sump cakes[c]

Ore Refinery Plant (Plant 2A)
High-grade residues[d]
Ores and ore concentrates[a]
Uranium (up to 10% enriched)
Uranium octo-oxide
Uranium trioxide
Uranyl nitrate

Aluminum oxide
Ammonia
Arsenic
Chromium
Lead
Sodium hydroxide
Silver
Sulfuric acid

Tetrachloroethylene
Tributyl phosphate

Kerosene
Low-grade residues[e]

Hot Raffinate Building (Plant 3E)
Ore raffinate[f]

Magnesium fluoride
Sodium hydroxide

Tetrachloroethylene
Tributyl phosphate
1,1,1-Trichloroethane

Kerosene
Low-grade residues[e]

Green Salt Plant (Plant 4A)
Thorium oxide
Thorium tetrafluoride
Uranium octo-oxide
Uranium tetrafluoride
Uranium tetrafluoride (depleted and enriched up to 1.25%)
Uranium dioxide
Uranium trioxide

Ammonia
Anhydrous ammonia
Catalyst
Hydrofluoric acid up to 30%
Hydrofluoric acid (anhydrous and aqueous)
Potassium fluoride
Potassium hydroxide
Mercury
Refrigerants

Metal Production Plant (5A)
Uranium
Uranium octo-oxide
Uranium tetrafluoride
Uranium trioxide
Uranium metal (up to 1.25% enriched)
Uranium (up to 1.25% enriched)
Uranium-contaminated filter cake
Cadmium

Chromium
Lead
Magnesium
Magnesium fluoride
Magnesium oxide
Mercury
Yttrium oxide
Zirconium
Zirconium oxide

Benzene
Perchloroethylene
1,1,1-Trichloroethane
Trichloroethylene

Cooling, hydraulic, and lubricating oil
Shell turbo 68 oil

Metals Fabrication Plant (Plant 6A)
Uranium
Uranium metal
Uranium octo-oxide

Uranium-contaminated sump cake
Uranyl nitrate

Ammonia
Cadmium
Chromium
Lead
Lithium chloride
Lithium carbonate
Magnesium oxide
Potassium carbonate
Potassium chloride
Sodium chloride
Sodium hydroxide
Sodium sulfide

Benzene
2-Butanone
Chlorobenzene
1,1,1-Trichloroethane
Trichloroethylene

Cooling, hydraulic, and lubricating oils
Water-soluble oils

Plant 7 (7A)
Uranium dioxide
Uranium hexafluoride
Uranium tetrafluoride
Uranium trioxide
Uranyl fluoride

Ammonia
Catalyst
Hydrofluoric acid (aqueous and anhydrous)

Bird droppings

TABLE 1-1
(Continued)

Scrap Recovery Plant (Plant 8A)
Calcium uranate
Ammonium diuranate cake
High-grade residues[d]
Prill[g]
Thorium
Thorium hydroxide
Thorium oxalate
Thorium oxides
Thorium tetrafluoride
Uranium metal
Uranium metal (up to 1.25% enriched)
Uranium octo-oxide
Uranium tetrafluoride
Uranium- and thorium-contaminated water
Uranium-contaminated filters, dust collector bags and gloves
Uranium-contaminated sump cake
Uranyl ammonium phosphate cake

Ammonia
Ammonium hydroxide
Arsenic
Calcium carbonate
Calcium fluoride
Copper
Copper sulfate
Graphite
Hydrochloric acid
Hydrofluoric acid (aqueous and anhydrous)
Lead
Lithium carbonate
Magnesium
Magnesium fluoride
Magnesium fluoride slag
Mercury
Phosphoric acid
Potassium carbonate
Potassium hydroxide
Sodium hydroxide
Sulfur dioxide

Acetone
Carbon tetrachloride
Diatomaceous earth
Ethylbenzene
Methyl ethyl ketone
Perchloroethlyene
Tetrachloroethylene
Toluene
Tributyl phosphate
1,1,1-Trichloroethane
Trichlorethylene
Xylene

Low-grade residues[e]
Lubricating, hydraulic, and cooling oil sludges
Oil- & solvent-contaminated gloves and rags[b]

Wet, low-grade sump and scrap cakes

Special Products Plant (Plant 9A)
Depleted uranium
Prill[g]
Thorium
Thorium tetrafluoride
Uranium metal
Uranium (up to 2.1% enriched)
Uranium octo-oxide
Uranium tetrafluoride
Uranyl nitrate

Aluminum
Ammonia
Copper
Dolomite
Hydrofluoric acid (aqueous)
Lithium carbonate
Magnesium
Magnesium fluoride
Nickel
Potassium carbonate
Potassium chloride
Sodium chloride
Sodium hydroxide
Zinc fluoride
Zirconium

Cooling, hydraulic, and lubricating oils
Degreasing solvents

Pilot Plant Wet Side (Plant 13A)
Barium
Barium chloride
Barium sulfate
Radium
Thorium
Thorium hydroxide
Thorium nitrate
Thorium oxalate
Thorium tetrafluoride
Uranium
Uranium (up to 2.5% enriched)
Uranium octo-oxide

Aluminum
Ammonia
Cadmium

Calcium fluoride
Chromium
Copper
Hydrochloric acid
Hydrofluoric acid
Hydrofluoric acid (aqueous)
Lead

Magnesium oxide
Magnesium fluoride
Mercury
Nickel
Oxalic acid
Sodium chloride
Sodium hydroxide
Zinc fluoride

Di-amyl-amyl phosphonate
Tributyl phosphate
1,1,1-Trichloroethane

Kerosene

Laboratory Building (Plant 15)
Europium-152
Lanthanum
Niobium
Plutonium
Thorium
Thorium nitrate
Uranium
Uranium octo-oxide
Uranyl nitrate

Acetic acid
Ammonia
Asbestos
Chromic acid
Hydrochloric acid
Hydrofluoric acid
Lead
Mercury
Metals[e]
Perchloric acid
Platinum
Silver
Sulfuric acid

Acetone
PCBs
Solvents
Tetrachloroethylene
1,1,1-Trichloroethane

TABLE 1-1
(Continued)

Pilot Plant Annex (Plant 37)
Thorium
Thorium tetrafluoride
Uranium
Uranium (up to 1.25% enriched)
Uranium octo-oxide
Uranium tetrafluoride
Uranium metal (up to 5% enriched)

Calcium
Magnesium
Magnesium fluoride
Magnesium oxide
Potassium chloride
Sodium chloride
Zinc
Zinc fluoride
Zirconium oxide

Lubricating oils
Quench oil

Incinerator Building (Plant 39A)
Ore raffinate[f]
Uranium
Uranium trioxide
Uranium-contaminated sump cakes[c]
Uranium-contaminated paper, pallets, and trash

Acetone
Ammonia
Perchloroethlyene
1,1,1-Trichloroethane
Trichloroethylene

Spent lubricating and hydraulic oils
Spent solvents[b]

Pilot Plant - Uranium Hexafluoride to Uranium Tetrafluoride Facility (Plant 54A)
Thorium
Thorium metal
Thorium tetrafluoride
Uranium
Uranium and thorium sawdust
Uranium hexafluoride
Uranium tetrafluoride
Uranium metal
Uranium metal (up to 1.25% enriched)
Uranyl fluoride

Ammonia
Calcium
Calcium fluoride
Hydrofluoric acid (anhydrous)
Magnesium
Magnesium fluoride
Zinc
Zinc fluoride

Perchloroethylene

Coolant
Water soluble oil

Plant 2 East Pad (74A)
Uranium (up to 5% enriched)
Uranium trioxide (up to 3% enriched)
Uranyl nitrate

Plant 2 West Pad (74B)
Ore and ore concentrates[a]
Uranium dioxide
Uranium octo-oxide
Uranium trioxide
Uranyl ammonium phosphate cakes
Uranyl nitrate

Aluminum oxide
Ammonium diuranate
Lead
Magnesium fluoride

Oil
Urea

Plant 8 East Pad (74C)[b]
Thorium compounds
Uranium
Uranium metal (up to 1.25% enriched)
Uranium-contaminated water and sludges

Magnesium fluoride

Dust collector residues
Oil-contaminated water

Plant 8 West Pad (74D)[b]
Thorium
Uranium
Uranium-contaminated sump cakes

Copper
Sodium hydroxide

1,1,1-Trichloroethane

Oil residues

Plant 4 Pad (74E)
Uranium
Uranium dioxide
Uranium octo-oxide
Uranium tetrafluoride

Uranium trioxide

Plant 7 Pad (74F)
Uranium hexafluoride
Uranium tetrafluoride
Uranium trioxide
Uranyl fluoride

Plant 5 East Pad (74G)
Uranium (up to 1.25% enriched)
Uranium tetrafluoride

Magnesium

Plant 5 South Pad (74H)
Uranium tetrafluoride

Magnesium fluoride

Plant 6 Pads (74J)
Uranium metal (up to 1.25% enriched)

Plant 9 Pad (74K)
Radium
Strontium-90
Thorium
Thorium compounds
Thorium tetrafluoride
Uranium
Uranium metal (up to 2.1% enriched)
Uranium octo-oxide
Uranium- and thorium-contaminated sump cake and dust collector residues

Calcium fluoride
Magnesium fluoride

TABLE 1-1
(Continued)

Building 65 West Pad (74L)
Thorium compounds
Uranium and thorium metal and ingots

Baled drums & lids

Building 64 East Pad and Railroad Dock (74M)
Uranium and thorium compounds

Magnesium

Building 12 North Pad (74N)
Ethylene glycol
1,1,1-Trichloroethane
Trichloroethylene

Diesel fuel
Lubricating and hydraulic oils

Decontamination Pad (74P)
Thorium
Uranium
Uranium- and thorium-contaminated metal, equipment, and tanks

Oil

Plant 8 Old Metal Dissolver Pad (74Q)
Prill[g]

Hydrochloric acid
Magnesium

Plant 8 North Pad (74R)
Thorium metal
Uranium
Uranium octo-oxide
Uranium metal (up to 1.25% enriched)
Uranium-contaminated gloves, rags, and bags

Ammonium hydroxide
Magnesium
Sulfur dioxide

Plant 1 Storage Pad (74T)[h]
Barium
Ore and ore concentrates[a]
Radium
Technetium-99 residues
Thorium
Thorium compounds
Uranium (up to 1.25% enriched)

Uranium octo-oxide
Uranium trioxide

Lead
Lithium carbonate
Magnesium fluoride

Acetone
Methylene chloride
Perchloroethylene
1,1,1-Trichloroethane

Pilot Plant Pad (74U)
Uranium and thorium compounds
Uranium hexafluoride

Ammonia
Hydrofluoric acid (aqueous)

Oil

Laboratory Pad (74V)[h]
Uranium and thorium samples

Ammonia
Hydrofluoric acid

Di-amyl-amyl phosphonate
Tributyl phosphate

Kerosene

[a] Ore includes pitchblende and other unrefined ores; concentrates were refined somewhat at the mine site.
[b] Primarily 1,1,1-Trichloroethane, Trichloroethylene, Perchloroethylene.
[c] Precipitants from the filtration of uranium or thorium solutions.
[d] Includes Ammonium diuranate, uranyl ammonium phosphate, uranium tetrafluoride, uranium octo-oxide, uranium dioxide, and uranium trioxide.
[e] Residual material from magnesium fluoride, sump cakes, heat treating salts.
[f] Material stripped from uranium ores during refinery extraction process.
[g] Pieces of uranium and magnesium.
[h] Designated a Hazardous Waste Management Unit.

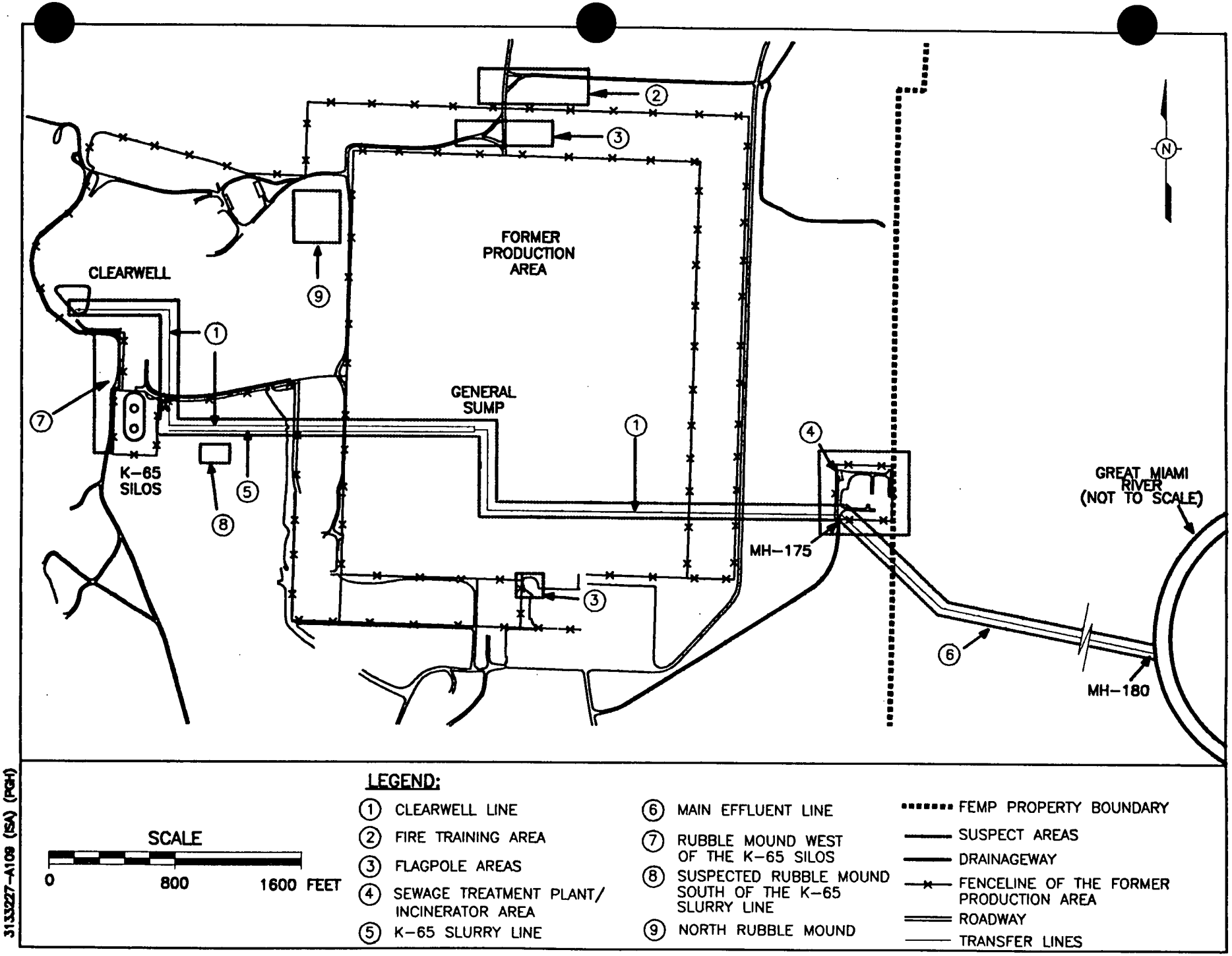


FIGURE 1-11 SUSPECT AREAS AT THE FEMP

former flagpole area north of the former production area. Three methods of geophysical surveying were performed to identify magnetic anomalies in the north flagpole area. These methods included gravimetric, magnetic, and ground penetrating radar (GPR) surveys. The results from the surveys indicate that magnetic anomalies were recorded in the north flagpole area. During trenching operations in the proximity where the four highest magnetic anomalies occurred, metallic surface debris was discovered. This debris did not contain radioactive wastes. Therefore, the theory of buried radioactive wastes in the north flagpole area has been discarded. Both of these areas are indicated by a number "3" in Figure 1-11.

The rubble mounds represent locations where rubble has been placed on the land surface outside of the former production area. One mound is west of the K-65 silos along the east bank of Paddys Run. The second rubble mound is located in the northeast corner of the Waste Storage Area just outside the northwest corner of the former production area. A third disturbed area south of the K-65 slurry line, identified on old aerial photographs, was thought to be a rubble mound. However, further investigations showed this area was more likely disturbed ground associated with a leak in the slurry line. The rubble mounds are marked by numbers "7," "9," and "8," respectively in Figure 1-11.

The K-65 slurry line is placed within a 2.5-foot covered concrete trench that is 1500 feet long and runs from the K-65 silo site into the former production area. It was used in the early years of plant operation to transport material from the raffinate building to the silos. For purposes of defining the suspect area, the security fence is considered the east boundary. A portion of the Clearwell line which connects the Clearwell and Manhole 175 also runs through this concrete trench. The Clearwell line was a pressurized process line, but now carries surface water runoff that enters the Clearwell. The flow is eventually discharged from Manhole 175. The K-65 slurry line and the Clearwell line to Manhole 175 are marked by numbers "5" and "1," respectively, in Figure 1-11.

The main effluent line connects Manhole 175 at the sewage treatment plant to the Great Miami River. Surface water from the Clearwell and treated wastewater are discharged through this line. Testing of soil along the main effluent line to date has indicated no constituents above PRG concentrations; however, additional testing along the entire length is ongoing. The location is depicted in Figure 1-11, marked number "6."

The sewage treatment plant/incinerator area encompasses an area approximately 300 feet by 300 feet and is located due east of the southeast corner of the former production area. The location is shown in the area marked by the number "4" in Figure 1-11. Sanitary wastes are transported to the sewage treatment plant for treatment to meet effluent concentrations in accordance with the FEMP's NPDES permit. The sludge drying beds are periodically cleaned and the sludge is drummed for disposal.

A solid waste incinerator is located in the northwest corner of the sewage treatment plant. The incinerator operated from November 1954 until December 1979. Examples of the types of materials that were burned in this incinerator are dust collector bags, office paper, former production area wood and paper, wooden pallets, and waste oil and sludges.

The fire training area is approximately 400 feet by 125 feet and is located north of the security fence that runs along the north side of the former production area. It was used for training FEMP fire fighters to respond to fires in buildings, oil fires, and fires around tanks. This area includes a fire-training building, an oil-fire pond, and a metal trough containing water and oil. This location is marked as number "2" in Figure 1-11.

2.0 SITE DESCRIPTION

This section describes the important physical properties, characteristics, and previous site investigations of the FEMP and the surrounding study area.

2.1 SURFACE WATER HYDROLOGY

The major surface water features relevant to Operable Unit 5 include the Great Miami River, Paddys Run, and the SSOD.

2.1.1 Great Miami River

The FEMP is located within the Great Miami River drainage basin but above the river's present-day floodplain. The Great Miami River (Figure 2-1) receives the FEMP effluent discharge and represents the main surface water feature in the vicinity of the site. The river flows generally to the southwest and has a drainage area of approximately 3360 square miles at the Hamilton gage, which is located about ten miles upstream from the FEMP discharge outfall.

The river exhibits meandering patterns that result in sharp directional changes over distances of less than 3000 feet. Directly east of the FEMP and within the RI/FS study area, the river passes through a 180-degree curve known as the "Big Bend" (Figure 2-1). A 90-degree bend in the river also occurs near New Baltimore, approximately two miles downstream from the FEMP point of discharge.

The average discharge of the Great Miami River at Hamilton, based on 55 years of records, is 3305 cubic feet/second (ft^3/s). Using drainage area scaling, the corresponding average flow at the FEMP point of discharge has been estimated to be 3460 ft^3/s. The maximum discharge ever recorded for the Great Miami River at Hamilton occurred on March 26, 1913 and was estimated to be 352,000 ft^3/s. The maximum discharge since the construction in 1922 of five retention basins, located approximately seven miles upstream of Ross, was 108,000 ft^3/s and occurred on January 21, 1959. The ten-year flood discharge has been calculated to be 81,455 ft^3/s for the site reach. The minimum daily discharge of 155 ft^3/s was recorded on September 27, 1941. This value is approximately half of the seven-day, ten-year low flow value ($Q_{7\text{-}10}$) of 267 ft^3/s, as computed by the U.S. Geological Survey (USGS) for the Hamilton gage. This translates to 280 ft^3/s at the site reach.

2.1.2 Paddys Run

Natural surface drainage from the FEMP is primarily to Paddys Run. Paddys Run originates north of the site, drains southward along the west side of the FEMP, and eventually enters the Great Miami River approximately 1.5 miles south of the FEMP effluent discharge point (Figure 2-1). This stream loses flow to the underlying aquifer along much of its course due to its highly permeable channel bottom, which is carved through the till and into the sands and gravels of the Great Miami Aquifer.

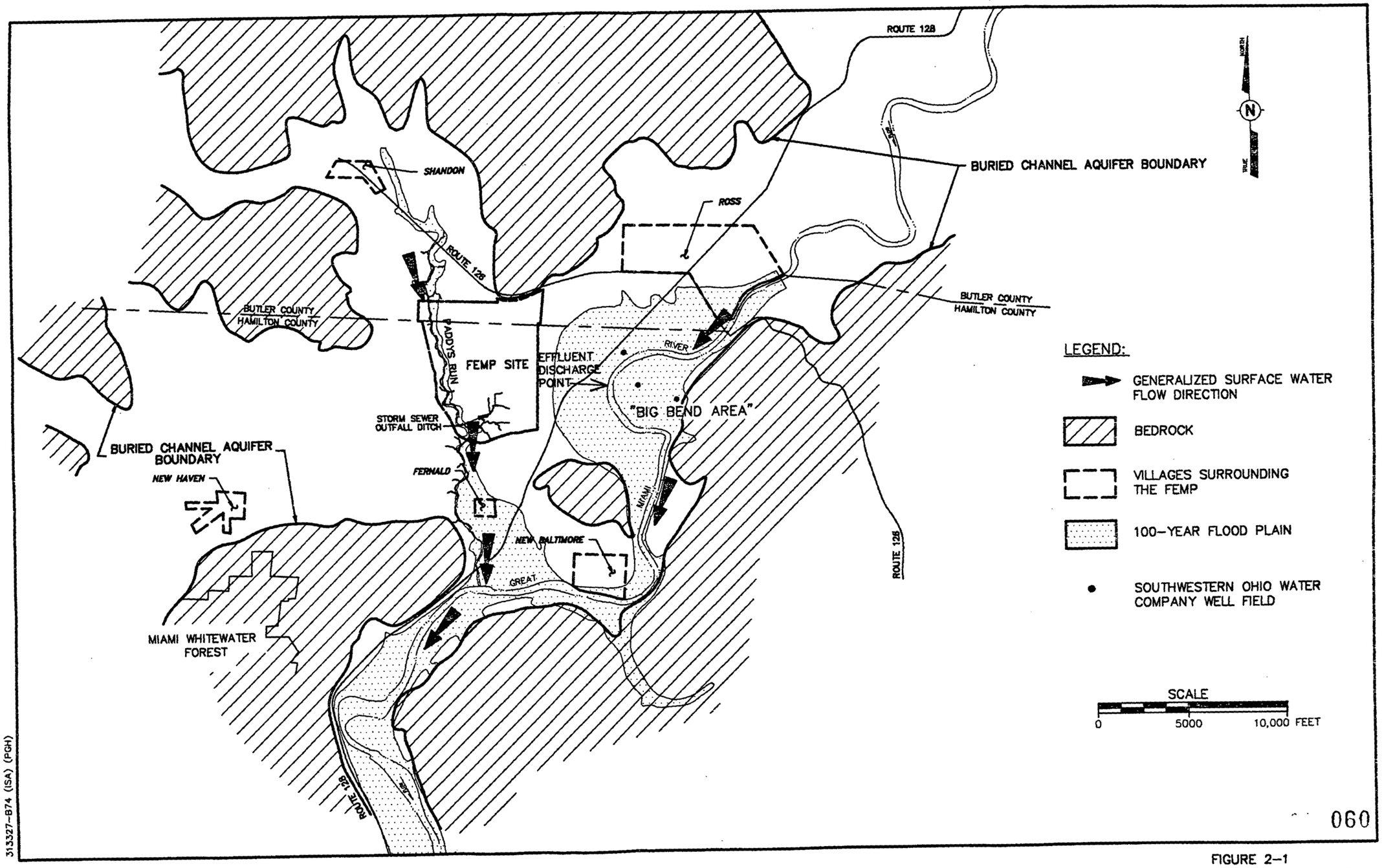


FIGURE 2-1
SURFACE WATER HYDROLOGY AND
100-YEAR FLOOD PLAIN AT THE FEMP

Paddys Run is an ungaged, intermittent stream that flows primarily between January and May, with an estimated discharge for this period ranging between 0.2 and 4.0 ft^3/s (Dames & Moore 1985a).

2.1.3 SSOD

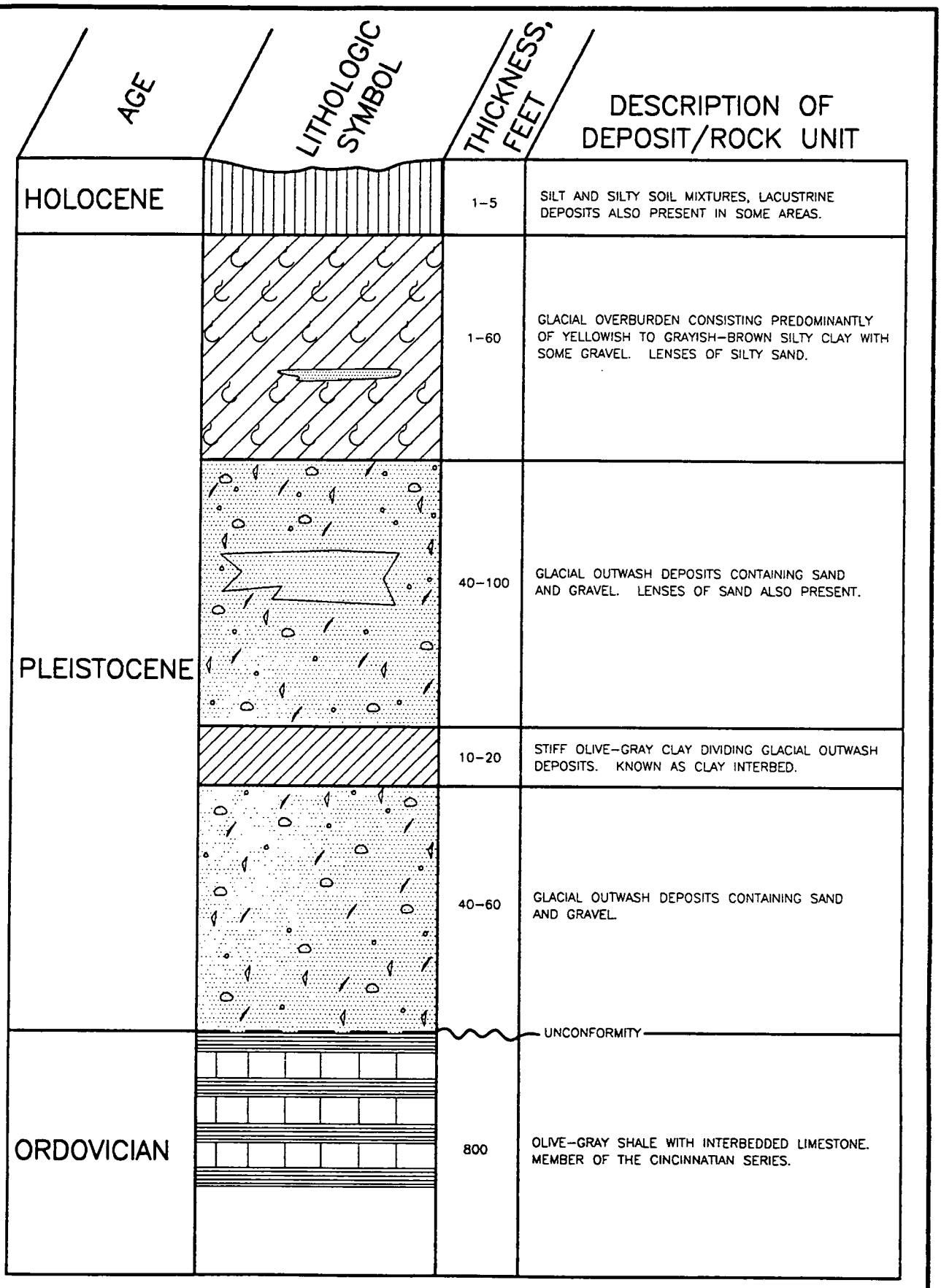
A principal drainage feature of the FEMP is a tributary to Paddys Run known as the SSOD. This drainage course originates east of the former production area, flows southwest across the southern portion of the site, and enters Paddys Run near the southwest corner of the property (Figure 2-1). Much of the stream bottom of this drainage course is composed of sand and gravel; therefore, vertical seepage rates through the stream bottom are similar to Paddys Run. This drainage course is generally dry throughout most of the year, with flows occurring during and immediately after precipitation events.

The SSOD historically conveyed surface water runoff from the former production area directly to Paddys Run when the capacity of the storm sewer lift station, which diverted low flow storm water to Manhole 175, was exceeded. A storm water retention basin was constructed at the head of the SSOD to minimize this occurrence. The first chamber of the storm water retention basin began operation in October 1986. The second chamber became operational in December 1988. Storm water runoff from the former production area is now conveyed to this retention basin. After at least a 24-hour retention period to allow for settling of suspended solids, the water is pumped out of the basin to the Great Miami River via the FEMP's main effluent line. The basin is designed to retain the runoff from a 10-year, 24-hour rainfall event. Only in the event of an overflow would storm water from the former production area enter the outfall ditch. Overflows have occurred seven times since 1986.

2.2 GROUNDWATER HYDROLOGY

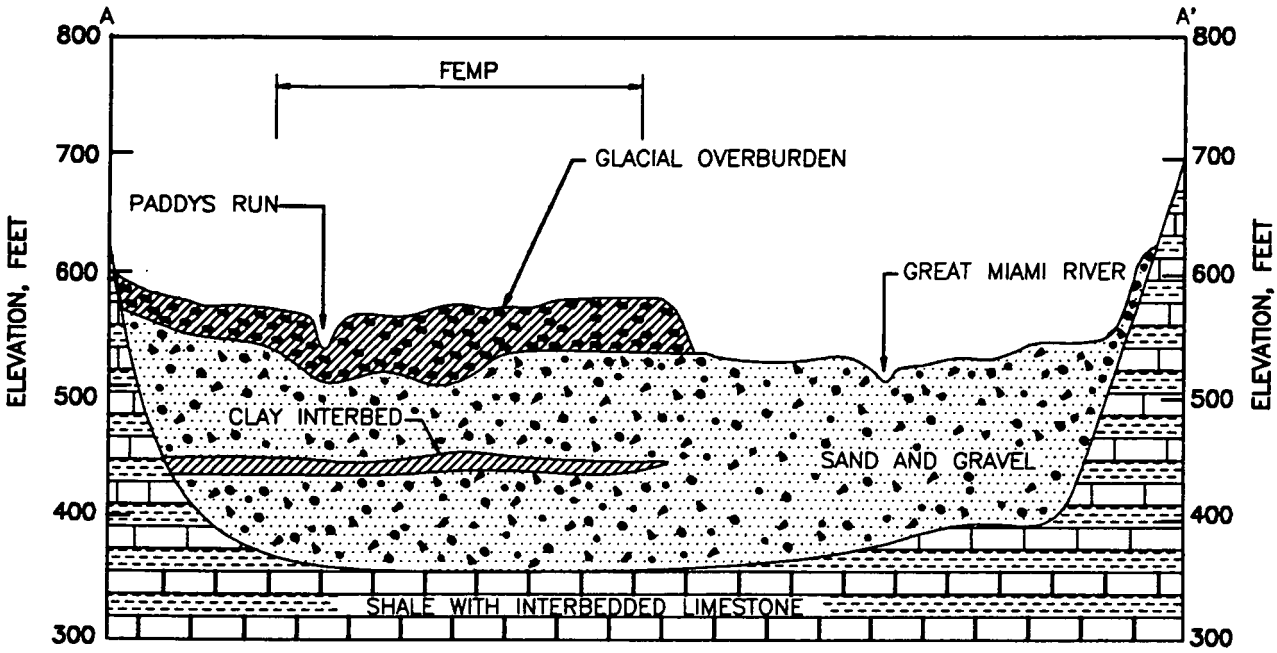
The FEMP is located within a two- to three-mile-wide buried bedrock valley known as the New Haven Trough. This valley formed as a result of river and glacial erosion and subsequently filled with glacial outwash materials and till. The bedrock in the vicinity of the FEMP consists of predominantly flat-lying, olive-gray Ordovician shales with thin, interbedded layers of limestone. This shale forms the floor and valley walls of the New Haven Trough. The buried channel is generally carved into this shale between 60 and more than 200 feet below the pre-erosional land surface in the vicinity of the FEMP.

Unconformably overlying the shales in the bedrock channel is approximately 150 feet of regionally extensive Pleistocene glacial valley fill deposits. Figure 2-2 is a generalized stratigraphic column of the valley fill deposits. As indicated by the generalized geologic cross section (Figure 2-3), the buried valley is about 1/2 to over 2 miles wide and is U-shaped, having a broad, relatively flat bottom and steep valley walls. Interbedded glacial till deposits occur within the outwash deposits, but in most



313327–A46 (IS/OUS) (PGH)

FIGURE 2–2. GENERALIZED STRATIGRAPHIC COLUMN OF THE FEMP REGION

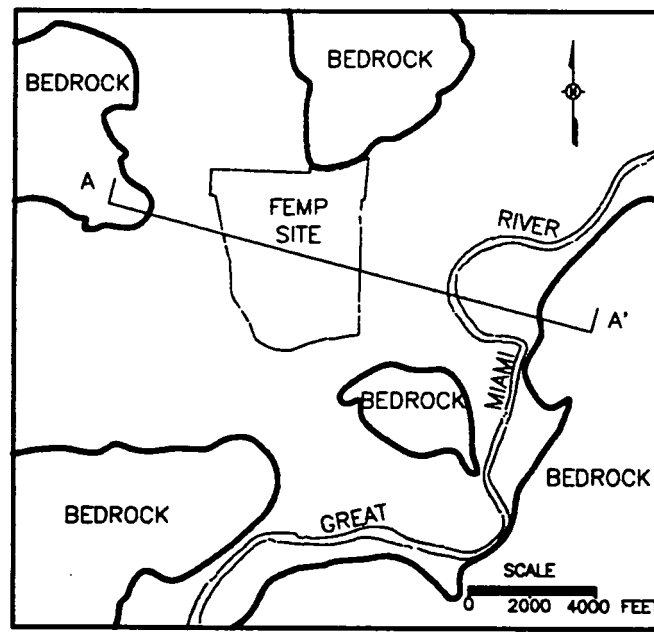


SECTION A–A' LOOKING NORTH

NOTES:

HORIZONTAL SCALE IS APPROXIMATELY 1" = 2500'

INFORMATION CONCERNING THE DEPTH AND ALTITUDE OF THE BEDROCK SHALE WAS OBTAINED FROM IT CORPORATION DRAWING 303317–8208.



LOCATION OF CROSS SECTION

313327–A47 (IS/OU5) (PGH)

FIGURE 2–3 SCHEMATIC CROSS SECTION OF BURIED CHANNEL

cases are of limited lateral extent. The till deposits are composed primarily of poorly sorted pebbles, cobbles, and boulders in a predominantly clay matrix.

In some areas, glacial till deposits overlie the bedrock uplands and portions of the outwash materials where they form the thick, unconsolidated sediment layers beneath the present soil zone. This glacial till is composed of dense, silty clay that varies in composition vertically and laterally. The glacial overburden contains lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt with layers of silty clay.

Within the glacial overburden deposits, there are numerous water-bearing zones that have limited interconnection. The majority of these zones are of glaciofluvial origin and consist of small beds of highly sorted sands and gravels. These beds are probably the result of small meltwater streams that occurred along the ice margin and within the glacier itself. Generally, these glaciofluvial interbeds are considered to be major water-bearing units within the glacial overburden. However, movement of water and contaminants within these units is minimal due to the limited extent and interconnection of these units.

Regional hydrogeologic environments of the buried channel aquifer (Great Miami Aquifer) have been investigated and reported by the USGS in a paper entitled "Groundwater Hydrology and Geology of the Lower Great Miami River Valley, Ohio" (Spieker 1968a). A hydrogeologic environment describes a portion of an aquifer possessing hydrologic and geologic properties that differ from the properties of the aquifer in adjacent areas. Five major hydrogeologic environments have been identified and mapped in the Great Miami River Valley. Types I, III, and V environments generally describe the hydrogeologic conditions in the vicinity of the FEMP and are summarized in the following paragraphs.

The Type I hydrogeological environment is found along the floodplain of the Great Miami River to the south and east of the FEMP facility. The aquifer is principally composed of sand and gravel. Scattered lenses of clay and other fine-grained material may exist anywhere in the aquifer. These lenses are not of sufficient thickness or areal extent to affect groundwater movement. The potential for infiltration from streams exists in these areas. Transmissivity values, or the amount of water that can be transmitted horizontally by the aquifer, generally range from 40,000 to 67,000 square feet per day (ft^2/day). The Type I aquifer has an estimated storage coefficient of about 0.2. Individual wells can yield as much as 3000 gpm.

The Type III hydrogeologic environment is characterized by 50 or more feet of clayey till overlying the main buried channel aquifer. In the region of the FEMP, the buried channel aquifer is further divided into an upper and lower part by a semipervious clay layer approximately 10 to 20 feet thick, occurring approximately 120 feet below land surface. Hence, the lower aquifer is classed as a

semiconfined or leaky confined aquifer. A coefficient of storage of 0.001 was estimated for the lower sand and gravel aquifer. Estimated transmissivities for the entire aquifer range from 4700 to 40,000 ft^2/day.

The Type V hydrogeologic environment includes all of the area outside of the buried channel. These areas are uplands and consist of shale with interbedded limestone overlain by 50 feet or less of clay-rich till. Large quantities of groundwater are not generally transmitted through this material. Well yields vary widely, typically ranging from near 0 to 10 gpm. However, because sand and gravel lenses are erratically distributed within the overlying till, wells completed in these units may yield up to 50 gpm.

The principal sources of recharge to the Great Miami Aquifer in the FEMP area are direct precipitation, stream infiltration, bedrock leakage, and leakage from the glacial overburden. Infiltration of rainfall and snowmelt is the dominant regional source of groundwater recharge, providing approximately 570,000 gallons per day (gpd) per square mile of catchment area, or roughly 12 inches per year (evenly distributed) to the aquifer (Dove 1961). Much of the precipitation that runs off the glacial overburden on the FEMP property enters Paddys Run and the SSOD, both of which are subject to leakage directly to the aquifer along portions of their lengths. These streams are intermittent and provide groundwater recharge on a sporadic basis.

Large pumping wells of the Southwestern Ohio Water Company (SOWC), located at the "Big Bend" meander of the Great Miami River east of the FEMP (Figure 2-1), cause a portion of the river water to infiltrate through the riverbed and recharge the aquifer (i.e., induced recharge). In other areas not influenced by pumping wells, groundwater generally flows from the aquifer to the river, except during dry periods when the elevation of the water table is below the bed of the river. Recharge to the Great Miami Aquifer from groundwater in the bedrock is limited due to the low permeability of the bedrock shales and limestones; however, small amounts of water occur in erratically distributed joints and cracks and produce seepage to the glacial deposits. The hydraulic conductivity of the shale and limestone is estimated to be low, with many bedrock wells failing to yield even gpm (Dove 1961). The leakage rate of groundwater from the bedrock valley wall into the alluvial aquifer has been estimated to be 38 gpd per lineal foot of valley wall contact with the glacial deposits (200,000 gpd per lineal mile) (Dove 1961).

The groundwater in the regional aquifer enters the FEMP vicinity from the buried valleys primarily from the west and the north. Natural gradients cause the groundwater to exit the FEMP area by either flowing to the southeast toward the Great Miami River upstream from New Baltimore or by flowing south through the branch of the bedrock channel west of New Baltimore.

The SOWC pumping wells, located in the "Big Bend" meander of the Great Miami River east of the FEMP (Figure 2-4), produce a pronounced and persistent cone of depression in the potentiometric surface centered on the pumping wells.

A groundwater elevation map (Figure 2-4) and the results of groundwater flow models indicate that the resultant cone of depression from the SOWC wells influences groundwater flow patterns beneath the FEMP. In particular, a groundwater flow divide is created such that groundwater underlying the northern portion of the FEMP, including those areas underlying the waste storage area and the former production area, flows to the east toward the SOWC wells and the Great Miami River. Groundwater from the southern and southwestern portion of the FEMP flows along the natural gradient to the south-southwest. Near the southwest corner of the FEMP, a groundwater component from the west is also present due to the western leg of the buried channel. This causes the recharge from certain reaches of Paddys Run to flow southeast until the regional southern component of flow is encountered.

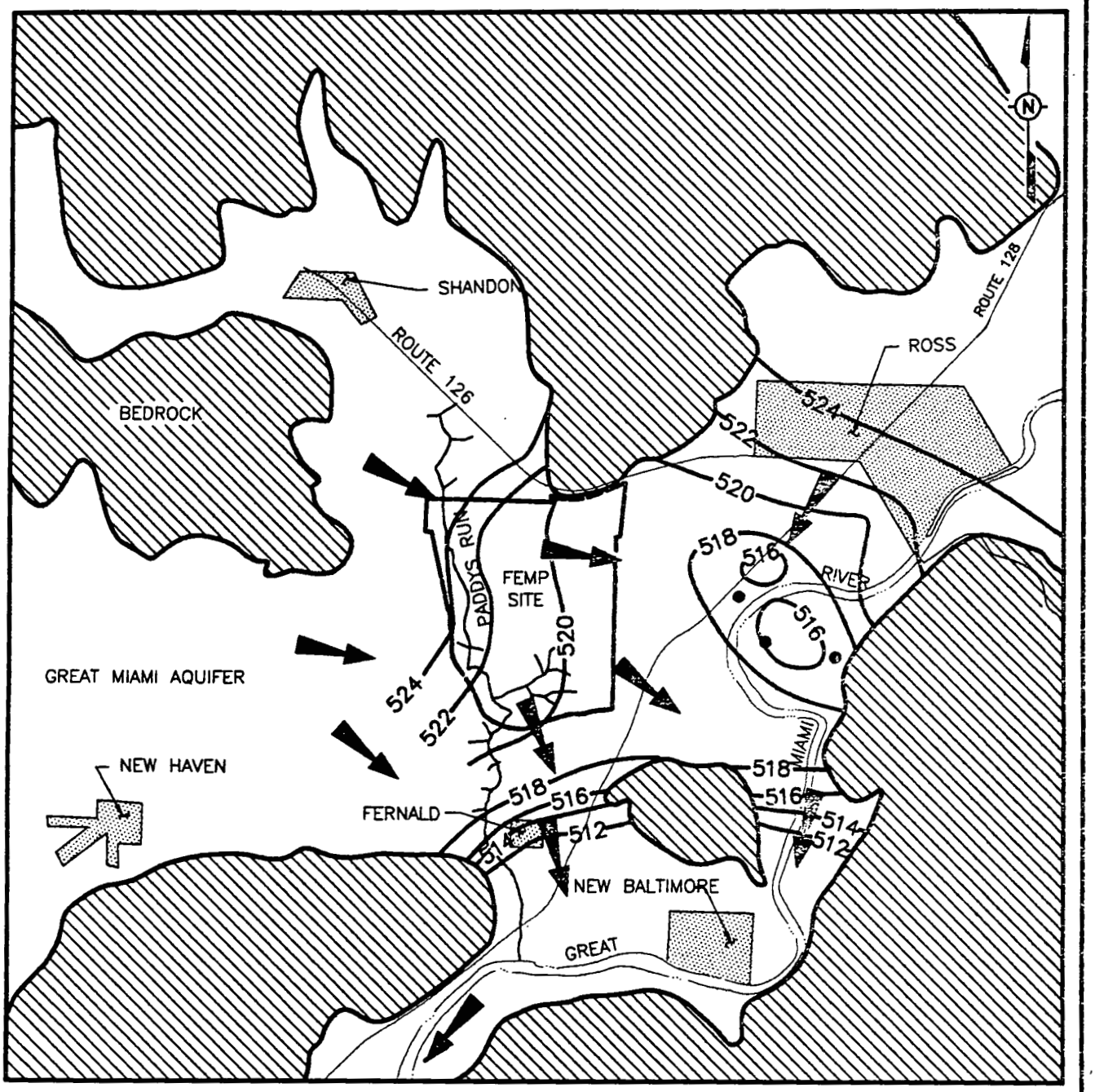
Over most of the FEMP facility, horizontal hydraulic gradients measured in the Great Miami Aquifer are about 0.00075 to 0.00100 ft/ft (4.0 to 5.3 ft/mile). Hydraulic gradients increase sharply near (1) the water-supply wells in the Big Bend area due to cones of depression caused by pumping, (2) south of the FEMP around the town of Fernald where the Great Miami Aquifer is constricted by bedrock highs, and (3) northeast of New Baltimore where the aquifer is also constricted between bedrock highs (Figure 2-4). Near the town of Fernald, the horizontal hydraulic gradient in the Great Miami Aquifer (GMA) is about 0.0027 ft/ft (14.1 ft/mile), which is roughly 3 times greater than hydraulic gradients at the FEMP.

2.3 SOILS

Soils in the region were formed in parent materials that were deposited by the action of Wisconsin and Illinoian glaciers. These materials consist mainly of glacial till, but include sand, gravel, glacial lake clays, and silt.

Three major soil associations have been mapped in the vicinity of the FEMP (Figure 2-5) by the U.S. Department of Agriculture (USDA et al., 1980, 1982): Fussell-Xenia-Wynn, Fincastle-Xenia-Wynn, and Fox-Genesee. The soils are usually light-colored, acidic, and well-drained. Many of the soils have developed on wind-blown material (loess), except along present and old river basins where the Fox-Genesee soils are of glacial till origin. The soils are moderately high in agricultural productivity and are frequently used for growing cash crops and producing livestock. Tables 2-1, 2-2, 2-3, and 2-4 give the engineering, physical, and chemical properties for the soil types found in the region of the FEMP, while Figure 2-5 is a soils map of the area.

Soils at the FEMP site are primarily categorized as Fincastle-Xenia silt loams. These soils are light colored, medium acid, and moderately high in productivity when properly managed. Moisture-



NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUNDWATER CONTOUR MAP ARE ALL COMPLETED IN THE SAND AND GRAVEL AQUIFER. HOWEVER, COMPLETION DEPTHS FOR SOME WELLS ARE UNKNOWN. IN THE VICINITY OF THE COLLECTOR WELLS, GROUNDWATER ELEVATIONS WOULD DEPEND ON COMPLETION DEPTH. DEEPER WELLS IN THE AQUIFER WOULD INDICATE LOWER WATER LEVEL ELEVATIONS BECAUSE OF VERTICAL GRADIENTS CREATED BY PUMPING AT DEPTH. THEREFORE, WATER TABLE ELEVATION CONTOURS SHOWN IN THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

2. GROUNDWATER ELEVATIONS WERE MEASURED DURING MAY 1988

3. BASED ON WATER ELEVATION MEASUREMENTS FROM MIAMI CONSERVANCY DISTRICT, MONITORING WELLS AND RI/FS WELLS.

SCALE

0 2500 5000 FEET

LEGEND:

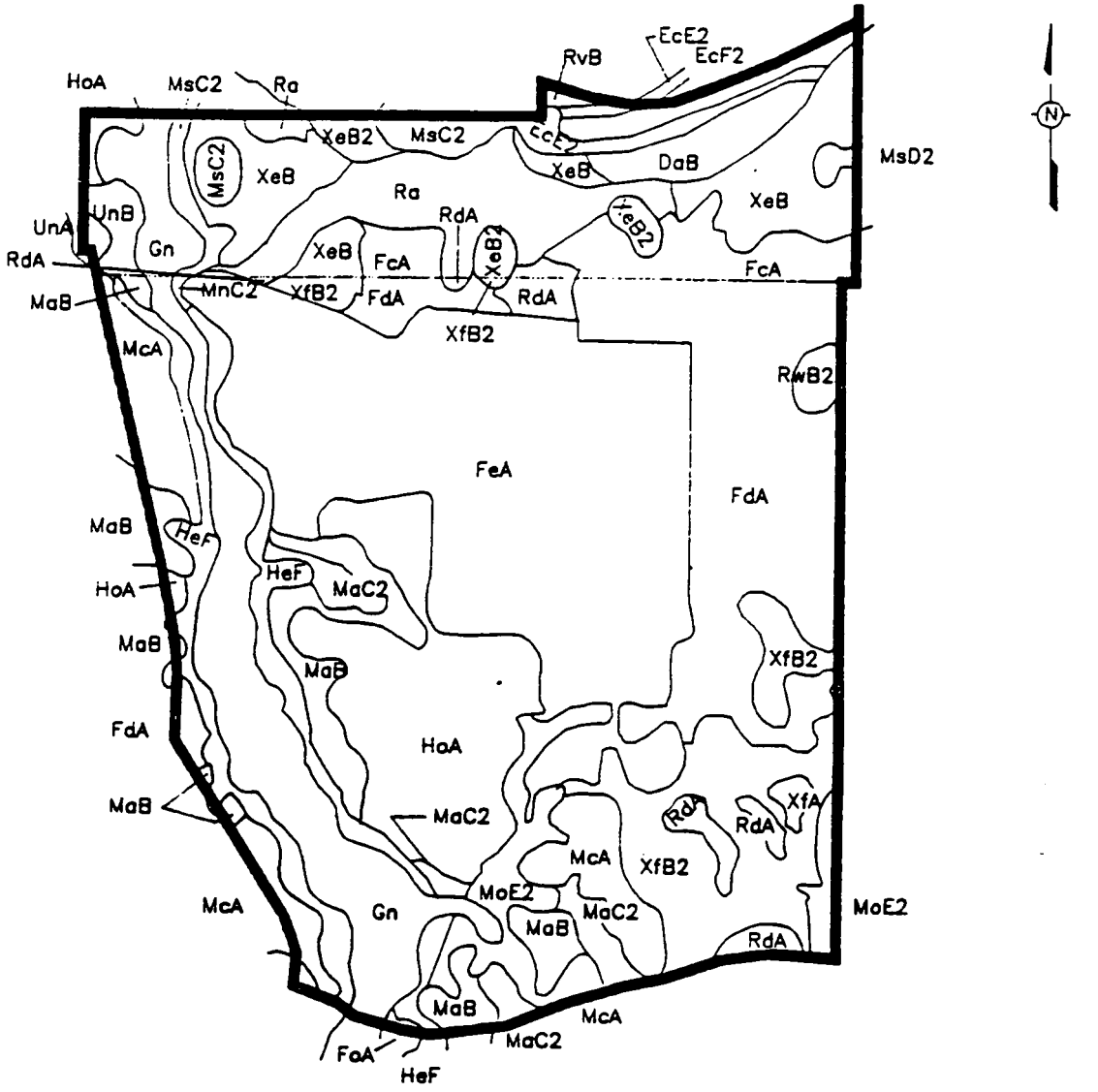
GENERALIZED GROUNDWATER FLOW DIRECTION.

BEDROCK OUTSIDE GREAT MIAMI AQUIFER

SOUTHWESTERN OHIO WATER COMPANY WELL

524 GROUNDWATER CONTOUR (FEET MSL)

FIGURE 2-4 GENERALIZED GROUNDWATER FLOW IN BURIED CHANNEL AQUIFER



LEGEND:

SOIL SYMBOL BY COUNTY

SOIL NAME	BUTLER COUNTY	HAMILTON COUNTY
DANA	DaB	N/A
EDEN	EcE2, EcF2	N/A
FINCASTLE	FcA	FdA, FeA
FOX	N/A	FoA
GENESEE	Gn	Gn
HENNEPIN	N/A	HeF
HENSHAW	HoA	HoA
MARKLAND	N/A	MaB, MaC2
MARTINSVILLE	N/A	McA
MIAMIAN	N/A	MnC2
MIAMIAN–HENNEPIN	N/A	MoE2
MIAMIAN–RUSSELL	MsC2, MsD2	N/A
RAGSDALE	Ra	N/A
RAUB	N/A	RdA
RUSSELL	N/A	RwB2
UNIONTOWN	UnA, UnB	N/A
XENIA	XeB, XeB2	XfA, XfB2

SOURCE:

USDA 1980, 1982

SCALE

0 900 1800 FEET

602A_FND56_BP_FND

FIGURE 2–5 FEMP SOIL MAP

TABLE 2-1
PHYSICAL AND CHEMICAL PROPERTIES OF BUTLER COUNTY SOILS ON THE FEMP

Soil Name and Map Symbol	Depth (Inches)	Permeability (Inches/Hr)	Available Water Capacity (Inches/Inches)	Soil Reaction pH	Shrink-Swell Potential
DaA, DaB	0-13	0.6-2.0	0.22-0.24	5.6-7.3	Low
Dana	13-40	0.6-2.0	0.18-0.20	5.1-6.0	Moderate
	40-44	0.6-2.0	0.15-0.19	6.1-7.3	Moderate
	44-60	0.2-0.6	0.05-0.19	6.6-8.4	Low
EcE2, EcF2	0-5	0.06-0.6	0.12-0.18	5.1-8.4	Moderate
Eden	5-27	0.06-0.2	0.10-0.15	5.1-8.4	Moderate
	27-40	-	-	-	-
FdA, FdB	0-8	0.6-2.0	0.22-0.24	5.1-6.5	Low
Fincastle	8-28	0.2-0.6	0.18-0.20	5.1-5.5	Moderate
	28-42	0.06-0.6	0.15-0.19	5.1-6.0	Moderate
	42-56	<0.06	0.04-0.08	7.4-8.4	Moderate
	56	-	-	-	-
Gn	0-8	0.6-2.0	0.20-0.24	6.1-7.8	Low
Genesee	8-34	0.6-2.0	0.17-0.22	6.1-8.4	Low
	34-60	0.6-20	0.19-0.21	7.4-8.4	Low
HoA	0-9	0.6-2.0	0.18-0.23	5.6-6.5	Low
Henshaw	9-50	0.2-0.6	0.15-0.19	5.1-7.3	Low
	50-60	0.2-0.6	0.17-0.22	6.6-8.4	Low
MsC2, MsD2	0-6	0.6-2.0	0.17-0.20	5.6-7.3	Low
Miamian	6-22	0.2-0.6	0.12-0.18	4.5-7.8	Moderate
	22-60	0.2-0.6	0.06-0.10	7.4-8.4	Low
RwB2	0-10	0.6-2.0	0.21-0.24	5.6-7.3	Low
Russell	10-22	0.6-2.0	0.18-0.20	4.5-6.0	Moderate
	22-36	0.6-2.0	0.15-0.19	5.6-7.3	Moderate
	36-60	0.2-0.6	0.05-0.19	7.4-8.4	Low

TABLE 2-1
(Continued)

Soil Name and Map Symbol	Depth (Inches)	Permeability (Inches/Hr)	Available Water Capacity (Inches/Inches)	Soil Reaction pH	Shrink-Swell Potential
Ra	0-12	0.6-2.0	0.21-0.23	6.1-7.3	Moderate
Ragsdale	12-50	0.06-0.2	0.18-0.20	6.1-7.3	Moderate
	50-72	0.06-0.2	0.20-0.22	6.6-8.4	Low
RdA, RdB	0-15	0.6-2.0	0.22-0.24	5.6-7.3	Low
Raub	15-37	0.06-0.2	0.18-0.20	5.1-6.5	Moderate
	37-43	0.06-0.2	0.15-0.19	6.1-7.3	Moderate
	43-60	0.06-0.6	0.05-0.19	7.4-8.4	Low
UnA, UnB	0-10	0.6-2.0	0.19-0.33	5.1-7.3	Low
Uniontown	10-49	0.6-2.0	0.18-0.22	5.1-7.8	Low
	49-66	0.2-2.0	0.18-0.22	6.6-8.4	Low
XfA, XfB, Xf2	0-10	0.6-2.0	0.22-0.24	6.6-7.3	Low
Xenia	10-31	0.2-0.6	0.18-0.20	5.1-6.0	Moderate
	31-72	0.2-2.0	0.05-0.19	7.9-8.4	Low
XfA, XfB, XfB2	0-8	0.6-2.0	0.22-0.24	6.6-7.3	Low
Xenia	8-26	0.2-0.6	0.18-0.20	5.1-6.0	Moderate
	26-42	0.2-0.6	0.15-0.19	5.1-7.3	Moderate
	42-59	0.2-0.6	0.04-0.08	7.9-8.4	Moderate
	59	-	-	-	-

Source: U.S. Department of Agriculture, Soil Conservation Service, Ohio Department of Natural Resources, Division of Lands and Soil, and Ohio Agricultural Research and Development Center, 1980, "Soil Survey of Butler County, Ohio," USDA, ODNR, and Ohio Agricultural Research and Development Center, n.p.

TABLE 2-2
ENGINEERING PROPERTIES AND CLASSIFICATIONS OF BUTLER COUNTY SOILS ON THE FEMP

Soil Name and Map Symbol	Depth (Inches)	USDA Texture	Unified Classification Symbol	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit (Pct)	Plasticity Index
DaA, DaB	0-13	Silty loam	CL	100	100	95-100	85-95	30-35	8-12
Dana	13-40	Silty clay loam	CL	100	100	95-100	85-98	38-50	20-32
	40-44	Clay loam	CL	90-100	90-95	80-90	65-75	37-50	17-30
	44-60	Loam	CL, ML, CL-ML	85-95	80-90	75-85	50-65	17-30	2-14
EcE2, EcF2	0-5	Silty clay loam	ML, CL	85-100	80-100	75-100	70-100	35-65	12-35
Eden	5-27	Flaggy silty clay, flaggy clay, silty clay	MH, CH	75-100	70-100	65-100	60-100	-	-
	27-40	Weathered bedrock	MH, CH, CL	-	-	-	-	45-75	20-45
FdA, FdB	0-8	Silt loam	CL, ML	100	95-100	90-100	75-93	27-36	4-12
Fincastle	8-28	Silty clay loam	CL, CH	100	100	95-100	85-95	38-54	20-32
	28-42	Silty clay loam, clay loam	CH, CL	95-100	90-98	85-95	75-85	45-58	30-38
	42-56	Flaggy clay loam	CL	85-95	75-90	70-85	55-75	30-50	15-35
	56	Weathered bedrock	-	-	-	-	-	-	-
Gn	0-8	Loam	ML, CL	100	100	90-100	75-85	26-40	3-15
Genesee	8-34	Silty loam, loam	ML, CL	100	100	90-100	75-85	26-40	3-15
	34-60	Stratified sandy loam to silt loam	ML, CL	90-100	85-100	60-80	50-70	26-40	3-15
HoA	0-9	Silt loam	ML, CL, CL, ML	95-100	95-100	90-100	80-100	25-35	3-10
Henshaw	9-50	Silty clay loam, silt loam	CL, ML	95-100	95-100	95-100	85-100	30-40	8-18
	50-60	Silt loam, silty clay loam	ML, CL, CL-ML	95-100	90-100	85-100	75-100	25-40	5-15
MsC2, MsD2;	0-6	Silt loam	ML	95-100	95-100	90-100	70-95	26-40	4-12
Miamian	6-22	Silty clay loam, clay loam, clay	CL	85-100	80-100	75-95	70-85	32-50	15-30
	22-60	Loam, silt loam	CL, ML, CL-ML	75-95	75-90	65-85	50-75	20-35	3-13
RwB2	0-10	Silt loam	CL, CL-ML	100	95-100	80-100	50-90	20-35	5-15
Russell	10-22	Silty clay loam, silt loam	CL	100	100	95-100	85-95	35-50	20-35
	22-36	Clay loam, loam	CL	90-100	90-95	80-90	65-75	35-50	17-31
	36-60	Loam, clay loam	CL, ML CL-ML	85-95	80-90	75-85	50-65	<30	2-14
Ra	0-12	Silty clay loam	CL	100	100	90-100	80-100	35-50	15-30
Ragsdale	12-50	Silty clay loam	CL	100	100	90-100	80-95	35-50	15-30
	50-72	Silt loam	CL, CL-ML	100	100	90-100	70-90	25-35	5-15

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TABLE 2-2
(Continued)

Soil Name and Map Symbol	Depth (Inches)	USDA Texture	Unified Classification Symbol	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit (Pct)	Plasticity Index
RdA, RdB	0-15	Silt loam	CL, CL-ML	100	100	90-100	75-95	25-35	5-15
Raub	15-37	Silty clay loam	CL, CH	100	100	95-100	80-95	35-55	20-35
	37-43	Clay loam, silty clay loam	CL	95-100	90-100	85-95	60-85	35-50	15-25
	43-60	Loam, clay loam	CL, ML SC, SM	85-95	80-90	70-85	40-65	15-30	NP-15
UnA, UnB	0-10	Silt loam	ML, CL-ML	100	95-100	90-100	80-100	25-35	2-10
Uniontown	10-49	Silt loam, silty clay loam	CL, ML	100	95-100	90-100	85-100	30-45	7-20
	49-66	Silt loam, silty clay loam	ML, CL	90-100	90-100	85-100	75-100	30-45	7-20
XeA, XeB, XeB2	0-10	Silt loam	CL, CL-ML	100	100	90-100	70-100	25-35	5-15
Xenia	10-31	Silty clay loam	CL	100	100	90-100	80-95	35-50	15-30
	31-72	Loam, clay loam	CL, ML SC, SM	85-95	80-90	75-90	40-65	25-30	NP-15
XfA, Xf2B, XfB2	0-8	Silt loam	CL, CL-ML	100	100	90-100	70-100	25-35	5-15
Xenia	8-26	Silty clay loam	CL	100	100	90-100	80-95	35-50	15-30
	26-42	Clay loam, silty clay loam	CL	92-100	90-95	75-95	65-75	35-50	15-30
	42-59	Stoney clay loam	CL	85-95	75-90	70-85	55-75	30-50	15-35
	59	Weathered bedrock	-	-	-	-	-	-	-

The symbol < means less than; > means more than. Absence of any entry indicates that data were not estimated.

Source: U.S. Dept. of Argiculture, Soil Conservation Service, Ohio Dept. of Natural Resources, Division of Lands and Soil, and Ohio Agricultural Research and Development Center, 1980, "Soil Survey of Butler County, Ohio," USDA, ODNR, and Ohio Argicultural Research and Development Center, n.p.

TABLE 2-3
PHYSICAL AND CHEMICAL PROPERTIES OF HAMILTON COUNTY SOILS ON THE FEMP

Soil Name and Map Symbol	Depth (Inches)	Moist Bulk Density (g/cm^3)	Permeability (Inches/Hr)	Available Water Capacity Inches/Inches	Shrink-Swell Potential
EpA, EpB2, EpC2	0-7	1.30-1.50	0.6-2.0	0.18-0.22	Low
Eldean	7-36	1.40-1.60	0.2-2.0	0.08-0.14	Moderate
	36-60		>6.0	0.01-0.04	Low
FdA	0-8	1.40-1.55	0.6-2.0	0.22-0.24	Low
Fincastle	8-33	1.45-1.65	0.2-0.6	0.18-0.20	Moderate
	33-42	1.45-1.65	0.2-0.6	0.15-0.19	Moderate
	42-70	1.55-1.90	0.06-0.2	0.05-0.19	Low
FeA	0-8	1.40-1.55	0.6-2.0	0.22-0.24	Low
Fincastle	8-33	1.45-1.65	0.2-0.6	0.18-0.20	Moderate
	33-42	1.45-1.65	0.2-0.6	0.15-0.19	Moderate
	42-70	1.55-1.90	0.06-0.2	0.05-0.19	Low
Gn	0-9	1.30-1.50	0.6-2.0	0.20-0.24	Low
Genesee	9-35	1.30-1.50	0.6-2.0	0.17-0.22	Low
	35-60	1.30-1.50	0.6-2.0	0.19-0.21	Low
HeF	0-2	1.20-1.40	0.6-2.0	0.18-0.24	Low
Hennepin	1-12	1.30-1.60	0.2-2.0	0.14-0.22	Low
	12-60	1.45-1.70	0.06-0.6	0.07-0.11	Low

TABLE 2-3
(Continued)

Soil Name and Map Symbol	Depth (Inches)	Moist Bulk Density (g/cm^3)	Permeability (Inches/Hr)	Available Water Capacity Inches/Inches	Shrink-Swell Potential
EpA, EpB2, EpC2	0-7	1.30-1.50	0.6-2.0	0.18-0.22	Low
HoA	0-8	1.20-1.40	0.6-2.0	0.18-0.23	Low
Henshaw	8-44	1.20-1.40	0.2-0.6	0.15-0.19	Low
	44-66	1.20-1.40	0.2-0.6	0.17-0.22	Low
MaB, MaC2, MaD2, MaE2	0-10	1.35-1.50	0.2-0.6	0.18-0.23	Moderate
Markland	10-33	1.55-1.70	0.06-0.2	0.11-0.13	High
	33-60	1.55-1.70	0.06-0.2	0.09-0.11	High
McA, McB	0-9	1.30-1.45	0.6-2.0	0.20-0.24	Low
Martinsville	9-34	1.40-1.60	0.6-2.0	0.17-0.20	Moderate
	34-44	1.40-1.60	0.6-2.0	0.12-0.14	Low
	44-60	1.50-1.70	0.6-2.0	0.19-0.21	Low
MoD2, MoE2	0-6	1.30-1.50	0.6-2.0	0.17-0.20	Low
Miamian	6-24	1.45-1.70	0.2-0.6	0.12-0.18	Moderate
	24-60	1.60-1.82	0.2-0.6	0.06-0.10	Low
RwB2	0-7	1.30-1.45	0.6-2.0	0.21-0.24	Low
Russell	7-22	1.40-1.60	0.6-2.0	0.18-0.20	Moderate
	22-43	1.40-1.60	0.6-2.0	0.15-0.19	Moderate
	43-72	1.60-1.80	0.6-2.0	0.05-0.19	Low

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TABLE 2-3
(Continued)

Soil Name and Map Symbol	Depth (Inches)	Moist Bulk Density (g/cm^3)	Permeability (Inches/Hr)	Available Water Capacity Inches/Inches	Shrink-Swell Potential
EpA, EpB2, EpC2	0-7	1.30-1.50	0.6-2.0	0.18-0.22	Low
XfA, XfB2	0-9	1.40-1.55	0.6-2.0	0.22-0.24	Low
Xenia	9-26	1.45-1.65	0.2-0.6	0.18-0.20	Moderate
	26-46	1.45-1.65	0.2-0.6	0.15-0.19	Moderate
	46-72	1.55-1.90	0.2-2.0	0.05-0.19	Low

Source: U.S. Department of Agriculture, Soil Conservation Service, Ohio Department of Natural Resources, Division of Lands and Soil, and Ohio Agricultural Research and Development Center, 1982, "Soil Survey of Hamilton County, Ohio," USDA, ODNR, and Ohio Agricultural Research and Development Center, n.p.

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TABLE 2-4

ENGINEERING INDEX PROPERTIES OF HAMILTON COUNTY SOILS ON THE FEMP

Soil Name and Map Symbol	Depth (Inches)	USDA Texture	Unified Classification Symbol	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit (Pct)	Plasticity Index
EpA, EpB2, EpC2	0-7	Loam	ML, CL-ML, CL	85-100	80-100	70-100	55-90	20-40	4-14
Eldean	7-36	Clay, clay loam, gravelly clay loam	CL, ML	75-100	60-100	55-95	50-80	38-50	12-23
	36-60	Stratified sand to gravel	GM, SM, GP-GM, SP-SM	30-70	20-50	5-40	0-35	-	NP
FdA	0-8	Silt Loam	CL, ML	100	95-100	90-100	75-93	27-36	4-12
Fincastle	8-33	Silty clay loam, silt loam	CL, CH	100	100	95-100	85-95	38-54	20-32
	33-42	Clay loam, loam, silty clay loam	CH, CL	95-100	90-98	85-95	75-85	45-58	30-38
	42-70	Loam, clay loam	CL, ML CL-ML	88-96	82-90	70-86	50-66	20-35	3-12
FeA	0-8	Silt loam	CL, ML	100	95-100	90-100	75-93	27-36	4-12
Fincastle	8-33	Silty clay loam, silt loam	CL, CH	100	100	95-100	85-95	38-54	20-32
	33-42	Clay loam, loam, silty clay loam	CH, CL	95-100	90-98	85-95	75-85	45-58	30-38
	42-70	Loam, clay loam	CL, ML, CL-ML	88-96	82-90	70-86	50-66	20-35	3-12
Gn	0-9	Loam	ML, CL	100	100	90-100	75-90	26-40	3-15
Genesee	9-35	Silt loam, loam	ML, CL	100	100	90-100	75-90	26-40	3-15
	35-60	Stratified sandy loam to silt loam	ML, CL, CL-ML	90-100	85-100	60-90	50-90	20-35	3-15
HeF	0-2	Silt loam	CL, CL-ML	90-100	85-100	70-100	60-95	25-40	5-20
Hennepin	2-12	Loam, sandy loam, silt loam	SC, SM-SC CL, CL-ML	85-100	80-100	65-100	35-95	20-50	5-25
	12-60	Loam, sandy loam, clay loam	SC, SM-SC	85-100	80-100	65-100	35-95	20-50	5-25

TABLE 2-4
(Continued)

Soil Name and Map Symbol	Depth (Inches)	USDA Texture	Unified Classification Symbol	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit (Pct)	Plasticity Index
HoA	0-8	Silt loam	ML, CL, CL-ML	95-100	95-100	90-100	80-100	20-35	3-10
Henshaw	8-44	Silty clay loam, silt loam	CL, ML	95-100	95-100	95-100	85-100	30-40	8-18
	44-66	Silt loam, silty clay loam	ML, CL, CL-ML	95-100	90-100	85-100	75-100	25-40	5-15
MaB, MaC2, MaD2, MaE2	0-10	Silty clay loam	CL, CH	100	100	95-100	85-95	35-55	20-35
Markland	10-33	Silty clay, clay, silty clay loam	CL, CH	100	100	95-100	90-95	45-60	25-35
	33-60	Stratified clay to silt loam	CL, CH	100	100	90-100	75-95	35-60	20-35
McA, McB	0-9	Silt loam	CL, CL-ML	100	90-100	80-100	60-90	22-33	4-12
Martinsville	9-34	Clay loam, silty clay loam, sandy clay loam	CL, SC	100	90-100	65-90	40-90	20-35	8-20
	34-44	Sandy loam, sandy clay loam, loam	SM, MLA-4	100	90-100	60-80	30-60	30-40	2-8
	44-60	Stratified sand to loam	CL, SC, CL-ML SM-SC	95-100	85-100	80-95	40-60	<25	4-9
MoD2, MoE2	0-6	Silt loam	ML	95-100	95-100	90-100	70-95	26-40	4-12
Miamian	6-24	Silty clay loam, clay loam, clay	CL	95-100	80-100	75-95	70-85	32-50	15-30
	24-60	Loam, clay loam	CL, ML, CL-ML	75-95	75-90	65-85	50-75	20-35	3-13
RwB2	0-7	Silt loam	CL, CL-ML	100	95-100	80-100	50-90	20-35	5-15
Russell	7-22	Silty clay loam, silt loam	CL	100	100	95-100	85-95	35-50	20-35
	22-43	Clay loam, loam	CL, ML, CL-ML	90-100	90-95	80-90	65-75	35-50	17-31
	43-72	Loam, clay loam	CL, ML, CL-ML	85-95	80-90	75-85	50-65	<30	2-14

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TABLE 2-4
(Continued)

Soil Name and Map Symbol	Depth (Inches)	USDA Texture	Unified Classification Symbol	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit (Pct)	Plasticity Index
XfA, XfB2	0-9	Silt loam	CL, CL-ML	100	100	90-100	70-100	25-35	5-15
Xenia	9-26	Silty clay loam	CL	100	100	90-100	80-95	35-50	15-30
	26-46	Clay loam	CL	92-100	90-95	75-95	65-75	35-50	15-30
	46-72	Loam	CL, ML, SC, SM	85-95	80-90	75-90	40-65	15-30	NP-15

Source: U.S. Department of Agriculture, Soil Conservation Service, Ohio Department of Natural Resources, Division of Lands and Soil, and Ohio Agricultural Research and Development Center, 1982, "Soil Survey of Hamilton County, Ohio", USDA, ODNR, and Ohio Agricultural Research and Development Center, n.p.

supplying capacity is moderate, as are fertility and organic content. The soils have formed in 18 to 40 inches of wind-blown silt (loess) over limy loam till. In areas where Fincastle soils are predominant, artificial drainage is required for moderate crop productivity. If artificial drainage is not used, the water table remains high for extended periods in winter and spring. Fincastle-Xenia soils also cover large areas west of the FEMP.

Prior to development of the FEMP, soils of the former production area consisted primarily of Fincastle silt loams. Fincastle soils are characterized by low permeability, moderate productivity, seasonal wetness, and low soil strength. Due to former production area development, native soils have been covered by introduced gravels, paving materials, and facilities. Areas that are currently planted with grasses and maintained as lawns or buffer zones tend to represent native Fincastle soils.

Soils along Paddys Run are categorized as Fox-Genesee loams. These soils are light colored, highly productive, moderately fertile, and contain moderate amounts of organic matter. Fox soils are slightly to medium acid, moderate in moisture-supplying capacity, and well drained. They have formed in 24 to 40 inches of silty materials over sand and gravel on level areas of the first terrace above the stream's normal floodplain. Fox-Genesee soils are well drained, high in moisture-supplying capacity, and are subject to flooding.

2.4 ECOLOGY

The following ecological data have been summarized from the report, "Biological and Ecological Site Characterization of the Feed Materials Production Center" (Facemire et al., 1990). Additional source documents are appropriately cited in the text.

The FEMP lies in the Oak-Hickory Forest Section of the Eastern Deciduous Forest as described by Bailey (1978). Habitat types identified, and the percentage of the total FEMP area represented by each, are ungrazed pastures (30 percent), grazed pastures (25 percent), deciduous woodlands (20 percent), riparian woodlands (12 percent), two pine plantations (11 percent), and a reclaimed flyash pile area (2 percent). Each of these habitats supports a distinct ecological community. A total of 47 species of trees and shrubs, 190 species of herbaceous plants, 20 mammal species, 98 bird species, 10 species of amphibians and reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates have been recorded from these habitats (Facemire et al., 1990).

Typical grasses found on the FEMP are red fescue, Kentucky bluegrass, timothy, and red top. Herbs include teasel, red and white clovers, and goldenrod. The dominant tree species in the pine plantations are white pine and Austrian pine, with Norway spruce occurring occasionally. Common trees in the deciduous woodlands are white ash, American elm, shellbark hickory, and slippery elm. Dominant tree species in the riparian woodlands are eastern cottonwood, hackberry, American elm, and box

elder. The reclaimed flyash pile area is dominated by American elm, eastern cottonwood, and black locust.

Mammal species observed on the FEMP include white-tailed deer, coyote, red fox, opossum, raccoon, groundhog, eastern cottontail, fox squirrel, and several species of bats. Common small mammals are the white-footed mouse, short-tailed shrew, meadow vole, meadow jumping mouse, and eastern chipmunk.

The most common birds breeding on site include the mourning dove, American robin, blue jay, American crow, American goldfinch, northern bobwhite, and common grackle. Species occurring in the greatest density are the goldfinch, song sparrow, and robin. Raptor species observed on site are the northern harrier, red-shouldered hawk, Cooper's hawk, red-tailed hawk, and American kestrel. The eastern screech owl and great horned owl are also common.

Amphibians and reptiles that occur on the FEMP include the American toad, spring peeper, eastern box turtle, and snapping turtle. Several species of snakes also occur on site, including the eastern garter snake, Butler's garter snake, black rat snake, northern water snake, and the queen snake.

Approximately 130 insect families from 15 orders are represented in FEMP habitats. Leaf hoppers are abundant in all habitats. Other common or regularly seen groups include short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

Forested jurisdictional wetlands as defined by the Federal Interagency Committee for Wetland Delineation (FICWD 1989) occupy approximately 50 acres north of the former production area. Emergent jurisdictional wetlands are found in areas along the railroad on the north side of the FEMP and in several drainageways. These wetlands are defined as areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. These habitats harbor small fish, amphibians, and a variety of benthic macroinvertebrates. The most common fish in Paddys Run are the bluntnose minnow, creek chub, and stoneroller minnow. The most common benthic macroinvertebrates are nonbiting midges, riffle beetles, mayflies, and stoneflies.

No federally listed threatened or endangered species were observed on the FEMP or in its immediate vicinity by Facemire et al. (1990). One species of mammal, the Indiana bat (Myotis sodalis), is listed as federally endangered and occurs in Butler and Hamilton Counties (ODNR, 1974). Surveys were conducted as part of the RI/FS at the FEMP to determine the distribution and presence of the Indiana bat and to identify potential habitat on the FEMP and in the immediate vicinity. The Indiana bat was not observed within the FEMP boundaries, but a breeding population was discovered on Banklick

Creek, a tributary to the Great Miami River, near Ross, Ohio (Figure 2-6). Habitats within the study area ranged from good to poor. Very little habitat was considered excellent, because of the lack of dead trees suitable for bat colonies. Of the habitat along the Great Miami River, 1 percent was classified as excellent, 19 percent good, 43 percent fair, and 40 percent poor. Most of the good habitat in the area was identified in the northern portion of the study area near Ross, Ohio. The habitat along Paddys Run was somewhat better, 4 percent rated excellent, 23 percent good, 54 percent fair, and 19 percent poor. However, no Indiana bats were captured or detected in the Paddys Run area using mist nets and an ultrasonic bat detector.

The running buffalo clover (Trifolium stoloniferum) is a federally endangered plant species that has been observed in the vicinity of the FEMP in the Miami Whitewater Forest. This species was not identified during the detailed FEMP plant species list compiled by Miami University during 1986 and 1987 (Facemire et al., 1990). In addition, this species has not been observed during recent RI/FS ecological surveys conducted for the Engineered Waste Management Facility of pasture grasslands in the northeastern corner of the FEMP and in meadows near the south pine plantation. Although this species has not been observed at the FEMP, it can be spread by grazing animals (e.g., cows), and annual surveys of the FEMP property have been proposed for the month of June, when the clover should be in bloom. Additional future surveys will be planned when wooded or pasture lands are to be cleared during the course of FEMP remedial actions.

Cincinnati crayfish (Orconectes sloanii) were collected in Paddys Run during the studies by Facmire et al. (1990). Historically, this crayfish has been collected primarily in tributaries of the Great Miami River system south of the confluence of Greenville Creek. Factors currently affecting the Cincinnati crayfish include urban development, stream impoundment, siltation, pollution, and competition with other crayfish species, particularly O. rusticus, which is also found in Paddys Run.

The cobblestone tiger beetle (Cicendela margipennis), which is under review by the U.S. Fish and Wildlife Service for possible inclusion in threatened or endangered species lists, was identified during the Indiana bat survey on a gravel bar in the Great Miami River two miles west-southwest of the bridge at New Baltimore, Ohio.

Three raptors, the red shouldered hawk (Buteo lineatus), Cooper's hawk (Accipiter cooperii), and northern harrier (Circus cyaneus), are listed as "Rare Species of Native Ohio Wild Animals" (Ohio Department of Natural Resources)[ODNR] 1982), and have been observed at the FEMP (Facemire et al., 1990). The Cooper's hawk is considered an uncommon, but regular breeding species in the Cincinnati vicinity (Cincinnati Nature Center 1978) and a threatened breeding species in Ohio (ODNR 1982). This species was frequently observed during the summer over the pine plantations and pastures throughout the FEMP (Facemire et al. 1990), and is considered an uncommon to common fall migrant

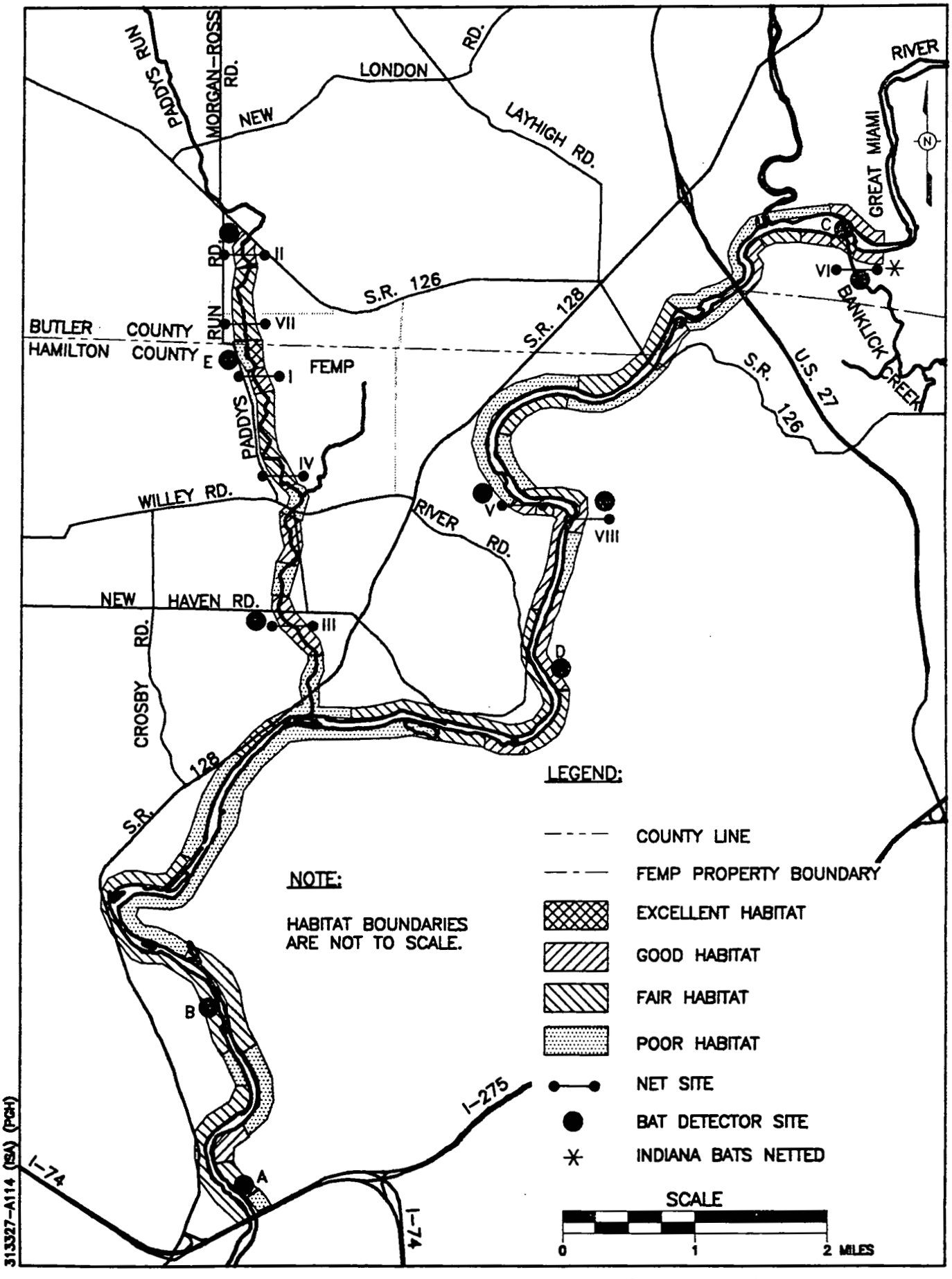

FIGURE 2-6 INDIANA BAT SAMPLING SITES AND HABITAT EVALUATION AT THE FEMP AND VICINITY

and winter resident in Ohio (Trautman and Trautman 1968). The northern harrier is listed as state endangered by the ODNR, Division of Wildlife (Order 1501:31-23-01).

Ohio populations of the cave salamander (Eurycea lucifuga), an amphibian species recognized as endangered, are limited to Butler, Hamilton, and Adams Counties (ODNR 1974). Reported locations of the cave salamander in the FEMP vicinity include the Mount Airy Forest, Grosbeck, one mile northeast of New Baltimore, Sheits Road near Blue Rock Road (ODNR 1986), and Miami Whitewater Forest. Surveys were conducted as part of the RI/FS to determine the distribution of the cave salamander and to identify potential habitat on the FEMP and in the immediate vicinity. The cave salamander was not observed within FEMP boundaries, but individuals were located near New London Road north of the FEMP and within the boundaries of Camp Ross trails northeast of the FEMP (Figure 2-7). Marginal habitat was identified along Paddys Run within the FEMP. Good to excellent habitat occurs in the vicinity of New London Road, New Haven Road, Camp Ross Trails, and Camp Fort Scott.

2.5 DEMOGRAPHY AND LAND USE

The land use surrounding the FEMP is mainly agricultural, including dairy, beef, corn, and soy bean production. Several industries, including Delta Steel, Albright & Wilson Americas, Inc., Ruetgers-Nease Chemical Company, a commercial gravel operation, a prefabricated building manufacturer, and a cement plant are located within two miles of the site. The Miami Whitewater Forest, a Hamilton County park, is located five miles to the southwest of the FEMP.

Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the FEMP. Downtown Cincinnati is approximately 18 miles southeast of the FEMP and the cities of Hamilton and Fairfield are 6 to 8 miles to the northeast. Based on the 1990 census results, there is an estimated population of over 22,927 within a 5-mile radius of the center of the FEMP (DOE 1992a).

The area surrounding the FEMP contains several sites of historical interest. The National Register of Historic Places lists five prehistoric Indian sites within a 3-mile radius. These include the Adena Circle, the Hogen-Borger Mound, the Demoret Mound, the Colerain Work, and the Dunlap Work. The closest site, the Colerain Work, is about one mile east of the FEMP. The State Historical Preservation Officer reports that there are no known sites of archaeological significance on the FEMP.

2.6 AMBIENT AIR

2.6.1 Regional Air Quality

The FEMP is located in a four-county area under the air quality responsibility of the Southwestern Ohio Air Pollution Control Agency (SWOAPCA). The state of Ohio, as represented by SWOAPCA,

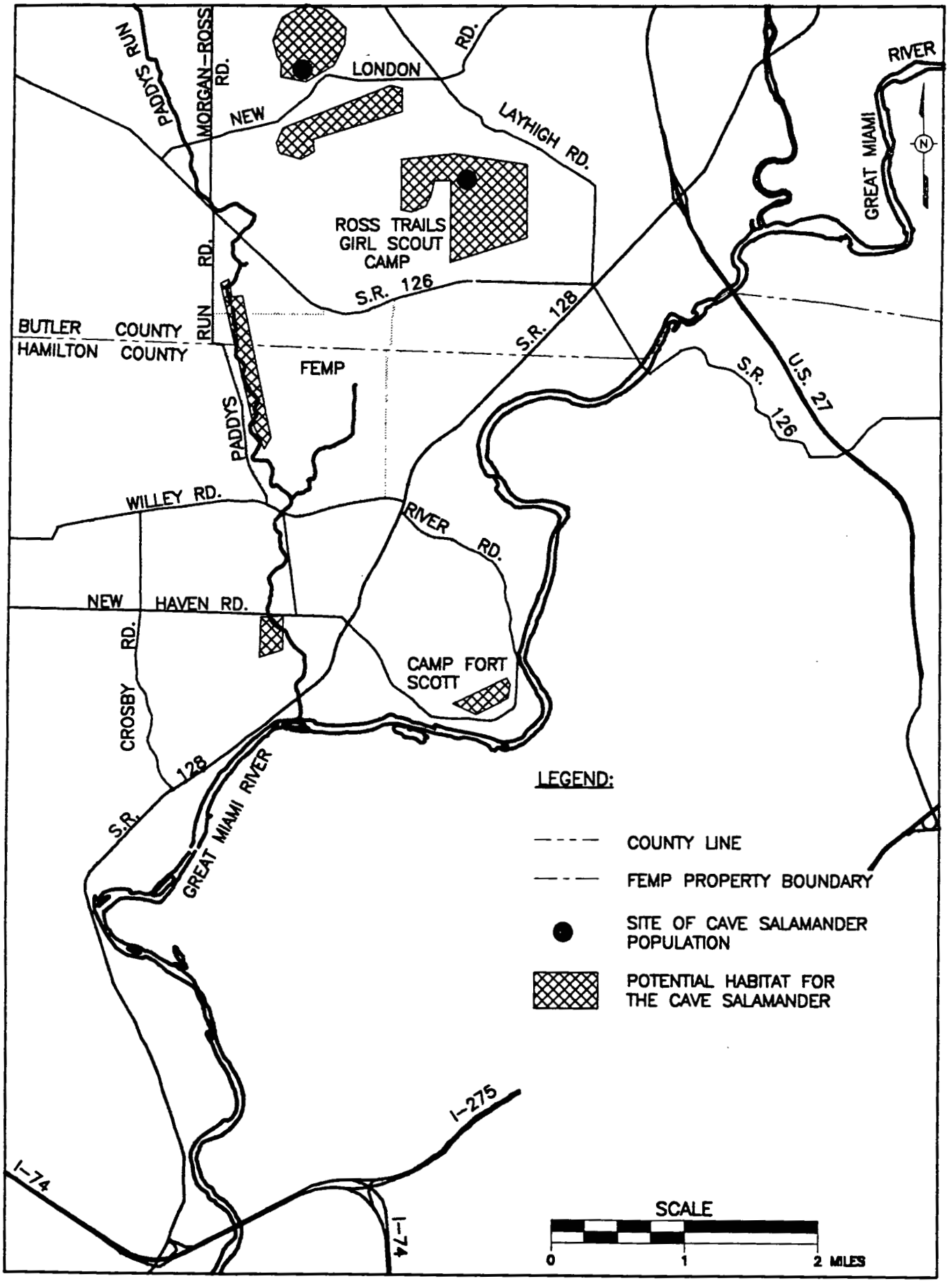

FIGURE 2-7 POPULATION LOCATIONS AND POTENTIAL HABITAT FOR THE CAVE SALAMANDER IN THE VICINITY OF THE FEMP

has adopted verbatim the National Ambient Air Quality Standards (NAAQS). There are no additional state or local ambient air quality standards. The NAAQS contain standards for the following six criterion pollutants: total suspended particulates (TSP), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), and lead (Pb). The region is in compliance for all pollutants except ozone, for which it is in nonattainment status. Occasional air pollution episodes in southwestern Ohio are usually the result of stable, stagnant air associated with a stationary high-pressure system. Low surface wind speeds and a temperature inversion (air temperature increasing with height in the atmosphere) combine to produce a "lid" over the area which dramatically reduces the dispersion of pollutants. Most air pollution episodes occur during late summer and early autumn.

Nonradiological air emissions which have been measured at the FEMP are as follows: TSP, NO_2, and SO_2 (WMCO 1987). The annual concentrations measured by SWOAPCA (1990) do not exceed the applicable federal and state standards for TSP, NO_2, and SO_2.

2.6.2 Meteorological Factors

Ambient air is affected by such meteorological factors as wind speed and direction (wind rose). The FEMP installed an on-site meteorological monitoring system in August 1986. The system includes a meteorological tower, monitoring instruments, a data logger, and a computer. The tower instruments measure wind speed and direction, ambient air temperature, lapse rate (a measure of atmospheric stability), dew point, temperature, relative humidity, barometric pressure, sigma theta (the standard deviation of horizontal wind direction over time and also a measure of atmospheric stability), and precipitation.

In October and November 1987, the National Oceanic and Atmospheric Administration (NOAA) conducted a study of meteorological conditions in the vicinity of the FEMP. The purpose of this month-long study was to examine the complexity of the local wind field at the FEMP, and to determine an appropriate level of meteorological monitoring for the region. The study included the installation of 12 temporary meteorological towers on site and off site within a 3-mile radius of the FEMP. Based on the data collected during the study, NOAA concluded that the Great Miami River valley and the ridges surrounding the FEMP significantly affected the flow of wind over and near the FEMP. Therefore, under certain meteorological conditions, additional monitoring data should be considered in the atmospheric dispersion model used to simulate the transport and dispersion of pollutants and toxic chemicals in the atmosphere. The NOAA recommendation to install a six-station network of meteorological stations to improve evaluations of the local wind field was not implemented because FEMP is no longer used for production purposes and the gaseous inventories of anhydrous hydrogen fluoride, ammonia, and uranium hexafluoride have been removed.

Although the NOAA study indicated that surface features such as the Great Miami River valley and the ridges surrounding the FEMP influence the local wind patterns, a study by IT Corporation (IT)

(IT 1986) showed that the wind flow data from the Cincinnati-Northern Kentucky International Airport (Cincinnati Airport) were sufficiently representative of local conditions to serve as a database for the years before the installation of the on-property meteorological system.

The prevailing winds at the 10-meter level of the FEMP tower during 1989 were from the southwest and west-southwest. Average monthly wind speeds at the site ranged from a low of 7 mph in August to a high of 11 mph in March.

Other climatological data recorded at the Fernald site during 1989 indicate that the temperature ranged from a minimum of minus 19.8 degrees Fahrenheit (°F) (minus 28.8 degrees Celsius [°C]) on December 22, 1989 to a high of 92.1°F (33.4°C) on July 11, 1989. The highest temperature recorded from 1960 through 1989 was 103°F in July 1988, and the lowest was minus 25°F in January 1977 (DOE 1992a).

Because of problems measuring the precipitation during heavy rainstorms at the Fernald site, precipitation data were obtained from the Cincinnati Airport. Precipitation for 1989, including melted snow, was 49.6 inches compared to the 30-year mean (1960-1989) of 40.6 inches. In addition, 23.3 inches of snowfall was reported at the Cincinnati Airport during 1989, almost identical to the 30-year mean (1960-1989) of 23.5 inches.

Before the tower was installed, and at times when the on-site meteorological system was not operating, the FEMP obtained its meteorological data from the National Weather Service Office at the Cincinnati Airport. Wind flow data from the James A. Cox International Airport at Dayton were used as a secondary source. The on-site system enables the FEMP to use site-specific meteorological data, thus improving the accuracy of computer models used to estimate the doses from routine atmospheric releases as well as potential doses that could result from any accidental release at the FEMP.

2.7 PREVIOUS SITE INVESTIGATIONS

2.7.1 Geologic Investigations

Geologic investigations of the area that surrounds and includes the FEMP have contributed substantial information to the RI/FS investigation. Fenneman (1916) performed an extensive survey of the geology in the Cincinnati area. This report describes in detail the interbedded limestone and shale bedrock and its mantle of glaciofluvial and alluvial sediments that comprise the buried channel aquifers in southwestern Ohio. Later investigators such as Durrell (1961) supported the earlier observations of Fenneman. The shape of the buried channel aquifer was further refined by Watkins and Spieker (1971) via geophysical surveys of the area around Fernald. More recent information includes various maps of the geology of Hamilton and Butler Counties, Ohio, as well as individual quadrangle maps of areas located in those counties (Leow 1985; Vormelker 1985; Ford 1974;

Swinford in preparation). Maps showing the extent and age of glacial till in the study area have also been produced (Brockman 1986). The Soil Conservation Service (USDA et al., 1980, 1982) performed soil surveys of Butler and Hamilton Counties, Ohio.

2.7.2 Surface Water Investigations

The Miami Conservancy District has kept precipitation and runoff records for the Great Miami River Valley since the early 1900s (Houck 1921). Precipitation records have also been kept at the Cincinnati Airport. Flood information for the Great Miami River and Paddys Run is available from the Federal Emergency Management Agency (FEMA 1982). Additional information on most Ohio streams, including the Great Miami River and Paddys Run, has been well documented with respect to flow duration and water quality (Cross and Hedges 1959; Ohio Environmental Protection Agency [OEPA] 1982).

Flow in the Great Miami River drainage basin is monitored by the USGS using a gaging station at Hamilton, Ohio. Flow regulation on the Great Miami River has been studied by Spieker (1968a); Paddys Run data have been compiled by Dames and Moore (1985a). Channelization and other modifications of Paddys Run and its tributaries in the FEMP have been documented by Dove (1961) and WMCO (1987). Surface water quality data for the FEMP area are available from the NLO for the period 1979 through 1985 and the OEPA for the period 1977 through 1983. WMCO and WEMCO have maintained surface water quality data since 1986.

2.7.3 Hydrogeologic Investigations

Dove (1961) and Spieker (1968a) extensively described the hydrology and hydrogeology of the Great Miami Aquifer in the lower Great Miami River Valley. These studies documented recharge rates, permeabilities of various lithologies, and other aquifer characteristics. Both also discussed groundwater/surface water interactions, specifically for the Great Miami River and Paddys Run. Other studies of the regional valley-fill aquifer in the vicinity of the FEMP include a study by the Miami Conservancy District (1985), several studies by the ODNR (Walker 1986; Walton and Schaefer 1956), and various contracted studies (GeoTrans 1985; Dames and Moore 1985a, b; ATEC Associates, Inc. 1982). Two other studies by Spieker (1968b, c) deal with the potential effects of increased pumping of the groundwater and future development and the groundwater resources, respectively.

2.7.4 Contamination Releases at the FEMP

Dove and Norris (1951) were the first to describe the possible fate of chemical and radionuclide releases that infiltrate the groundwater in the Great Miami Aquifer. Publications released in the last six years document radionuclide releases from the FEMP into the environment. These studies are from either "Report of Historic Uranium Releases from Current DOE Oak Ridge Operations Office Facilities" (DOE 1985) or are internal NLO/WMCO documents (Boback et al., 1985, 1986; WMCO 1987, 1988, 1989a, 1990a; Clark et al., 1989). Spieker and Norris (1962) investigated the radionuclide

contamination of the groundwater and the transport of the contaminated water through the Fernald, Ohio area. Additionally, the Ohio Department of Health (ODH) has documented radionuclide contamination in private wells in the FEMP area (ODH 1988). Sedam (1984) investigated the occurrence of uranium in the groundwater in the vicinity of the FEMP. Starkey et al. (1962) and the NLO (Spenceley 1983) performed internal investigations to distinguish between FEMP contamination and non-FEMP contamination. IT also conducted hydrogeologic studies of contaminant discharge to the Great Miami River (IT 1988).

2.7.5 Environmental Survey

For more than 10 years, the environment in and around the FEMP has been closely monitored by the DOE (Battelle et al., 1977; DOE 1985, 1987), Oak Ridge Associated Universities (ORAU 1985), various FEMP-related committees (WMCO 1986, 1987, 1988, 1989a, 1990a; Fleming and Ross 1984), and various contracted groups (IT 1986; Weston 1986, 1987; Battelle 1981). The DOE and ORAU documents include environmental impact assessments, RI/FS reports, and environmental surveys. Internal reports of studies by the NLO and WMCO include the annual Environmental Monitoring Reports and the Aquifer Contamination Control Reports (various authors 1965-present). These documents are available through DOE. The contracted studies represent more comprehensive environmental sampling and analysis programs and document the analytical results from a large number of groundwater, surface water, sediment, soil, and air samples. The analytical constituents include radionuclides, organic compounds, metals, and general water quality parameters. A sampling and analysis program to comply with RCRA provisions is also ongoing at the FEMP.

2.7.6 Vegetation and Wildlife Studies

Vegetation and wildlife in the FEMP area have been studied and characterized by WMCO, NLO, and OEPA. WMCO performed two studies of the fish that are indigenous to Paddys Run and the Great Miami River in the vicinity of the FEMP (WMCO 1986, 1987). The OEPA study (1982) was a more comprehensive study of the aquatic environment in the Great Miami River. A recent study by Facemire et al. (1990), under contract to WMCO, described the general terrestrial and aquatic environments of the FEMP and surrounding areas. The database compiled in this study is the most complete characterization of the environmental resources available.

3.0 NATURE AND EXTENT OF CONTAMINATION

Operable Unit 5 focuses on environmental media on and near the FEMP and contaminants associated with these media. The nature and extent of contamination in environmental media have been documented as part of several investigative efforts including the following:

- The RI/FS sampling and laboratory analytical program designed specifically to assess contamination of environmental media at and near the FEMP and to provide a basis for developing scenarios for remediation as necessary. This program includes radiological and nonradiological constituents. Summaries of the findings of this program with respect to soil, surface water, groundwater, flora, and fauna are included in this chapter.

- The sampling and laboratory analytical program for compliance with RCRA provisions (ASI/IT 1988; Dames & Moore 1986-1987). This program includes radiological, organic, and inorganic constituents. Pertinent information on groundwater quality characteristics at or near the FEMP collected as part of this program is included in this chapter.

- Annual monitoring completed by the facility operator on and near the FEMP, which is summarized in annual Environmental Monitoring Reports (WMCO 1986, 1987, 1988, 1989a, 1990a). This monitoring includes all media for both radiological and nonradiological parameters. Pertinent information from these reports regarding surface water, groundwater, and soil on or near the FEMP is included in this chapter and in Appendix A.

- Special or focused studies such as the human dose assessment study (IT 1989a), investigation of the impact of contamination at the FEMP on groundwater and surface water (IT 1988), and groundwater characterization studies (Dames & Moore 1985a, 1985b).

The nature and extent of contamination for Operable Unit 5 are based largely on the results of the RI/FS investigation, the RCRA monitoring program, and the most recent Environmental Monitoring Reports. The RI/FS samples/data were collected, analyzed, and evaluated using methods detailed in the Quality Assurance Project Plan (QAPP) (DOE 1988a). The resulting data are used as a primary data source for this document. Because the Environmental Monitoring program did not collect or evaluate data using the same procedures, those results are used as a secondary data source. Therefore, Environmental Monitoring data are used in support of the RI/FS data where possible, and also to fill informational gaps where they exist.

The results of the screening of alternatives that are presented in this document are limited by several factors. Specifically, this document is being prepared before the completion of several RI field activities important to Operable Unit 5 that are being conducted in response to the findings of the baseline RI program. While virtually all of the currently available data have been reviewed and

preliminarily evaluated, detailed analysis of the data will be conducted and presented in the Operable Unit 5 RI report scheduled for completion in June 1994. The baseline risk assessment, the results of which are fundamental to the establishment of cleanup criteria to support the FS, is also scheduled for completion in June 1994. Sitewide PRGs have, however, been developed using results of the RI/FS investigation presently available. The PRGs were developed using ARARs where available. If ARARs were not available, risk-based PRGs were developed. A 10^{-6} risk level in combination with a cancer slope factor (CSF) for carcinogens, or an HI and an RfD for noncarcinogens (DOE 1992a) were used to develop certain PRGs. These PRGs are intended only as a guide in determining media cleanup levels. Since cleanup criteria different than those used for this initial evaluation may be established as a result of the baseline risk assessment and since additional areas or contaminants of concern may be identified during the ongoing RI data development task, the remedial alternatives identified in this screening document may require modification as the FS process proceeds.

Even with the limitations cited above, the data evaluation completed for this initial screening of alternatives provides an appropriate foundation for the development and evaluation of remedial alternatives to address potential contamination problems associated with Operable Unit 5. It is unlikely, for example, that completion of the risk assessment and RI will negate any of the results of technology and process option identification and evaluation contained in this report. It is also unlikely that substantive changes would be required in remedial alternative components identified in this report. As currently envisioned, any modifications would likely be an expansion or contraction of actual areas (volumes) within various media requiring remediation. Any necessary modifications will be addressed and incorporated during the detailed analysis of alternatives.

With this in mind, the organizational framework for Section 3.0 of this report will proceed in the following manner:

- A brief discussion of ARARs and guidance to be considered (TBC)
- Presentation and discussion of PRGs
- Description of the nature and extent of contamination in relation to established PRG levels.

3.1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

3.1.1 Definition of an Applicable or Relevant and Appropriate Requirement

The DOE must comply with provisions of federal environmental statutes and regulations, as well as all applicable state and local requirements. In performing the RI/FS and subsequent remedial actions for

Operable Unit 5 within the framework of CERCLA/SARA/NCP, the FEMP is required to comply with all ARARs. ARARs are an integral part of the CERCLA remedial process. They serve as a basis for establishing criteria at all points of the process that must be attained to ensure protection of human health and the environment. In essence, all aspects of the remedial process are shaped through the identification and implementation of ARARs; from the development of PRGs to the development and screening of remedial alternatives. During the Detailed Analysis phase of the RI/FS process, all potential ARARs will be evaluated, and where appropriate, be correlated to each remedial alternative.

Applicable requirements are those federal and state regulatory requirements that directly and fully address or regulate the hazardous substance, pollutant, contaminant, action being taken, or other circumstance at a CERCLA site. Examples of federal statutes specifically cited in CERCLA from which requirements may apply include the Toxic Substances Control Act (TSCA), the Safe Drinking Water Act (SDWA), the Clean Air Act (CAA), the Clean Water Act (CWA), and the Marine Protection Research and Sanctuaries Act (MPRSA). Relevant and appropriate requirements are those federal and state human health and environmental regulatory requirements that address problems or situations sufficiently similar to those encountered at CERCLA sites and are appropriate to the circumstances of release or threatened release, so that their uses are well suited to the particular site. In such cases, application of these requirements would be relevant and appropriate although not mandated by law. Relevant and appropriate requirements are intended to carry the same weight as applicable requirements. A list of the potential ARARs identified for Operable Unit 5 are discussed in Appendix B.

3.1.2 Guidance to be Considered

ARARs may not exist or may not be sufficient to protect human health and the environment at a CERCLA site. Therefore, it is necessary to evaluate nonlegally binding or promulgated criteria, advisories, guidance, or policies for protective cleanup levels when determining cleanup requirements or designing a remedy. EPA and support agencies may, as appropriate, identify other advisories, criteria, or guidance to be considered for a particular remediation activity. This TBC category consists of advisories, criteria, or guidance that were developed by the EPA, other federal agencies, or states which generally fall into three categories: (1) Health effects information with a high degree of credibility; e.g., RfDs; (2) Technical information on how to perform or evaluate site investigations or response actions; and (3) Policy; e.g., EPA's groundwater policy. Requirements that are applicable or relevant and appropriate must be met by CERCLA remedial actions. Because TBCs are not promulgated or enforceable, they do not carry the same weight as ARARs and thus cannot be considered required cleanup standards. However, because the FEMP is a DOE facility, DOE orders must be accorded significant weight.

The application of the ARARs to Operable Unit 5 at the FEMP is difficult because the DOE and radionuclides (particularly uranium) have been exempt from some environmental regulations. From a radiological standpoint, the DOE has been primarily self-regulating for environmental activities and has established its own policies for environmental monitoring, waste disposal, and limits of exposure to employees and the public. EPA regulations regarding the handling and disposal of wastes containing radionuclides are included under programs established by the Uranium Mill Tailings Radiation Control Act of 1978 and the U.S. Nuclear Regulatory Commission (NRC). It should also be noted that DOE orders are not promulgated requirements but fall under the category of TBCs. The potential TBCs identified for Operable Unit 5 are discussed in Appendix B.

3.2 PRELIMINARY REMEDIATION GOALS

PRGs are "initial cleanup goals that (1) are protective of human health and the environment and (2) comply with ARARs. They are developed early in the RI/FS process and are based on readily available information" (EPA 1991a). The goals are also used as preliminary design criteria when evaluating the effectiveness and feasibility of technologies.

PRGs are chemical-specific, medium-specific numerical concentration limits that are developed "on the basis of chemical-specific ARARs, when available, other available information (i.e., RfDs), and site-specific risk-related factors. These preliminary remediation goals are reevaluated as site characterization data and information from the baseline risk assessment become available" (EPA 1988a).

Within this ISA document, the PRGs are used as standards for comparison of detected contaminant concentrations to aid in identifying the nature and extent of contamination. The PRGs are used as preliminary screening tools to initially establish a list of contaminants that require consideration when selecting process options and developing remedial alternatives.

The PRGs presented in this document were developed using "readily available ARARs . . . and other criteria, advisories or guidance" as specified in the preamble of the Code of Federal Regulations (CFR), Title 40, Part 300. When ARARs or other TBC values were not available, risk-based PRGs were developed using the CSF and a 1×10^{-6} incremental risk level for carcinogens and chemical-specific RfDs with a combined HI of 1.0 for noncarcinogens. Many identified ARARs have not been derived from risk levels that meet the CERCLA objective of being "protective of human health." Because of this, many PRGs based on ARARs could be less stringent than the EPA's suggested target range of 10^{-4} to 10^{-6} carcinogenic risk level. Furthermore, the risk-based PRG concentrations of some constituents (e.g., radionuclides) may even be less than background concentrations. However, because the PRGs are being used only as screening criteria, these relationships have a limited impact on the screening of alternatives. One impact of note, however, occurs when determining the volume of a

specific medium to be remediated with lower or more conservative PRGs. This, in turn, may have an impact on prospective costs.

The PRGs for this Operable Unit 5 ISA report originated from a draft form of the FEMP "Sitewide Characterization Report" (DOE 1992a). This is based on the fact that at the FEMP, only one set of initial PRGs has been developed. Because the initial PRGs are medium specific for the entire site, and not operable unit-specific, they are based on generic default exposure pathways and equation assumptions recommended by the EPA in "Risk Assessment Guidance for Superfund (RAGS): Volume 1 - Human Health Evaluation Manual, Part B, Development of Preliminary Remediation Goals" (EPA 1991a), and the exposure parameters presented in the Risk Assessment Work Plan Addendum (DOE 1992b), and are the same parameters that will be used in the baseline risk assessment. The exposure pathways used to develop sitewide PRGs are considered to be the "limiting" pathways, or pathways that often are responsible for much of the baseline risk. Note should be taken that with the exception of recommending the inclusion of environmental ARARs in the selection of PRGs, RAGS, Part B, addresses human health effects. Available environmental ARARs (e.g., water quality criteria from the CWA) have been used to develop PRGs for water quality.

The levels established as PRGs for this document are meant only as anticipated criteria. In fact, these initial PRGs will be modified throughout the feasibility study process as operable unit-specific risk assessments are completed. At the initial screening phase, alternatives remain flexible. Chemicals may be added or deleted from the list of chemicals of concern, or PRGs may be modified based on the identification of additional limiting exposure pathways. Modified PRGs will be presented in the Operable Unit 5 FS report.

PRGs are refined into final remediation levels and presented in the Record of Decision (ROD). Final remediation levels must meet threshold criteria of "protection of human health and the environment" and "compliance with ARARs," but may be modified based on balancing and modifying criteria and "factors relating to uncertainty, exposure, and technical feasibility" (EPA 1991a).

3.2.1 Contaminants of Concern

Not all chemicals detected and identified during site sampling pose significant health risks. The first step in the baseline risk assessment involves the identification of constituents considered as potential concerns. These constituents are then carried through the risk assessment process to evaluate exposure pathways and to ascertain present and future impacts on human health. The preliminary potential contaminants of concern or contaminants above detection limits are identified for Operable Unit 5 and are listed in Tables 3-1, 3-2, and 3-3. These tables present the PRGs for the Great Miami Aquifer, perched groundwater, soils/sediments, and surface water. It should be noted that the PRGs for the Great Miami Aquifer and the perched groundwater are the same because both are considered potable

TABLE 3-1
PRELIMINARY REMEDIATION GOALS[a] FOR DETECTED RADIONUCLIDES
OPERABLE UNIT 5

Radionuclide	Great Miami Aquifer Water Concentrations (pCi/L)	Perched Water Concentrations (pCi/L)	Surface Soils and Sediment Concentrations (pCi/g)	Surface Water Concentrations (pCi/L)
Strontium-90	4 (MCL)[b]	4 (MCL)	10 (CSF 10^{-6} - Based)[c]	4 (MCL)
Technetium-99	3750 (MCL)	3750 (MCL)	290 (CSF 10^{-6} - Based)	3750 (MCL)
Ruthenium-106	20 (MCL)	20 (MCL)	0.05 (CSF 10^{-6} - Based)	20 (MCL)
Cesium-137	110 (MCL)	110 (MCL)	0.02 (CSF 10^{-6} - Based)	110 (MCL)
Lead-210	1 (MCL)	1 (MCL)	0.6 (CSF 10^{-6} - Based)	1 (MCL)
Polonium-210	1 (4 mrem dose)[d]	1 (4 mrem dose)	e	1 (4 mrem dose)
Radium-224	e	e	e	e
Radium-226	20 (PMCL)[b]	20 (PMCL)	5[f] (TBC)[g]	20 (PMCL)
Radium-228	20 (PMCL)	20 (PMCL)	5[f] (TBC)[g]	20 (PMCL)
Actinium-227	0.4 (4 mrem dose limit)[g]	0.4 (4 mrem dose)	0.04 (CSF 10^{-6} - Based)	0.4 (4 mrem dose)
Protactinium-231	0.5 (4 mrem dose)	0.5 (4 mrem dose)	1.0 (CSF 10^{-6} - Based)	0.5 (4 mrem dose)
Thorium-228	14 (4 mrem dose)	14 (4 mrem dose)	0.006 (CSF 10^{-6} - Based)	14 (4 mrem dose)
Thorium-230	10 (4 mrem dose)	10 (4 mrem dose)	5 (TBC)	10 (4 mrem dose)
Thorium-232	2 (4 mrem dose)	2 (4 mrem dose)	5[f] (TBC)	2 (4 mrem dose)
Uranium-234	7 (PMCL)	7 (PMCL)	35 (TBC)	7 (PMCL)
Uranium-235	0.3 (PMCL)	0.3 (PMCL)	35 (TBC)	0.3 (PMCL)

See footnotes at end of table.

TABLE 3-1
(Continued)

Radionuclide	Great Miami Aquifer Water Concentrations (pCi/L)	Perched Water Concentrations (pCi/L)	Surface Soils and Sediment Concentrations (pCi/g)	Surface Water Concentrations (pCi/L)
Uranium-238	7 (PMCL)	7 (PMCL)	35 (TBC)	7 (PMCL)
Total Uranium	20 µg/L (PMCL)	20 µg/L (PMCL)	35 (TBC) 50 µg/g (TBC)	20 µg/L (PMCL)
Total Thorium[h]	18 µg/L (4 mrem dose)	18 µg/L (4 mrem dose)	5[f] (TBC) 45.5 µg/g (TBC)	18 µg/L (4 mrem dose)
Plutonium-238	2 (MCL)	2 (MCL)	0.5 (CSF 10^{-6} - Based)	2 (MCL)
Plutonium-239	2 (MCL)	2 (MCL)	0.6 (CSF 10^{-6} - Based)	2 (MCL)
Plutonium-240	2 (MCL)	2 (MCL)	0.5 (CSF 10^{-6} - Based)	2 (MCL)

[a]Risk-based preliminary remediation goals are based on exposure to individual compounds and do not take into account multiple contaminants and pathways.

[b]MCL/PMCL - Chemical-specific "maximum contaminant levels/proposed maximum contaminant levels" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[c]CSF - Chemical-specific "cancer slope factor," from U.S EPA HEAST and IRIS, calculated using a 10^{-6} risk level.

[d]PRG developed using the strictly applicable MCL of 4 mrem/year for man made beta and gamma emitters (40 CFR 141, 142). Value developed using a committed effective dose equivalent (CEDE) or critical organ dose equivalent (if available or if more conservative) to 4 mrem/year intake at a rate of 730 L/yr, using dose conversion factors (DCFs) from the EPA.

[e]Denotes no appropriate preliminary remediation goal is available.

[f]Includes progeny products.

See footnotes at end of table.

TABLE 3-1
(Continued)

[g]TBC - Chemical-specific guidance "to be considered" refers to pertinent suggested, nonregulatory concentration levels that represent health-based, recommended levels to be evaluated in the absence of applicable ARARs.

[h]PRGs for total thorium were calculated using the PRGs for isotopic Thorium-232 and the specific activity for Thorium-232. The specific activity for Thorium-232 is 1.1E-01 pCi/µg. This is possible because naturally occurring Thorium is present almost 100% as Thorium-232.

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TABLE 3-2

PRELIMINARY REMEDIATION GOALS[a] FOR DETECTED INORGANIC CONSTITUENTS OPERABLE UNIT 5

Inorganic Constituent	Great Miami Aquifer Water Concentrations (mg/L)	Perched Water Concentrations (mg/L)	Surface Soils and Sediment Concentrations (mg/kg)	Surface Water Concentrations (mg/L)
Aluminum	b	b	b	b
Ammonia	7.1 (RfD-Based)[c]	7.1 (RfD-Based)	124,356 (RfD-Based)	7.1 (RfD-Based)
Arsenic	0.05 (MCL)[d]	0.05 (MCL)	130 (RfD - Based)	0.05 (MCL)
Barium	2 (MCL)	2 (MCL)	6,400 (RfD - Based)	2 (MCL)[e]
Beryllium	0.001 (PMCL)[d]	0.001 (PMCL)	0.2 (CSF 10^{-6} - Based)[f]	0.001 (PMCL)
Cadmium	0.005 (MCLG)[g]	0.005 (MCLG)	130 (RfD - Based)	0.0011 (FAWQC[h]/Chronic)
Chromium (total)	0.1 (MCLG)	0.1 (MCLG)	640 (RfD - Based)[i]	0.1 (MCLG)
Cobalt	0.02 (RfD - Based)	0.02 (RfD - Based)	330 (RfD - Based)	0.02 (RfD - Based)[e]
Copper	1.3 (MCLG)	1.3 (MCLG)	b	0.012 (FAWQC/Chronic)[j]
Cyanide	0.2 (PMCLG)	0.2 (PMCLG)	2,560 (RfD - Based)	0.0052 (FAWQC/Chronic)
Lead	0.005 (MCL)	0.005 (MCL)	90 (RfD - Based)	0.0032 (FAWQC/Chronic)[j]
Manganese	0.7 (RfD - Based)	0.7 (RfD - Based)	12,800 (RfD - Based)	0.7 (RfD - Based)[e]
Mercury	0.002 (MCLG)	0.002 (MCLG)	40 (RfD - Based)	0.000012 (FAWQC/Chronic)
Molybdenum	0.03 (RfD - Based)	0.03 (RfD - Based)	510 (RfD - Based)	0.03 (RfD - Based)[e]
Nickel	0.1 (PMCLG)	0.1 (PMCLG)	2,600 (RfD - Based)	0.1 (PMCLG)
Nitrate	b	b	b	b
Selenium	0.05 (MCLG)	0.05 (MCLG)	640 (RfD - Based)	0.036 (FAWQC/Chronic)

See footnotes at end of table.

TABLE 3-2
(Continued)

Inorganic Constituent	Great Miami Aquifer Water Concentrations (mg/L)	Perched Water Concentrations (mg/L)	Surface Soils and Sediment Concentrations (mg/kg)	Surface Water Concentrations (mg/L)
Silver	0.05 (MCL)	0.05 (MCL)	380 (RfD - Based)	0.00012 (FAWQC/Chronic)[j]
Thallium	0.002 (PMCL)	0.002 (PMCL)	9 (RfD - Based)	0.0005 (PMCLG)
Vanadium	0.05 (RfD - Based)	0.05 (RfD - Based)	900 (RfD - Based)	0.05 (RfD - Based)[e]
Zinc	1 (RfD - Based)	1 (RfD - Based)	25,600 (RfD - Based)	0.11 (FAWQC/Chronic)[j]

[a]Risk-based preliminary remediation goals (PRG) are based on exposure to individual compounds and do not take into account multiple contaminants and pathways.

[b]Denotes no appropriate PRG is available.

[c]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

[d]MCL/PMCL - Chemical-specific "maximum contaminant levels/proposed maximum contaminant levels" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[e]No federal ambient water quality criterion available.

[f]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, calculated using a 10^{-6} risk level.

[g]MCLG/PMCLG - Chemical-specific "maximum contaminant level goals/proposed maximum contaminant level goals" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[h]FAWQC - Chemical-specific "federal ambient water quality criteria" are regulatory chemical concentration levels established in the U.S. EPA guidance document "Quality Criteria for Water, 1986."

[i]Risk-calculated PRGs for chromium were conducted using hexavalent chromium since this is the most conservative approach. All samples collected in the field were analyzed for total chromium.

[j]Insufficient data to develop criteria; value presented is the lowest observed effect level.

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TABLE 3-3

PRELIMINARY REMEDIATION GOALS[a] FOR DETECTED ORGANIC CONSTITUENTS OPERABLE UNIT 5

Organic Constituents	Great Miami Aquifer Water Concentrations (mg/L)	Perched Water Concentrations (mg/L)	Surface Soils and Sediment Concentrations (mg/kg)	Surface Water Concentrations (mg/L)
Acenaphthene	0.4 (RfD-Based)[b]	0.4 (RfD-Based)	7680 (RfD-Based)	0.4 (RfD-Based)
Acenaphthylene	c	c	c	c
Acetone	0.7 (RfD-Based)	0.7 (RfD-Based)	12,800 (RfD-Based)	0.7 (RfD-Based)[d]
Aldrin	2.147E-6 (CSF 10^{-6}-Based)[e]	2.147E-6 (CSF 10^{-6}-Based)	0.04118 (CSF 10^{-6}-Based)	2.147E-6 (CSF 10^{-6}-Based)
Alpha - BHC	c	c	c	c
Anthracene	2.0 (RfD-Based)	2.0 (RfD-Based)	38,400 (RfD-Based)	2.0 (RfD-Based)[d]
Benzene	0.005 (MCL) [f]	0.005 (MCL)	20 (CSF 10^{-6}-Based)	0.005 (MCL)
Benzo(a)anthracene	0.0001 (PMCL)[f]	0.0001 (PMCL)	c	0.0001 (PMCL)[d]
Benzo(b)fluoranthene	0.0002 (PMCL)	0.0002 (PMCL)	c	0.0002 (PMCL)[d]
Benzo(k)fluoranthene	0.0002 (PMCL)	0.0002 (PMCL)	c	0.0002 (PMCL)[d]
Benzo(g,h,i)perylene	c	c	c	c
Benzo(a)pyrene	0.0002 (PMCL)	0.0002 (PMCL)	0.06 (CSF 10^{-6}-Based)	0.0002 (PMCL)[d]
Benzoic Acid	29 (RfD-Based)	29 (RfD-Based)	512,000 (RfD-Based)	29 (RfD-Based)[d]
Benzyl Alcohol	2 (RfD-Based)	2 (RfD-Based)	38,400 (RfD-Based)	2 (RfD-Based)[d]
Beta BHC	c	c	c	c
Bis(2-ethylhexyl)-phthalate	0.003 (CSF 10^{-6}-Based)	0.003 (CSF 10^{-6}-Based)	50 (CSF 10^{-6}-Based)	0.003 (CSF 10^{-6}-Based)[d]
Bromochloromethane	c	c	c	c

See footnotes at end of table.

TABLE 3-3
(Continued)

Organic Constituents	Great Miami Aquifer Water Concentrations (mg/L)	Perched Water Concentrations (mg/L)	Surface Soils and Sediment Concentrations (mg/kg)	Surface Water Concentrations (mg/L)
Butanol	0.73 (RfD-Based)	0.73 (RfD-Based)	12,807 (RfD-Based)	0.73 (RfD-Based)
2-Butanone	0.4 (RfD-Based)	0.4 (RfD-Based)	6400 (RfD-Based)	0.4 (RfD-Based)[d]
Butyl benzyl phthalate	1 (RfD-Based)	1 (RfD-Based)	25,600 (RfD-Based)	1 (RfD-Based)[d]
Carbon tetrachloride	0.005 (MCL)	0.005 (MCL)	5 (CSF 10^{-6}-Based)	0.005 (MCL)
Carbon disulfide	0.7 (RfD-Based)	0.7 (RfD-Based)	12,800 (RfD-Based)	0.7 (RfD-Based)[d]
Chlorobenzene	0.1 (RfD-Based)	0.1 (RfD-Based)	2560 (RfD-Based)	0.05 (FAWQC[g]/Chronic)[h]
Chloroethane	c	c	c	c
Chloroform	0.1 (MCL)	0.1 (MCL)	100 (CSF 10^{-6}-Based)	0.1 (MCL)
Chrysene	0.0002 (PMCL)	0.0002 (PMCL)	c	0.0002 (PMCL)[d]
Cyclohexane	c	c	c	c
Dibenzo(a,h)-anthracene	0.0003 (PMCL)	0.0003 (PMCL)	c	0.0003 (PMCL)[d]
Dibenzofuran	c	c	c	c
Di-n-butyl phthalate	0.7 (RfD-Based)	0.7 (RfD-Based)	12,800 (RfD-Based)	0.7 (RfD-Based)
1,1-Dichloroethane	0.7 (RfD-Based)	0.7 (RfD-Based)	12,800 (RfD-Based)	0.7 (RfD-Based)
1,2-Dichloroethane	0.005 (MCL)	0.005 (MCL)	8 (CSF 10^{-6}-Based)	0.005 (MCL)
1,1-Dichloroethene	0.007 (MCL)	0.007 (MCL)	1 (CSF 10^{-6}-Based)	0.007 (MCL)
cis-1,2-Dichloroethene	0.07 (MCLG)[i]	0.07 (MCLG)	1280 (RfD-Based)	0.07 (MCLG)
trans-1,2-Dichloroethene	0.1 (MCLG)	0.1 (MCLG)	2560 (RfD-Based)	0.1 (MCLG)
Diethylphthalate	5.84 (RfD-Based)	5.84 (RfD-Based)	102,456 (RfD-Based)	5.84 (RfD-Based)

See footnotes at end of table.

TABLE 3-3
(Continued)

Organic Constituents	Great Miami Aquifer Water Concentrations (mg/L)	Perched Water Concentrations (mg/L)	Surface Soils and Sediment Concentrations (mg/kg)	Surface Water Concentrations (mg/L)
2,4-Dimethylphenol	0.1 (RfD-Based)	0.1 (RfD-Based)	2560 (RfD-Based)	0.1 (RfD-Based)
Dimethylphthalate	7.3 (RfD-Based)	7.3 (RfD-Based)	128,070 (RfD-Based)	7.3 (RfD-Based)
Ethylbenzene	0.7 (MCLG)	0.7 (MCLG)	1280 (RfD-Based)	0.7 (MCLG)
Fluoranthene	0.3 (RfD-Based)	0.3 (RfD-Based)	5120 (RfD-Based)	0.3 (RfD-Based)
Fluorene	0.3 (RfD-Based)	0.3 (RfD-Based)	5120 (RfD-Based)	0.3 (RfD-Based)[d]
Heptachlor	8.1 E-6 (CSF 10^{-6}-Based)	8.1 E-6 (CSF 10^{-6}-Based)	0.16 (CSF 10^{-6}-Based)	8.1 E-6 (CSF 10^{-6}-Based)
2-Hexanone	c	c	c	c
Indeno(1,2,3-cd)pyrene	0.0004 (PMCL)	0.0004 (PMCL)	c	0.0004 (PMCL)[d]
Isophorone	1.46 (RfD-Based)	1.46 (RfD-Based)	25,814 (RfD-Based)	1.46 (RfD-Based)
Methylene chloride	0.005 (PMCL)	0.005 (PMCL)	90 (CSF 10^{-6}-Based)	0.005 (PMCL)[d]
2-Methyl-4,6-Dinitrophenol	c	c	c	c
4-Methyl-2-pentanone	0.4 (RfD-Based)	0.4 (RfD-Based)	6400 (RfD-Based)	0.4 (RfD-Based)[d]
2-Methylnaphthalene	c	c	c	c
4-Methylphenol	c	c	c	c
Naphthalene	0.03 (RfD-Based)	0.03 (RfD-Based)	510 (RfD-Based)	0.03 (RfD-Based)
3-Nitroaniline	c	c	c	c
2-Nitrophenol	c	c	c	c
4-Nitrophenol	c	c	c	c
N-Nitrosodiethylamine	2E-07 (CSF 10^{-6} - Based)	2E-07 (CSF 10^{-6} - Based)	0.0047 (CSF 10^{-6}-Based)	c

See footnotes at end of table.

TABLE 3-3
(Continued)

Organic Constituents	Great Miami Aquifer Water Concentrations (mg/L)	Perched Water Concentrations (mg/L)	Surface Soils and Sediment Concentrations (mg/kg)	Surface Water Concentrations (mg/L)
N-Nitrosodi-phenylamine	0.007 (CSF 10^{-6}-Based)	0.007 (CSF 10^{-6}-Based)	100 (CSF 10^{-6}-Based)	0.007 (CSF 10^{-6}-Based)[d]
PCBs	0.0005 (MCL)	0.0005 (MCL)	10 (TBC)[j]	0.000014 (FAWQC/Chronic)
Pentachlorophenol	0.001 (MCL)	0.001 (MCL)	6 (CSF 10^{-6}-Based)	0.001 (MCL)
Phenanthrene	c	c	c	c
Phenol	4 (RfD-Based)	4 (RfD-Based)	76,800 (RfD-Based)	2.5 (FAWQC/Chronic)[h]
Pyrene	0.2 (RfD-Based)	0.2 (RfD-Based)	3800 (RfD-Based)	0.2 (RfD-Based)[d]
Tetrachloroethene	0.005 (MCL)	0.005 (MCL)	10 (CSF 10^{-6}-Based)	0.005 (MCL)
1,1,2,2-Tetrachloroethane	0.0002 (CSF 10^{-6}-Based)	0.0002 (CSF 10^{-6}-Based)	4 (CSF 10^{-6}-Based)	0.0002 (CSF 10^{-6}-Based)[d]
2,3,4,6-Tetrachlorophenol	c	c	c	c
Toluene	1 (MCL)	1 (MCL)	25,610 (RfD-Based)	1 (MCL)
1,1,1-Trichloroethane	0.2 (MCL)	0.2 (MCL)	11,526 (RfD-Based)	0.2 (MCL)
Trichloroethene	0.005 (MCL)	0.005 (MCL)	60 (CSF 10^{-6}-Based)	0.005 (MCL)
Vinyl Chloride	0.002 (MCL)	0.002 (MCL)	0.044 (CSF 10^{-6}-Based)	0.002 (MCL)
Xylenes (total)	10 (MCLG)	10 (MCLG)	256 (RfD-Based)	10 (MCLG)

See footnotes at end of table.

TABLE 3-3
(Continued)

[a]Risk-based preliminary remediation goals (PRG) are based on exposure to individual compounds and do not take into account multiple contaminants and pathways.

[b]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

[c]Denotes no appropriate PRGs is available.

[d]No federal ambient water quality criteria available.

[e]CFS - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, calculated using a 10^{-6} risk level.

[f]MCL/PMCL - Chemical-specific "maximum contaminant levels/proposed maximum contaminant levels" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[g]FAWQC - Chemical-specific "federal ambient water quality criteria" are regulatory chemical concentration levels established in the U.S. EPA guidance document "Quality Criteria for Water, 1986."

[h]Hardness dependent criteria (100 mg/L used).

[i]MCLG/PMCLG - Chemical-specific "maximum contaminant level goals/proposed maximum contaminant level goals" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[j]TBC - Chemical-specific guidance "to be considered" refers to pertinent suggested, nonregulatory concentration levels that represent health-based, recommended levels to be evaluated in the absence of applicable ARARs.

water sources. In addition, risk-based PRGs are derived for individual constituents and do not take into account any synergistic effects which may be possible with multiple contaminants.

The following text presents a discussion of the methodology that was used by the DOE (1992a) to develop PRGs based on ARARs/TBCs and based on risk calculations. The tables also include the method that was used to develop the PRGs for each contaminant in a specific medium.

3.2.2 Methods for ARARs-Based PRGs

The development of PRGs is concurrent with the identification of ARARs. In the case of the FEMP, ARARs may need to be interpreted in relation to site-specific conditions to ensure sufficient health protection based on multiple sources and pathways.

Chemical-specific ARARs and TBCs have been identified for radionuclide and nonradionuclide chemical concentrations in drinking water. In accordance with the NCP, at 40 CFR 300.430(e)(2)(i), the "maximum contaminant level goals (MCLG) established under the SDWA, that are set at levels above zero, shall be attained by remedial actions for groundwater or surface waters that are current or potential sources of drinking water, where the MCLGs are relevant and appropriate under the circumstances of the release based on the factors in 300.400(g)(2). If an MCLG is determined not to be relevant and appropriate, the corresponding maximum contaminant level (MCL) shall be attained where relevant and appropriate to the circumstances of the release." Furthermore, "where the MCLG for a contaminant has been set at a level of zero, the MCL promulgated for that contaminant shall be attained" under the previously-specified conditions.

Other ARARs that have been considered in formulating the PRGs are proposed MCLGs (PMCLG), proposed MCLs (PMCL), and ambient water quality criteria (AWQC) (EPA 1986a) (Table 3-4). If both an MCL and a PMCL exist for a constituent, the PMCL is used to develop the PRG because promulgation of these PMCLs is expected to occur in the near future.

Table 3-4 lists AWQC and state of Ohio Water Quality Standards (OWQS) that can be used to develop surface water PRGs. The AWQC represent guideline concentrations for chemicals that likely will not cause impairment to aquatic populations. These PRGs should be used in conjunction with drinking water PRGs listed in Tables 3-2 and 3-3. In cases where values in Table 3-4 are lower, they should be used in lieu of the drinking water PRGs.

3.2.3 Methods for Risk-Based PRGs

Risk-based PRGs have been developed for those constituents which do not have MCLGs, MCLs, PMCLGs, PMCLs, or other ARARs-based criteria.

TABLE 3-4

WATER QUALITY CRITERIA FOR PROTECTION OF AQUATIC SPECIES

Chemical	Federal Ambient Water Quality Criteria[a] (acute/chronic) (mg/L)	Ohio State Water Quality Standards[b] (maximum/30-day average) (mg/L)
Inorganics		
Antimony	9/1.6(*)	0.65/0.19
Arsenic	0.36/.19(*)	0.36/0.19
Beryllium	0.13/0.0053(*)	3.75/0.17
Cadmium	0.0039/0.0011(+)	0.02/0.02
Chromium	1.7/0.210	4.92/0.46
Copper	0.018/0.012(+)	0.06/0.04
Iron	[c]/1.0	[c]
Lead	0.082/0.0032(+)	0.63/0.03
Mercury	0.0024/0.000012	0.001/0.0002
Nickel	1.4/0.16(+)	4.51/0.50
Selenium	0.28/0.036	0.02/0.005
Silver	0.0041/0.00012(+)	0.01
Thallium	1.4/0.04(*)	[c]
Zinc	0.12/0.11(+)	0.33/0.30
Cyanide	0.022/0.0052	0.046/0.012(E)
Organics		
1,1,2-Trichloro-1,2,2-trifluoroethane	2.4/9.02(*)	[c]
1,1,2,2-Tetrachloroethane	[c]	1/0.36
1,1,1-Trichloroethane	31.2/[c](*)	2/0.088
1,1-Dichloroethene	11.6/[c](*)	1.5/0.078
1,2-Dichloroethane	118/20(*)	12/3.5
1,2-cis-Dichloroethene	11.6/[c](*)	[c]

See footnotes at end of table.

TABLE 3-4
(Continued)

Chemical	Federal Ambient Water Quality Criteria[a] (acute/chronic) (mg/L)	Ohio State Water Quality Standards[b] (maximum/30-day average) (mg/L)
1,2-trans-Dichloroethene	11.6/[c](*)	[c]
2,4-Dimethylphenol	2.12/[c](*)	[c]
Acenaphthene	1.7/0.52(*)	0.067/0.067
Acetone	[c]	0.55/0.078
Aroclor-1242	0.002/0.000014	[c]/0.001
Aroclor-1248	0.002/0.000014	[c]/0.001
Aroclor-1254	0.002/0.000014	[c]/0.001
Aroclor-1260	0.002/0.000014	[c]/0.001
Benzene	5.3/[c](*)	1.1/0.56
Bis(2-ethylhexyl)phthalate	[c]	1.1/0.0084
Butyl benzyl phthalate	[c]	0.23/0.049
Carbon Tetrachloride	35.2/[c](*)	1.8/0.28
Chlordane	0.0024/0.0000043	0.00001/0.0000048
Chlorobenzene	0.25/0.05(*)	0.59/0.026
Chloroform	28.9/1.24(*)	1.8/0.079
DDT	0.0011/0.000001	0.000001/0.00000024
Di-n-butyl Phthalate	[c]	0.35/0.19
Ethylbenzene	32/[c](*)	1.4/0.062
Fluoranthene	3.9/[c](*)	0.2/0.0089
beta-Hexachlorocyclohexane	0.002/0.00008	[c]/0.00055
Methylene Chloride	[c]	9.7/0.43
N-nitrosodiphenylamine	[c]	0.29/0.013
Naphthalene	2.3/0.620	0.16/0.044
Pentachlorophenol	0.02/0.013(++)	0.04/0.02
Phenol	10.2/2.5(*)	5.3/0.37 (E)
Tetrachloroethene	5.28/0.84(*)	0.54/0.073
Toluene	17.5/[c]	2.4/1.7

See footnotes at end of table.

TABLE 3-4
(Continued)

Chemical	Federal Ambient Water Quality Criteria[a] (acute/chronic) (mg/L)	Ohio State Water Quality Standards[b] (maximum/30-day average) (mg/L)
Trichloroethene	46/21.9(*)	1.7/0.075
Vinyl Chloride	0.002	[c]/5.25
Xylenes (total)	10	[c]

[a]Federal ambient water quality criteria from "Quality Criteria for Water 1986" (EPA 1986a). Values are for freshwater species. Footnotes listed by EPA (1986a include: (*) - hardness dependent criteria (100 mg/L used); (+) - insufficient data to develop criteria. Value presented is a LOEL (Lowest Observed Effect Level: (++) - pH dependent criteria (7.8 pH used).

[b]Numerical criteria from Ohio Water Quality Standards. Chapter 3745-1 of the Ohio Administrative Code values are for modified warm weather habitats unless notes by (E), which represents "exceptional" warm weather habitat.

[c]Criteria/standard(s) do not exist for this constituent.

Development of initial risk-based PRGs requires the following information:

- Chemicals of potential concern
- Environmental media of potential concern
- Probable future land use and exposures
- Chemical-specific toxicity information
- Target risk levels.

The chemicals of potential concern are discussed in Sections 3.4 through 3.7. The environmental media of potential concern are groundwater (perched groundwater and regional aquifer), soils/sediments, and surface water. To develop PRGs, it is assumed that the future land-use scenario is the resident farmer. Toxicity data used to develop PRGs are CSFs and RfDs from the Integrated Risk Information Systems (IRIS) database (EPA 1991b) and Health Effects Assessment Summary Tables (HEAST) (EPA 1991d). Target risk levels and future exposure are addressed here in more detail.

3.2.4 Target Risk Levels

In developing risk-based PRGs, a target risk level (TR) must be established for carcinogens ($1x10^{-6}$), and a target hazard quotient (THQ) and target hazard index (THI) (the sum of the THQs) must be established for noncarcinogens. Once these levels are established, they can be used in conjunction with toxicity data and exposure equations to calculate PRGs.

The EPA indicates that the cumulative site THI should be less than 1. However, no direct guidance is available on apportioning the allowable levels among the various chemicals in the various environmental media. The most applicable regulatory guidance comes from the Office of Drinking Water (ODW), which, in calculating MCLGs, uses a relative source contribution (RSC) factor to account for the contribution from other sources of exposure (EPA 1989a). If sufficient data are not available to evaluate the drinking water exposure relative to other exposures, the ODW assumes other exposures account for 80 percent of the total, leaving 20 percent for water. Thus, the default RSC is 20 percent (0.20).

This method can be adapted to the development of PRGs for noncarcinogens. Because it is not known what additional sources are contributing to total exposure, the default RSC of 0.20 will be used to develop individual chemical/media-specific PRGs, helping to ensure that the total THI from each exposure does not exceed 1. Thus, the THQ for medium-specific, noncarcinogenic effects will be 0.2, helping to ensure the THI is less than equal to 1, as recommended by the EPA (1991a).

3.2.5 Exposure Pathways

The risk-based PRGs presented in Tables 3-1, 3-2, and 3-3 were calculated using a number of exposure pathways and associated equations. The drinking water pathway was used to develop groundwater PRGs for organic compounds, inorganics, and radionuclides, with the exception of radon

(EPA 1991a). PRGs for radon were developed using methods specified in 40 CFR 141, which requires that additional pathways, such as gaseous emissions into the home, be taken into account.

PRGs for perched groundwater were developed based on the assumption that the perched zones at the site are a potential potable water source. The risk-based concentrations are calculated assuming a very conservative drinking water exposure pathway. PRGs for the Great Miami Aquifer were also developed based on a drinking water exposure pathway.

PRGs for soils and sediments were developed under the assumption that direct contact will occur with the contaminated material. The EPA suggests that for residential land use, soil PRGs should be based on direct ingestion (EPA 1990a; EPA 1991a). In addition, since it is assumed that a resident farmer may plow the land annually, there is potential for disturbed soil to result in volatile and particulate emissions to the air. For radionuclides, direct external radiation exposures were also considered.

Surface water PRGs were developed, in part, using the same methods that were used for the Great Miami Aquifer. However, if the AWQC for a given constituent is a lower concentration, this more conservative value is used for the surface water PRG. For those constituents which have no ARARs-based PRGs, a risk-based PRG was calculated using the drinking water exposure pathway discussed previously.

Site-specific parameters and exposure equations used to develop the PRGs are available in the RI/FS Work Plan Addenda (DOE 1992b) and the Sitewide Characterization Report, Part III: Feasibility Study Report (DOE 1992a). Equations used are from RAGS (EPA 1991a).

The remainder of this chapter provides a discussion of contaminant distribution in various media and the associated contaminant fate, migration pathways, and potential receptors. Because of the large number of tables referenced in this section, tabular data summaries are presented in Appendix A.

3.3 ONGOING INVESTIGATIONS

Several investigations within the scope of Operable Unit 5 are still in progress. The extent of contamination presented in this report is based on data currently available. The interpretation of site conditions provided by existing data is judged adequate to perform the initial screening of alternatives. The complete data sets will be included in the Operable Unit 5 RI report and alternatives presented in this document will be refined during the detailed analysis based on new data. Investigations related to Operable Unit 5 that are currently in progress or yet to be performed include the following:

- Paddys Run South Investigation - consists of the installation of twelve 2000-series wells along Paddys Run, south of the FEMP, with the contingency to install twelve

3000-series wells. Groundwater samples are collected monthly for one year, as well as stream flow and stream infiltration measurements and surface water sampling.

- Facilities Testing Investigation - consists of additional systematic borings within the FEMP former production area and suspect areas. Piezometers are installed in borings where water is encountered.

- 31-Well Program - consists of the installation of wells to better define a uranium plume predominantly in the southern area of the FEMP.

- Miscellaneous Additional Wells Program - consists of the installation, sampling, and analysis of 16 priority monitoring wells and 9 contingency wells.

- Operable Unit 5 Work Plan Addenda - consists of additional investigations to characterize soils and groundwater in the vicinity of the biodenitrification surge lagoon and storm water retention basin; the K-65 slurry line and the Clearwell line; the sewage treatment area; the KC-2 warehouse area and electrical substation; the Plant 1 pad; the southeast quadrant of the former production area; and the fire training area.

- FEMP Underground Petroleum Storage Tank Closure Program - consists of an assessment for closing five tank locations in the former production area and includes characterizing soils and perched groundwater in the vicinity of each tank group. Four of these five tank locations involve tank removals, and the fifth location involves closure of a tank by abandonment in place. Current plans call for the closure of three of the sites under RCRA Subtitle I Regulations. The other two tank removal sites have petroleum and nonpetroleum contamination which could not be excavated and therefore may be addressed as CERCLA removal or remedial actions.

3.4 GROUNDWATER

This section addresses the groundwater quality of the glacial overburden perched zones and the Great Miami Aquifer, based on the results of samples collected from RI/FS and RCRA Groundwater Assessment sampling programs. Data that were available as of December 1, 1991 in the Fernald database, which include samples collected from May 1988 to August 1991, are used as the basis of the following discussion. Parameters analyzed for in these samples include radiological constituents, metals, general chemical parameters, and organic compounds.

Groundwater at the FEMP has been extensively characterized at and near the site. The perched groundwater zone, as monitored by a network of wells designated as the 1000-series wells (Figures 3-1 through 3-5), is contained primarily within sand lenses in the till. The regional aquifer is the primary source of water for domestic, industrial, and commercial use in the vicinity of the FEMP. A well monitoring network has been established to monitor the portion of the regional aquifer impacted or potentially impacted by the FEMP operations. These wells are designated as the 2000-, 3000-, and 4000-series wells. The 2000-series wells are screened approximately 5 feet above to 10 feet below the

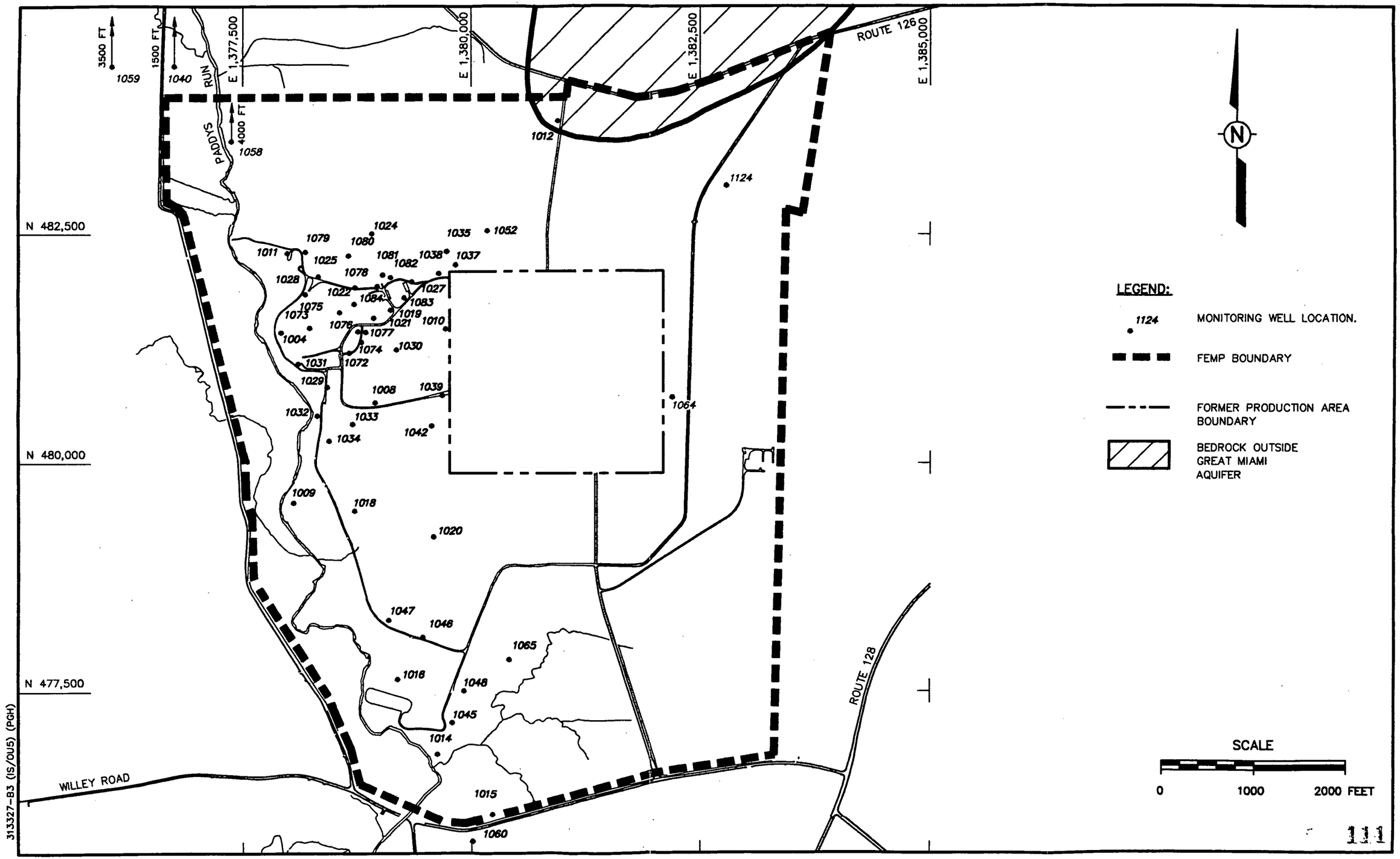


FIGURE 3–1
LOCATION OF THE 1000–SERIES WELLS
OUTSIDE THE FORMER PRODUCTION AREA
OF THE FEMP

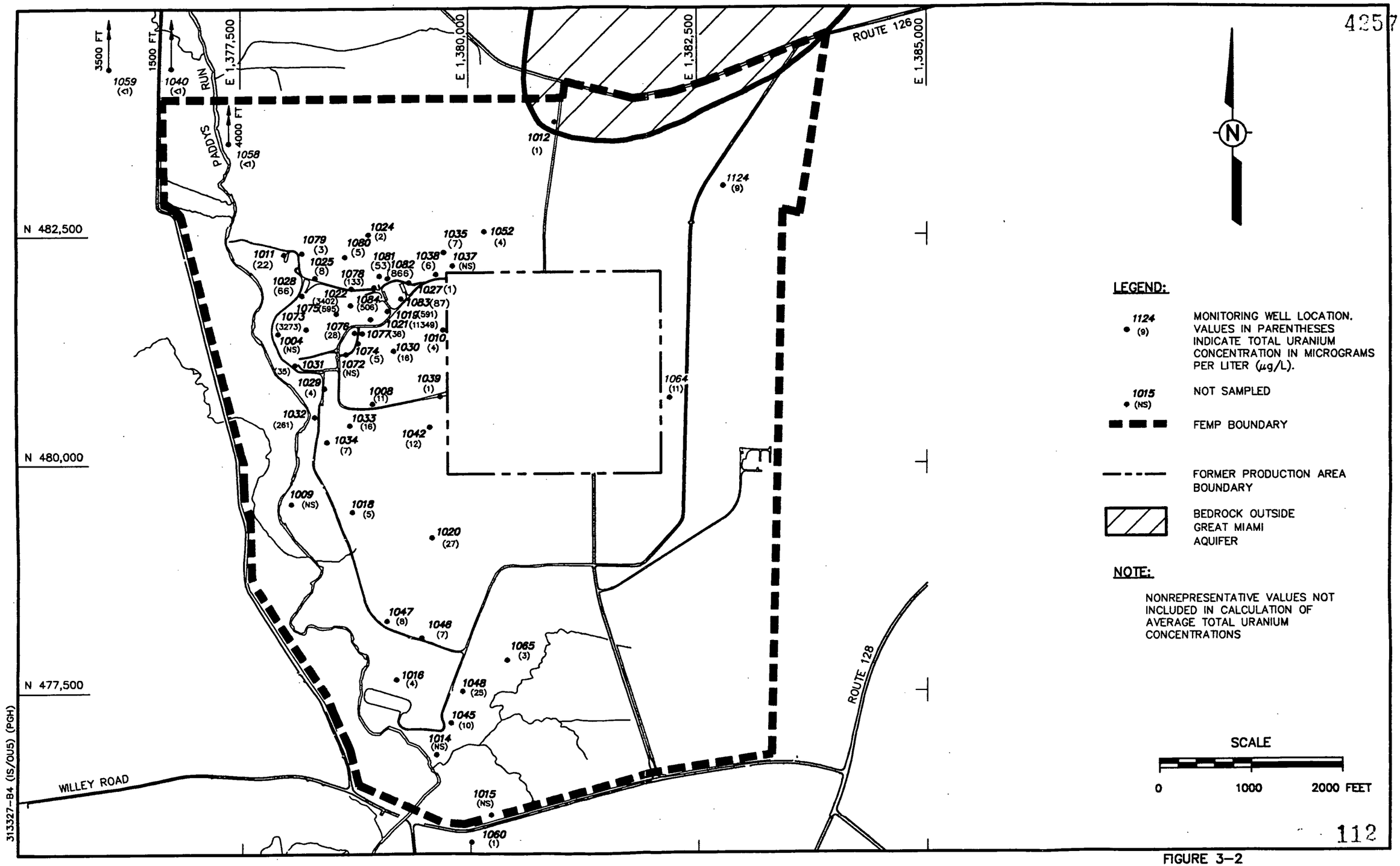


FIGURE 3-2
AVERAGE URANIUM CONCENTRATION IN GROUNDWATER
1000-SERIES WELLS
OUTSIDE THE FORMER PRODUCTION AREA
RCRA AND RI/FS SAMPLING DATA FROM
SECOND QUARTER 1988 THROUGH
FOURTH QUARTER 1989

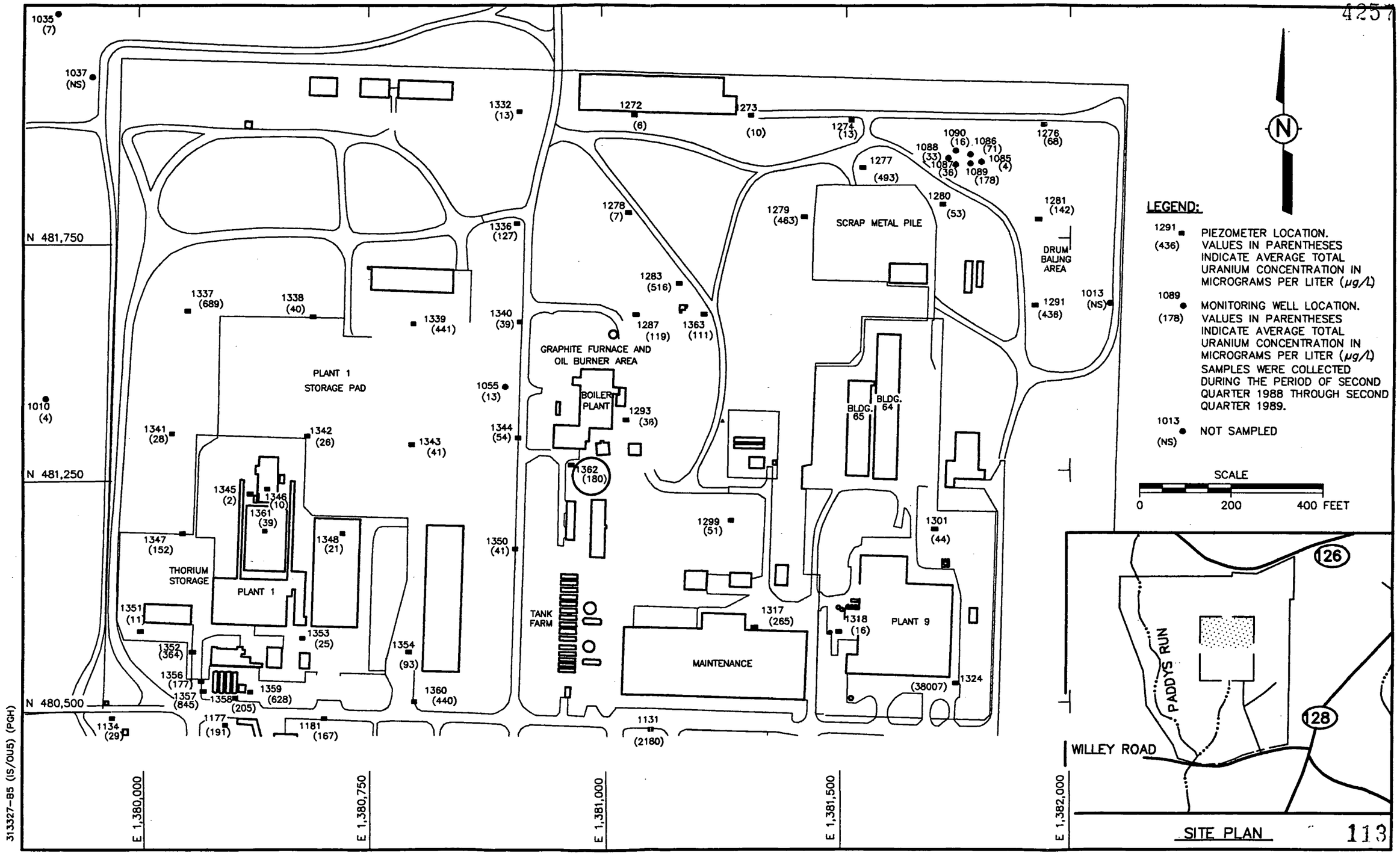


FIGURE 3-3
AVERAGE URANIUM CONCENTRATION IN GROUNDWATER
1000-SERIES WELLS
FORMER PRODUCTION AREA OF THE FEMP NORTHERN HALF
APRIL 1989 – JANUARY 1990

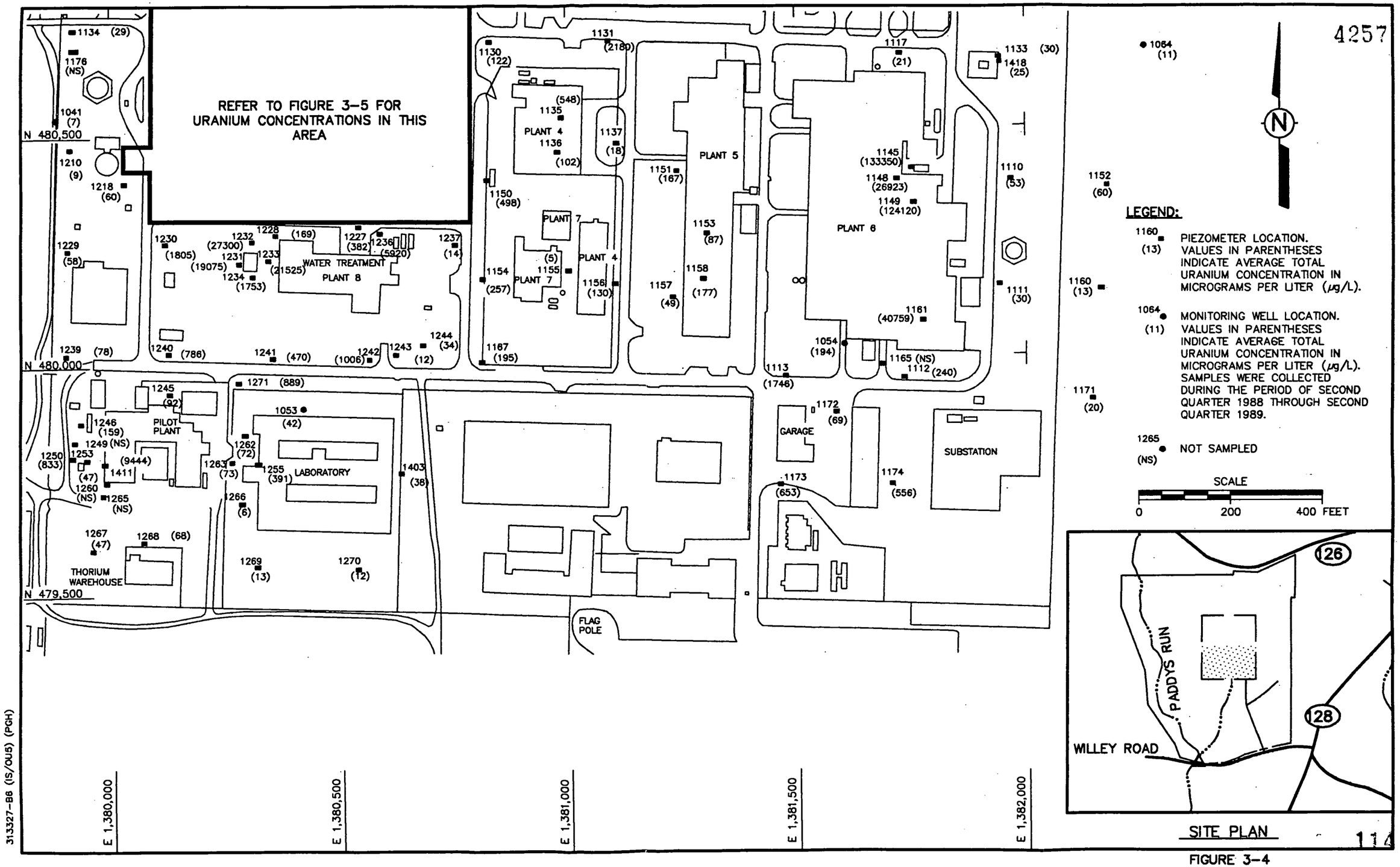


FIGURE 3-4
AVERAGE URANIUM CONCENTRATION IN GROUNDWATER
1000-SERIES WELLS
FORMER PRODUCTION AREA OF THE FEMP SOUTHERN HALF
APRIL 1989 – JANUARY 1990

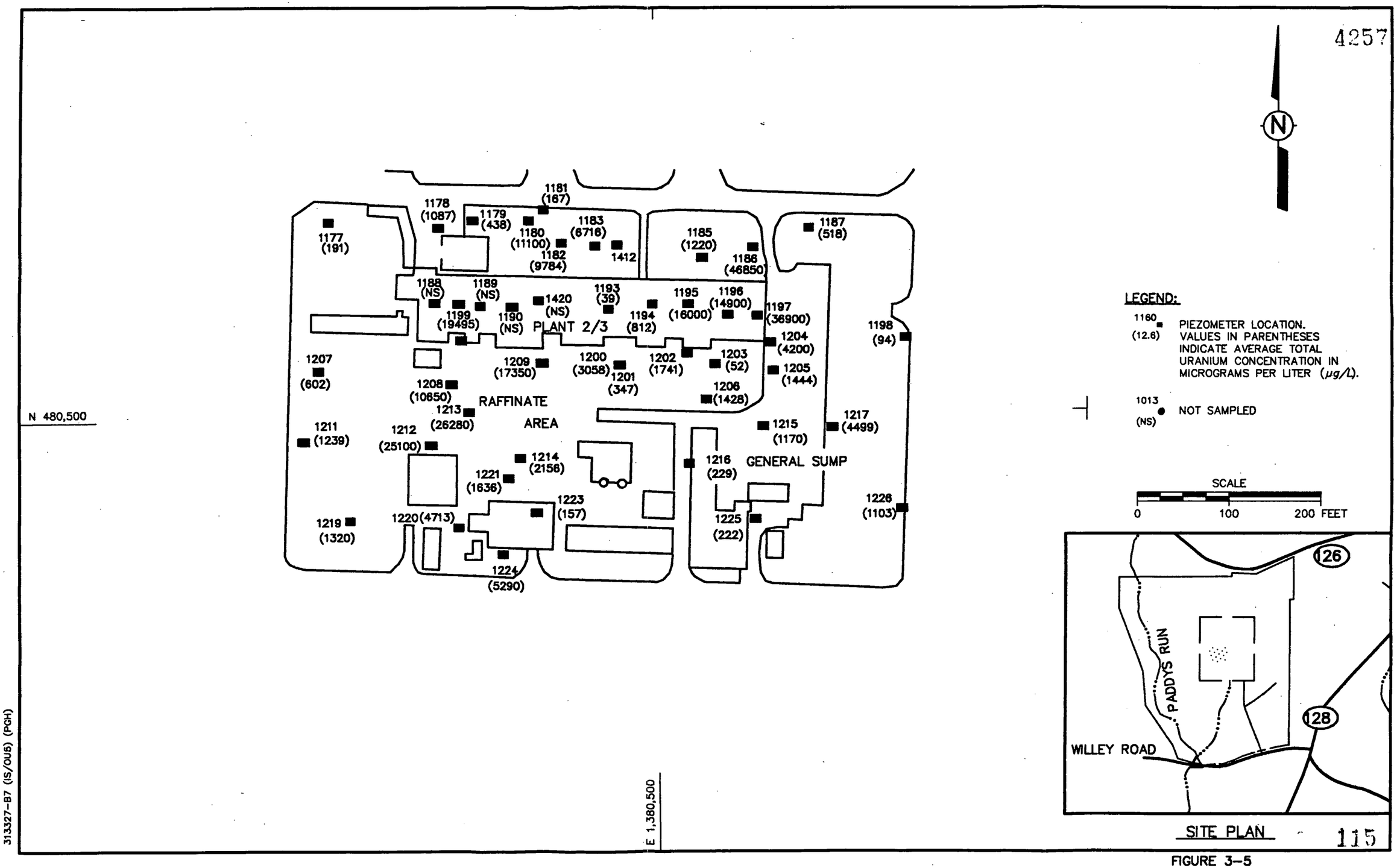


FIGURE 3–5
AVERAGE URANIUM CONCENTRATION IN GROUNDWATER
1000–SERIES WELLS
FORMER PRODUCTION AREA OF THE FEMP PLANT 2/3
AND VICINITY
APRIL 1989 – JANUARY 1990

water table. The 3000-series wells have 10 feet of screen approximately near the middle of the aquifer. The 4000-series wells have 10 feet of screen near the bottom of the aquifer. Both the perched groundwater and the regional aquifer, which are collectively referred to as groundwater, have been investigated as part of Operable Unit 5.

A summary of the RI/FS and RCRA groundwater data is presented in Appendix A, Tables A-1 through A-14. These tables contain radiological, metal, organic, and general chemistry data for the perched groundwater zone and the Great Miami Aquifer. Complete data sets will be provided in the Operable Unit 5 RI report.

Groundwater quality in the vicinity of the FEMP was statistically compared to background water quality, which was established based on chemical characteristics identified in selected background monitoring wells. Background wells were selected to reflect groundwater quality not influenced by operations at the FEMP. An upper tolerance limit (UTL) was calculated for each constituent detected in the background water samples. Groundwater quality observed from the other monitoring wells or piezometers are then compared to the UTL for each constituent. The strategies of background well selection are different for the glacial overburden and the sand and gravel aquifer monitoring and are addressed separately. The statistical analysis followed the methods outlined in the RI/FS Work Plan Addenda (DOE 1992b). Since the hydrogeological setting of the perched groundwater zone is different from the Great Miami Aquifer, discussions of groundwater quality in these two hydrogeological systems are presented separately in this section.

This Operable Unit 5 ISA report relies on the background groundwater quality characteristics developed and presented in the Sitewide Characterization Report (DOE 1992a). Since the issuance of that comprehensive document, the adequacy of the wells selected as representative of background conditions has been questioned by the EPA and the OEPA. Efforts are under way at this time to reevaluate the selection of representative background wells, validate the completeness and quality of these data, and review the statistical procedures used to characterize background groundwater quality.

Although a new set of background chemical characteristics will be developed that may be more complete, reliable, and representative of the FEMP area background conditions, these new values are not available for incorporation into this Operable Unit 5 ISA Report. For the purpose of background discussion in this report, the Operable Unit 5 ISA will consider those background groundwater conditions presented in the Sitewide Characterization Report (DOE 1992a). The revised background groundwater conditions will be reviewed and adopted for use in future Operable Unit 5 reports for the RI and the FS.

3.4.1 Perched Groundwater Quality

Since perched groundwater zones are isolated and are not completely interconnected in the vicinity of the FEMP, groundwater defined as upgradient may not be absolutely suitable to establish background water quality. Thus, wells that are considered to produce typical water quality for perched groundwater were selected as background wells. As such, Monitoring Wells 1024, 1052, 1059, 1060, and 1065 are designated as background wells for glacial overburden groundwater. These wells are located in areas that are not likely to have been impacted by FEMP activities. Radiological and nonradiological constituents detected in samples from these wells are summarized in Appendix A, Table A-1. Locations of 1000-series perched zone monitoring wells and piezometers are illustrated in Figures 3-1 through 3-5. As discussed in Section 3.4, revised and validated background groundwater data are projected for use in later stage Operable Unit 5 Reports.

Radiological constituents detected in background samples include Radium-228, Thorium-228 and -230, Uranium-234 and -238, total thorium, and total uranium. With the exception of uranium species, detections of these constituents were inconsistent and their concentrations were low. Total uranium has the highest frequency of detection, 19 of 27 samples. Uranium concentrations in these samples ranged from 0.8 to 11 µg/L.

Calcium is the dominant cation constituent in background samples, followed by magnesium, sodium, and potassium. Average concentrations of these constituents in background samples are 98.9, 35.7, 23.1, and 6.8 mg/L, respectively. Sulfate is the dominant anion constituent in background perched groundwater, followed by chloride and fluoride. Average concentrations of these constituents are 72.9, 8.81, and 0.71 mg/L, respectively. Organic compounds present in background water samples include acetone, carbon disulfide, methylene chloride, n-nitrosodiphenylamine, and phenols. Detections of acetone and methylene chloride in background samples were most likely related to laboratory contamination, since they are common laboratory contaminants and the detections were either below the detection limits or were associated with a laboratory method blank detection. With the exception of these two compounds, concentrations of organic compounds detected in background samples ranged from 0.002 to 0.04 mg/L.

3.4.1.1 Radiological Constituents

Uranium is the most widespread radiological constituent in the perched groundwater. Wells containing total uranium and uranium isotopes above the UTLs and their average concentration ranges are listed in Appendix A, Table A-2. Isotopic uranium data are used to examine uranium isotopic ratios in groundwater. Among the four isotopes, Uranium-234 and -238 dominate the perched groundwater at the FEMP. The observed Uranium-238/Uranium-234 ratios in the majority of the perched groundwater samples that showed elevated uranium concentrations are generally greater than one. This usually indicates deviation from naturally occurring source-related contamination.

The UTL of total uranium calculated from background samples is 6 µg/L. Average concentrations of total uranium in groundwater sampled from the piezometers located in the former production area ranged from 7 to 568,000 µg/L. The maximum concentrations were found in samples collected from Well 1324, which is located in the Plant 9 area. A large area with total uranium concentrations of above 1000 µg/L was observed in perched groundwater beneath the Plant 2/3, Plant 6, and Plant 8 areas, which are all located in the southern half of the former production area.

Elevated average total uranium concentrations in shallow groundwater samples collected from the waste storage area ranged from 7 to 11,500 µg/L. Groundwater collected from two wells located southwest of the former production area, Wells 1020 and 1523, also contained uranium, at 61 and 17 µg/L, respectively.

Samples collected from all of the eight piezometers located in the fire training area showed elevated total uranium concentrations ranging from 14 to 117 µg/L. A water sample collected from the oil-fire pond during May 1990 revealed the highest total uranium concentration found in any water sample from the area. Groundwater samples were collected from all six wells located in the vicinity of the sewage treatment plant, Wells 1441 to 1444, 1447, and 1448. Average total uranium concentrations in these wells ranged from 13 to 3230 µg/L. Uranium concentrations in perched groundwater were also found in wells located in the vicinity of South Field; i.e., Wells 1045, 1046, 1047, 1048, 1516, and 1517, and a well situated west of Paddys Run along the southwestern boundary of the FEMP, Well 1518.

Most detections of radium isotopes and thorium isotopes in perched groundwater samples were low level and were not recurrent in most of the wells. As shown in Appendix A, Table A-3, among the samples collected from 1000-series wells, repeated detections of one or more of these constituents occurred in 31 wells. In addition to these wells, these radionuclides were also detected in the sample collected from each of 31 other 1000-series wells as shown in Table A-3. The majority of these 62 wells are located in the former production area and the waste storage area. Perched groundwater samples collected from piezometers located in the vicinity of the fire training area showed detections of Radium-226 and thorium isotopes. Concentrations of these constituents detected in these wells ranged from 1.21 to 5.93 pCi/L. Groundwater samples collected from the wells located in the vicinity of the sewage treatment plant showed detections of Radium-226, Technetium-99, and thorium isotopes. Samples from Well 1046, which is located north of South Field, also contained repeated detections of Thorium-228 and Thorium-230 with concentrations ranging from 1.1 to 7.8 pCi/L. At Well 1020, located southwest of the former production area, Radium-226, Thorium-228, and Thorium-230 were detected with average concentrations of 1.125, 0.88, and 0.734 pCi/L, respectively. The source of these detections cannot be stated conclusively.

Total thorium was detected only once, at 3 µg/L, out of the 13 samples from the background wells. Average concentrations of total thorium in the other 1000-series wells ranged from less than the detection limit to 370 µg/L. Wells containing average total thorium concentrations above 3 µg/L and their concentration ranges are stated in Table A-2. As with the radiological constituents discussed previously, samples from 1000-series wells in the vicinity of the waste storage area, the former production area, the sewage treatment plant, the fire training area, and South Field contained total thorium concentrations that were above the level of the only detection in background samples.

Cesium-137, plutonium isotopes, and ruthenium-106 were not detected in any RI/FS and RCRA perched groundwater samples. Neptunium-237 and uranium-235 were respectively detected in one sample from Wells 1035 and 1032. Detections of Strontium-90 in perched groundwater were sporadic and inconsistent. However, Strontium-90 was detected in the only sample collected from Wells 1221, 1411, and 1643, with concentrations ranging from 5.35 to 15.9 pCi/L (Table A-3). Wells 1221 and 1411 are located in the former production area, and Well 1643 is located in the waste pit area.

3.4.1.2 Metals

Metals detected in perched groundwater are summarized in Tables A-4 through A-7 of Appendix A. Twenty-one metals were detected in background perched groundwater under the ongoing RI/FS and RCRA sampling (Table A-4). Arsenic, cobalt, and molybdenum were only detected once among these samples. The concentrations of these single detections were used as the UTLs. Wells containing average metal concentrations above these UTLs and their average concentration ranges are listed in Table A-5.

As with the background samples, calcium is the dominant cation in perched groundwater from the other 1000-series wells, followed by magnesium, sodium, and potassium. Although not reported in background samples, antimony, osmium, selenium, silicon, and thallium were detected in the other 1000-series wells. However, molybdenum was detected in background samples, but not detected in the other 1000-series wells. Detections of most trace or heavy metals were near the method detection limits or nonrecurrent. The majority of these nonrecurrent, low-level detections may be due to analytical uncertainty. However, occurrences of various metals in the waste storage area, former production area, sewage treatment plant, and fire training area may be associated with former production activities.

Above background concentrations of most metals were reported in a number of wells located in the waste storage area and the former production area (Table A-5). In addition, groundwater samples from wells located in South Field, Wells 1016, 1046, and 1058, contained above background concentrations of barium and/or calcium. Selenium was also detected in Wells 1016 and 1046. Samples from wells in the sewage treatment plant area contained elevated concentrations of aluminum, calcium,

manganese, and sodium. Elevated concentrations of aluminum, calcium, and manganese were also found in various wells located in the fire training area. Samples from wells located northwest of the FEMP property, Wells 1040, 1058, and 1059, contained above background concentrations of arsenic, barium, copper, and iron that may not be related to the activities of the FEMP.

3.4.1.3 General Chemical Parameters

This section discusses anions, total Kjeldahl nitrogen (TKN), total organic halides (TOX), and total organic nitrogen (TON) in perched groundwater at the FEMP site. Although analyses of TKN, TOX, and TON are related to organic compounds, these parameters are included in this section to characterize general organic chemistry in groundwater samples. The UTLs for general chemical constituents detected in background samples were calculated and are listed as follows:

- Ammonia - 0.362 mg/L
- Nitrate - 0.341 mg/L
- TKN - 0.959 mg/L
- TON - 0.403 mg/L
- Chloride - 40.1 mg/L
- Phosphorus - 0.488 mg/L
- TOC - 13.0 mg/L
- Fluoride - 1.62 mg/L
- Sulfate - 211 mg/L
- TOX - 0.066 mg/L

Wells containing average concentrations of these parameters that exceeded the UTLs are listed in Table A-6.

Although concentrations of general chemical constituents were quite variable, most of the maximum concentrations occurred in samples from wells located in the waste storage area (Table A-6). Elevated concentrations of ammonia, chloride, fluoride, nitrate, phosphorus, sulfate, TKN, TOX, and TON were found in various wells located in the waste pit area. A sulfide concentration of 4.26 mg/L was also detected in a sample from Well 1025 located south of waste pit 5. Elevated ammonia, chloride, nitrate, TKN, TOC, and TOX were reported in samples from Well 1031, located in the vicinity of the Clearwell. Cyanide was also detected in a sample from this well. Groundwater from Wells 1039, 1041, and 1042, which are located in the vicinity of the lime sludge ponds, contained elevated chloride, TKN, and/or TON. At Wells 1029, 1032, and 1034, which are located in the vicinity of Silos 1 and 2, groundwater had elevated nitrate concentrations. Elevated concentrations of chloride and sulfate were also found in samples from Well 1032.

The most common constituents detected above background in the former production area were nitrate, cyanide, TON, and sulfate (Table A-6). Samples from wells located near the sewage treatment plant and South Field also showed elevated concentrations of nitrate. Elevated concentrations of TKN, TOX, and TON were also reported in South Field. Elevated concentrations of chloride, nitrate, and TKN were found in samples from Wells 1012 and 1124, which are located north and northeast of the former production area, respectively. Groundwater from Well 1012 also contained elevated concentrations of ammonia, ranging from 1.00 to 1.67 mg/L. However, the different groundwater

chemistry revealed by samples from these two wells may not be related to the FEMP. Elevated concentrations of ammonia, TKN, and TON were found in samples from wells located northwest of the FEMP property, Wells 1040 and 1058. Again, these elevated concentrations may not be related to the FEMP.

3.4.1.4 Organic Compounds

Compared to background samples, a greater variety of organic compounds were detected in samples from the other 1000-series wells (Table A-7 of Appendix A). Only volatile organic compounds (VOC); semivolatile organic compounds (SVOC); and a pesticide, heptachlor epoxide, were detected in these samples; polychlorinated biphenyls were not found in any sample. Although found in samples from many wells, detections of acetone, 2-butanone, and methylene chloride were generally low level and associated with detections in the method blanks.

As shown in Table A-7, a variety of VOCs and SVOCs were detected in samples from Wells 1031 and 1643, which are located in the Clearwell and burn pit areas, respectively. Carbon disulfide, n-nitrosodiphenylamine, and phenol were detected in a sample collected from Well 1052 located in the area of the solid waste landfill. In addition to phenols, 33 other organic compounds were detected in samples from 1000-series wells located in the waste storage area.

Samples from wells in the former production area also contained a variety of VOCs and SVOCs. Specific areas where organic compounds were detected include the vicinity of Plant 6, Plant 2/3, Plant 9, the boiler plant, and the pilot plant. In addition to phenols, 27 VOCs and SVOCs were detected in these areas. A pesticide, heptachlor epoxide, was also detected in a sample from Well 1324, which is located in the vicinity of Plant 9.

Also listed in Table A-7 are a variety of VOCs and SVOCs detected in perched groundwater from wells located in the vicinity of the sewage treatment plant and the vicinity of the fire training area. 1,1-Dichloroethane, 1,2-dichloroethylene, 1,1,1-trichloroethane, and trichloroethene were also found in wells located in the vicinity of South Field, Wells 1016 and 1517.

3.4.2 Great Miami Aquifer Groundwater Quality

Three flow systems of the Great Miami Aquifer converge in the vicinity of the FEMP (Figure 3-6). Groundwater in the Dry Fork Section of the New Haven Trough generally flows from west to east and turns to south following the Paddys Run Outlet. Groundwater in the Shandon Tributary of the New Haven Trough generally flows to the southeast, and groundwater in the Ross Section of the New Haven Trough flows southwest and turns to southeast when it converges with groundwater from the Shandon Tributary. A flow divide exists in the southern portion of the FEMP that separates Dry Fork

Section groundwater from Shandon Tributary groundwater. The location of the divide fluctuates, depending on flow conditions. Therefore, mixing occurs along the divide. A sensitivity analysis using a range of groundwater flow conditions showed that the location of the flow divide can fluctuate up to 750 feet on either side of the divide.

Groundwater from the Ross Section does not enter the FEMP. The divide separating the Ross Section groundwater and the Shandon Tributary groundwater is influenced by pumping of the collector wells located near the big bend of the Great Miami River.

Due to the hydrogeological configuration in the vicinity of the FEMP, wells are grouped prior to the analysis of water quality based on where they are located with respect to the groundwater flow divides. Since groundwater samples from different background areas revealed distinguishable chemical characteristics, background wells are also grouped according to the flow regime described previously. Thus, the background wells, as well as the downgradient monitoring wells, are divided into Dry Fork, Shandon, Dry Fork-Shandon Divide, and Ross groups. Because the lower portion of the Great Miami Aquifer is recharged only by groundwater from the Dry Fork Sction, 4000-series downgradient wells are included in the Dry Fork group. The combination of analytical results from Dry Fork and Shandon background samples were used to construct the UTLs for the Dry Fork-Shandon Divide groundwater chemistry. Background wells designated in these groups are listed as follows:

- Dry Fork background wells - Wells 2036, 2057, and 2123
- Shandon background wells - Wells 2043, 2050, 2056, 2066, and 2105
- Dry Fork-Shandon Divide background wells - Wells 2036, 2043, 2050, 2056, 2057, 2066, 2105, and 2123
- Ross background wells - Wells 2026, 2121, 2122, 3063, 3099, and 3100

As discussed in Section 3.4, revised and validated background groundwater data are projected for use in later stage Operable Unit 5 reports.

The radiological constituents detected in the Dry Fork background samples were thorium-230 and total uranium. In addition to these two constituents, Radium-226 and -228, Technetium-99, and Thorium-228 were also detected in Shandon background samples. It is noted that Technetium-99 is a uranium fission product. Due to its high solubility in water and the nonrecurrent detection in background samples, the detection of Technetium-99 in the background sample was most likely related to laboratory contamination. Finally, radiological constituents detected in Ross background samples included Radium-226 and -228, Thorium-228 and -230, total thorium, and total uranium. Total uranium had the highest frequencies of detections in samples from all background areas.

Calcium dominates the cation concentrations in groundwater samples from all background areas. In Dry Fork and Ross background samples, it was followed by magnesium, sodium, and potassium. In the Shandon background samples, sodium concentrations were generally greater than magnesium concentrations. In Dry Fork and Ross background groundwater, sulfate is the dominant anion, followed by chloride and nitrate. However, in Shandon background groundwater, chloride dominates the anion constituents, followed by sulfate and ammonia.

Concentrations of ammonia and nitrate in samples from Dry Fork and Ross background wells are very different from those in samples from Shandon background wells. Average ammonia concentrations in Dry Fork and Ross background samples were 0.098 and 0.077 mg/L, respectively, while the average ammonia concentration in Shandon background samples was 2.81 mg/L. Average nitrate concentrations in Dry Fork and Ross background samples were 5.34 and 5.35 mg/L, respectively, while the average nitrate concentration in Shandon background samples was 0.25 mg/L. These differences indicate that the Shandon Tributary of the Great Miami Aquifer is a chemically reduced environment relative to Dry Fork and Ross background areas. Similar indications are also revealed by the differences of iron and manganese between Dry Fork and Ross Background samples and Shandon background samples.

Phenols are the most widespread organic compounds in samples from wells located in all background areas. In addition to phenols, acetone, methylene chloride, n-nitrosodiphenylamine, toluene, and bis(2-ethylhexyl) phthalate were detected in Shandon background samples. However, concentrations of these compounds were generally low and might be related to laboratory contamination.

3.4.2.1 Radiological Constituents

Upper tolerance limits of radiological constituents detected in background samples were calculated and are listed as follows:

- Dry Fork background;
  - Thorium-230 - 2.1 pCi/L
  - Total uranium - 1 µg/L
- Shandon background
  - Radium-226 - 1.75 pCi/L
  - Technetium-99 - 36 pCi/L
  - Thorium-230 - 2.5 pCi/L
  - Radium-228 - 4.8 pCi/L
  - Thorium-228 - 1.8 pCi/L
  - Total uranium - 2 µg/L
- Dry Fork - Shandon Divide background:
  - Radium-226 - 1.4 pCi/L
  - Technetium-99 - 36 pCi/L
  - Thorium-230 - 1.4 pCi/L
  - Radium-228 - 4.8 pCi/L
  - Thorium-228 - 0.95 pCi/L
  - Total uranium - 2 µg/L

- Ross background:
  - Radium-226 - 1.1 pCi/L
  - Thorium-228 - 1.4 pCi/L
  - Total thorium - 5 µg/L
  - Radium-228 - 4.6 pCi/L
  - Thorium-230 - 1.4 pCi/L
  - Total uranium - 1 µg/L

Radiological constituents detected in 2000, 3000, and 4000-series (Figures 3-7, 3-8, and 3-9) well groundwater are summarized in Tables A-8 and A-9 of Appendix A. Uranium is the most widespread contaminant in the Great Miami Aquifer, as in perched groundwater. Concentrations of uranium in the regional aquifer groundwater in the FEMP area were generally lower than uranium concentrations found in perched groundwater. Wells containing total uranium and uranium isotopes above the UTLs and their average concentration ranges are included in Table A-9. Uranium-234 and -238 are the dominant uranium species in the regional aquifer at the FEMP.

Statistically elevated uranium concentrations were found in groundwater samples from wells located in the waste storage area, the former production area, South Field, along Paddys Run, along the SSOD, and other locations. Average concentrations of total uranium in samples from these wells ranged from 2 to 580 µg/L . The highest concentrations of total uranium were found in a well located northwest of South Field; Well 2046; and a well located along the SSOD, Well 2387.

Elevated total uranium concentrations were also found in groundwater from wells along Paddys Run between the K-65 silos and its confluence with the SSOD, Wells 2009, 2018, 2044, 2047, 2107, 2108, 3009, 3108, and 4108. Consistently elevated uranium concentrations, ranging from 212 to 258 µg/L, were found in samples from Well 2397, which is located in the vicinity of the Storm Water Retention Basin.

Total thorium was not detected in any samples from wells located in the Dry Fork and Shandon background areas. Total thorium was detected in samples from wells located in the waste storage area, the former production area, South Field, along the SSOD, and the downgradient area from the local industries south of the FEMP property (Table A-9). Additionally, total thorium was also detected in wells located outside or upgradient of the FEMP property. Repeated detections of total thorium were found in samples from Wells 2045, 2020, 2127, 3069, and 3125. Well 2045 is located in the vicinity of South Field, and Well 3069 is situated along the southern boundary of the FEMP property. Wells 2127 and 3125 are both located along the Paddys Run south of the FEMP property. Well 2020 is located southwest of the former production area. Total thorium concentrations detected in these five wells ranged from 2 to 10 µg/L.

The majority of detections of radium isotopes, Technetium-99, and thorium isotopes in samples from 2000, 3000, and 4000-series wells were low level and were not recurrent. Wells containing repeated detections of these constituents are listed in Table A-8. Additionally, Technetium-99, Thorium-228,

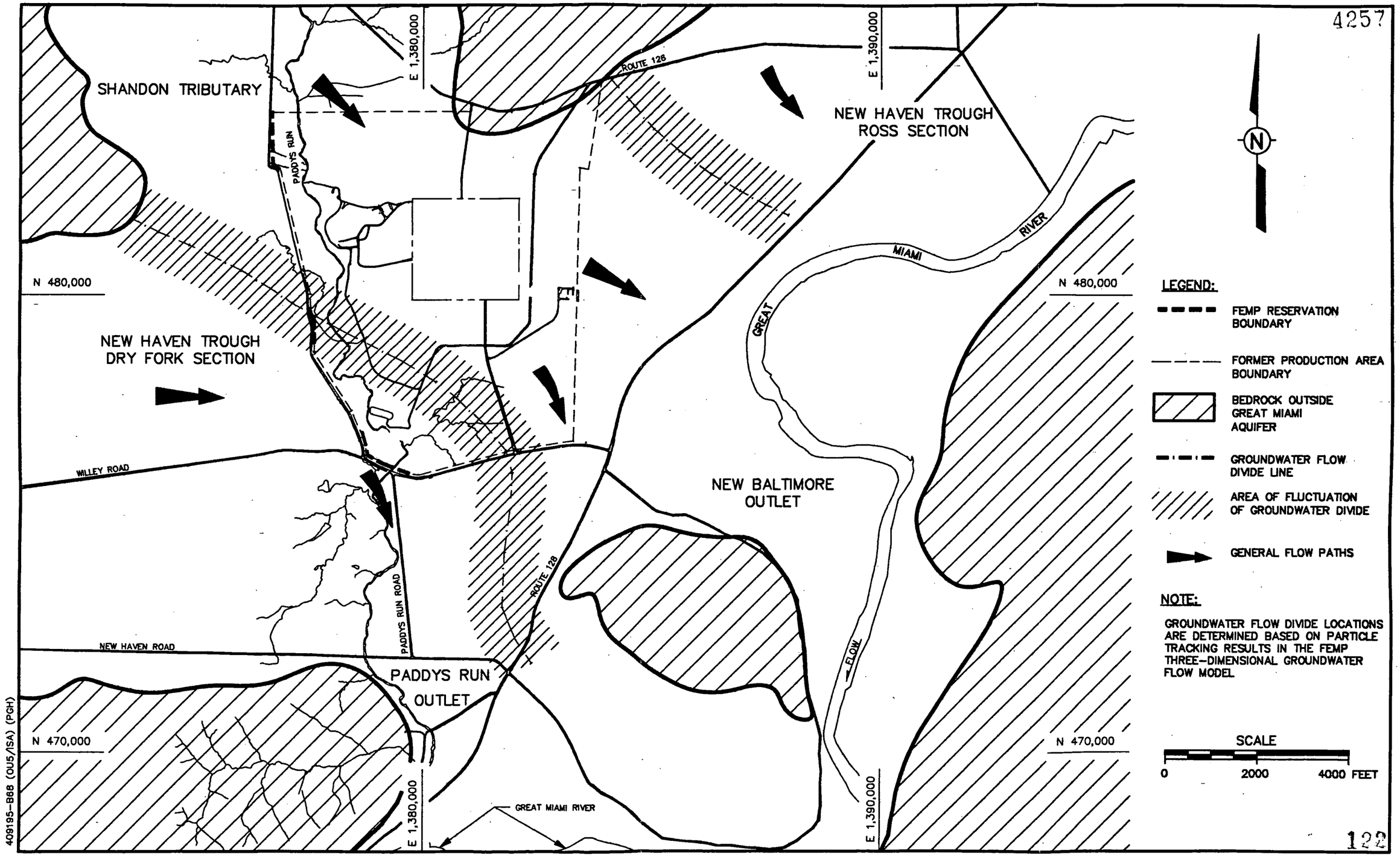


FIGURE 3-6
GROUNDWATER FLOW DIVIDES

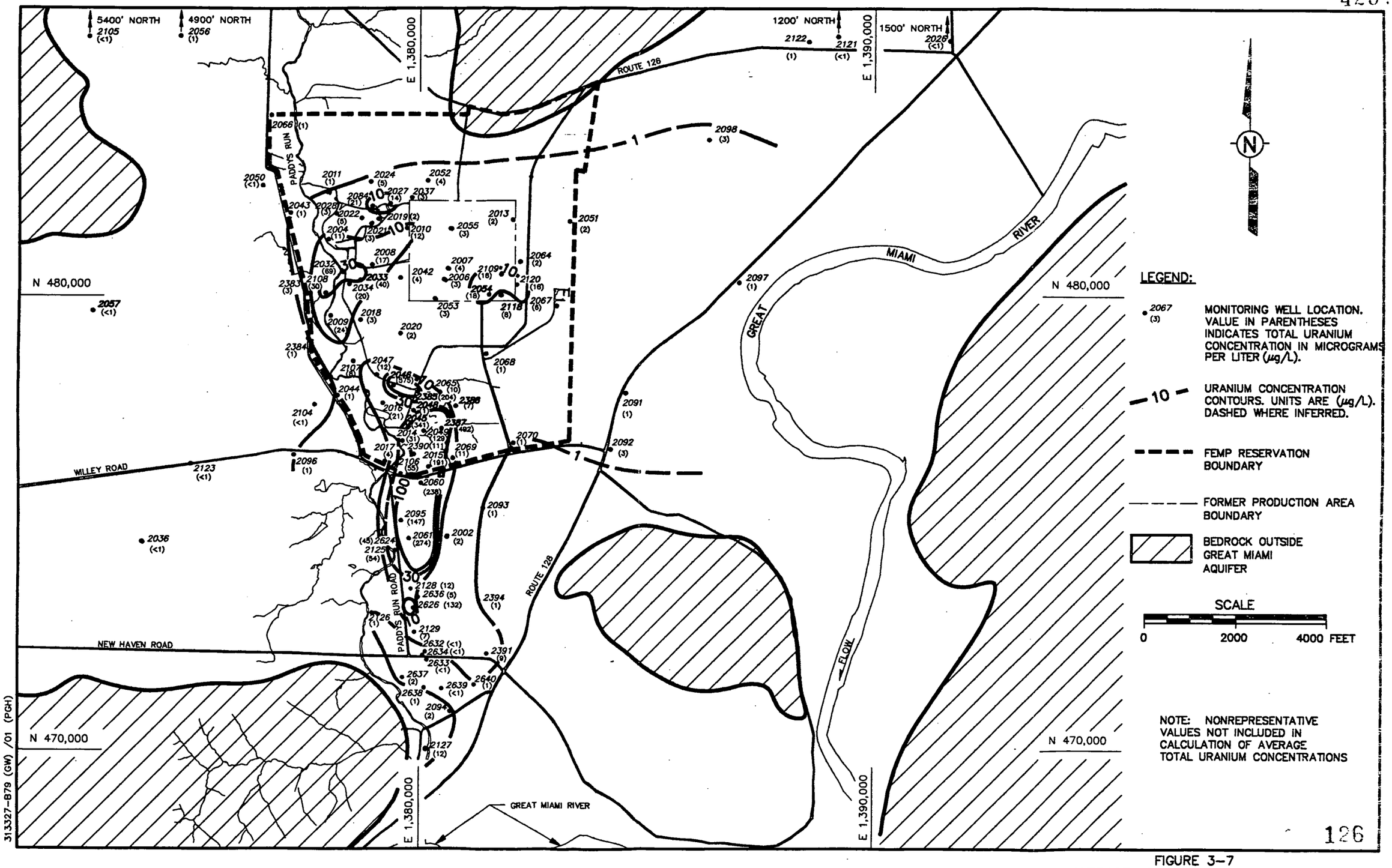


FIGURE 3-7
AVERAGE URANIUM CONCENTRATION
IN GROUNDWATER
2000 SERIES WELLS
SECOND QUARTER 1988 THROUGH
SECOND QUARTER 1990

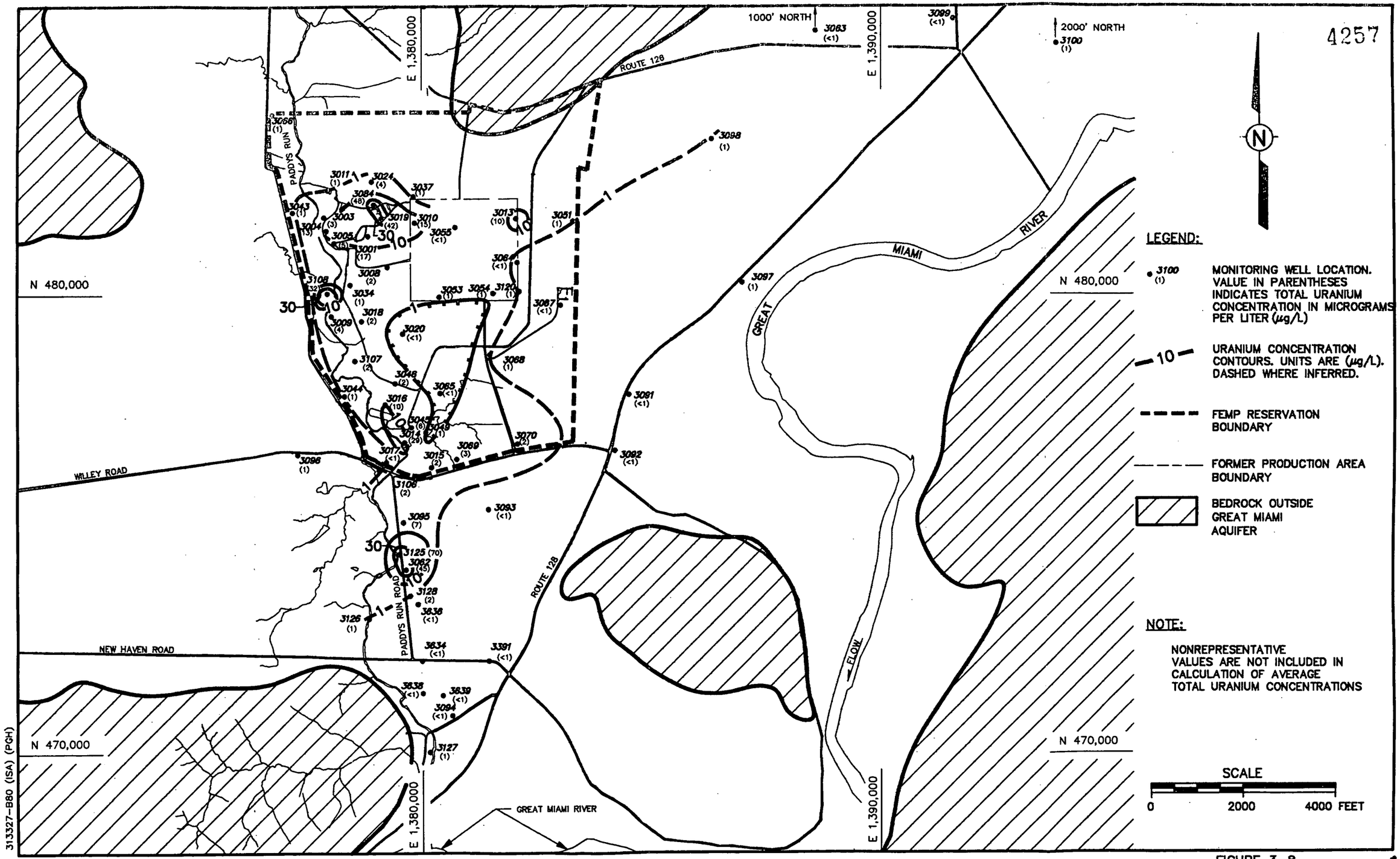


FIGURE 3-8
AVERAGE URANIUM CONCENTRATION
IN GROUNDWATER, 3000 SERIES WELLS
SECOND QUARTER 1988 THROUGH
SECOND QUARTER 1990

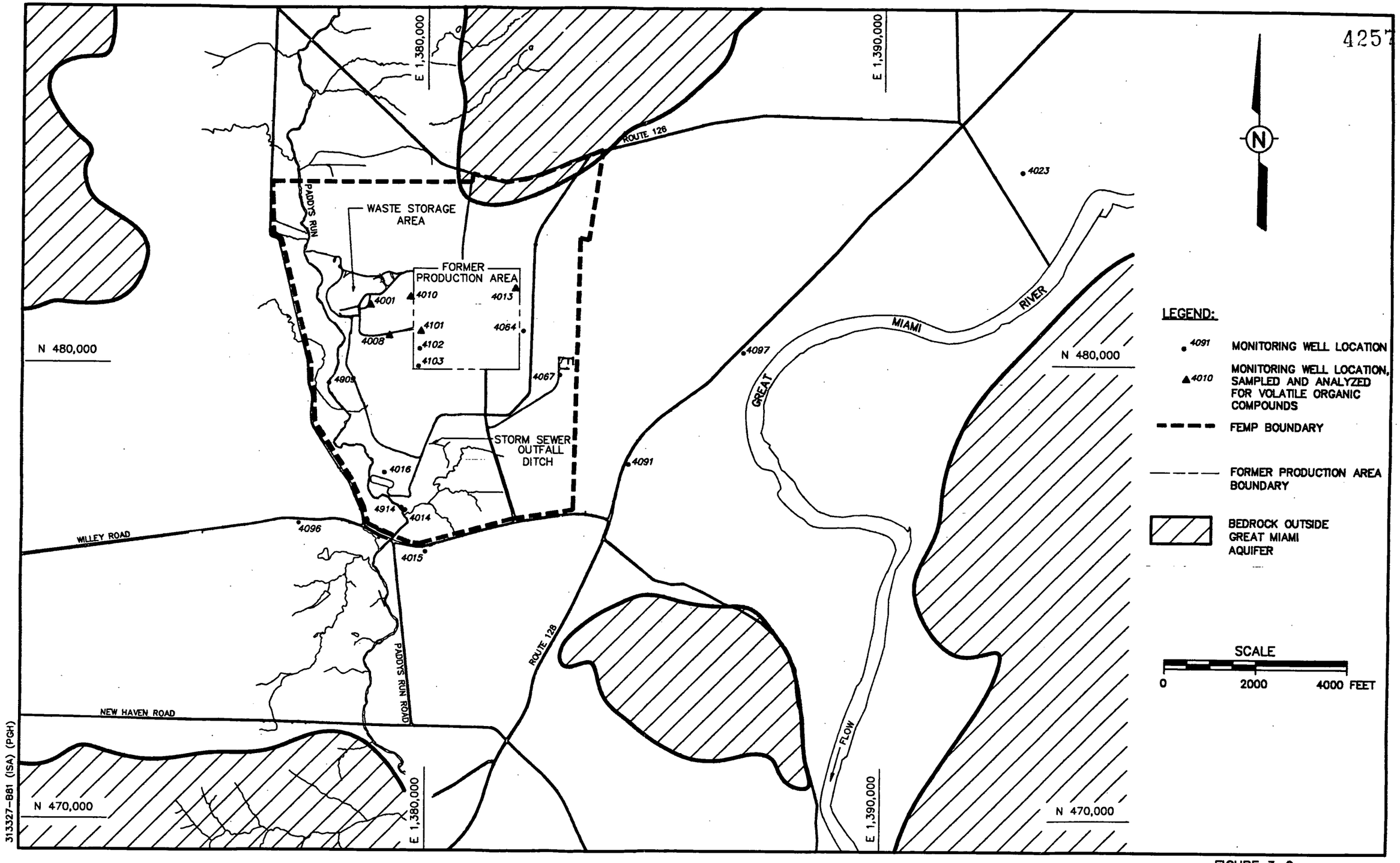


FIGURE 3-9
LOCATION OF THE 4000-SERIES WELLS AT THE FEMP

and/or Thorium-230 were also detected in the only sample collected from Wells 2032, 2385, 2554, 2643, 2649, and 3390.

Samples from wells located in the vicinity of South Field along the SSOD and Paddys Run, downstream from its confluence with the SSOD, had repeated detections of Radium-226 and -228 and Thorium-228 and -232. Among these constituents, Radium-226 and Thorium-228 were repeatedly detected in samples from Well 2561, which is located approximately 1.5 miles south of the southern boundary of the FEMP. In addition to these locations, Radium-226 was repeatedly detected in samples from Wells 3055 and 4101, located in the former production area, and Wells 3043 and 3066, located along the northwestern boundary of the FEMP property. Concentrations of Radium-226 in these samples ranged from 1.1 to 8.5 pCi/L. Repeated detections of Radium-228 also occurred in samples from Well 2044 located along the southwestern boundary of the FEMP property. Thorium-228 and -230 were repeatedly detected in the only sample collected from Wells 2022 and 2032, and Thorium-228 was also repeatedly detected in samples from Well 2018. Well 2032 is located in the vicinity of the K-65 silos, and Wells 2018 and 2020 are located southwest of the former production area.

Samples from wells located in the waste pit area contained consistent detections of technetium-99 with concentrations ranging from 123 to 5510 pCi/L. Technetium-99 was also detected in the only sample collected from Well 3390 located immediately downgradient from the confluence of Paddys Run and the SSOD.

Cesium-137, plutonium isotopes, Ruthenium-106, and Uranium-235 were not detected in any RI/FS and RCRA samples. Neptunium-237 was detected in only one sample collected from Well 2004 at 1.0 pCi/L. Detections of Strontium-90 in the regional aquifer groundwater were sporadic and inconsistent. Repeated detections of Strontium-90 occurred only in samples from Wells 2021 and 2128, with concentrations ranging from 7.61 to 38.5 pCi/L (Table A-8). The only sample collected from Well 2649 was also found containing Strontium-90 concentration of 6.8 pCi/L. Well 2128 is located along Paddys Run Road south of the FEMP property, and Wells 2021 and 2649 are situated in the waste pit area. As addressed previously, repeated detections of Strontium-90 also occurred in perched groundwater collected from the waste pit area.

3.4.2.2 Metals

Metals detected in the 2000, 3000, and 4000-series (Figures 3-7, 3-8 and 3-9) well groundwater are summarized in Table A-10 of Appendix A. The UTLs calculated from background samples are listed in Table A-11. Above background concentrations of a variety of metals were found in samples from the 2000, 3000, and 4000-series wells in the waste storage area, the former production area, the South Plume, and other areas (Table A-10).

3.4.2.3 General Chemical Parameters

The UTLs of these parameters calculated from background samples are included in Table A-12. Wells with groundwater samples containing above background concentrations of these chemicals are listed in Table A-13. Although analyses of TKN, TOC, TOX, and TON are related to organic compounds, discussions of these parameters are included in this section to characterize general organic chemistry in groundwater samples. As with radiological constituents and metals, above background concentrations of general chemical parameters are present in groundwater samples from a variety of areas on and adjacent to the FEMP.

Nitrate, phosphorus, and sulfate were commonly detected above background in the waste storage area, while sulfate, phosphorus, and sulfide were common in the former production area (Table A-13). Phosphorus, sulfate, TOC, TOX, and TON were commonly present above background in South Plume samples. In other areas of the FEMP, phosphorus, sulfate, and sulfide were the most common general chemical parameters detected above background.

3.4.2.4 Organic Compounds

Fourteen VOCs, 11 SVOCs, and three pesticides were found in samples from the Great Miami Aquifer. PCBs were not detected in any of these samples. Wells where groundwater samples contained organic compounds are listed in Table A-14. The shallower portion of the regional aquifer, monitored by the 2000-series wells, revealed more variety and greater area of organic compound detections than the lower portion of the aquifer that is monitored by 3000- and 4000-series wells. Organic contaminants were mainly found in areas that are associated with the previous production or the waste storage activities. These areas include the former production area, the waste storage area, South Field, and the sewage treatment plant. Detections of organic compounds were also reported in groundwater samples from an area inside and south of the local industries located along Paddys Run Road, south of the FEMP property, and along Paddys Run in the vicinity. This contamination plume has partially overlapped with the South Plume that originated from inside the FEMP property. In addition to these traceable organic contaminations, various organic compounds at low concentrations were also sporadically detected in samples from other areas.

Acetone, 2-butanone, methylene chloride, toluene, and phthalates were found in samples from many wells. However, these compounds are recognized as common laboratory contaminants. With the exceptions of the detections of acetone in Wells 2011 and 2019, methylene chloride in Well 2019, toluene in Well 3001, di-n-butyl phthalate in Wells 2109 and Well 3043, diethyl phthalate in Well 2065, and bis(2-ethylhexyl)phthalate in Well 3043, their concentrations were either lower than the detection limits and/or were reported in conjunction with detections in the associated method blanks. Wells 2011, 2019, and 3001 are located in the waste pit area, and Well 2109 is located in the

former production area. Well 2065 is located south of the storm water retention basin, and Well 3043 is located along the western boundary of the FEMP property west of the waste storage area.

Phenols are the most widespread organic compounds in the Great Miami Aquifer. This is most likely attributable to their high solubilities in water. Phenols were detected in 37 samples out of the 62 samples from the background wells. The UTLs of phenols calculated from background samples for Dry Fork, Shandon, Dry Fork-Shandon Divide, and Ross background wells are 0.034, 0.061, 0.036, and 0.032 mg/L, respectively. The maximum phenols concentration in downgradient wells, 11.5 mg/L, was reported in a sample from Well 3126. However, this analytical result may not be reliable, since the other phenols analytical results in samples from this well ranged from below the 0.01 mg/L detection limit to 0.03 mg/L. Excluding Well 3126, the maximum phenols concentration, 1.2 mg/L, was reported in a sample from Well 3001. Excluding Well 3126, phenols concentrations above the UTLs were found in Wells 2007, 2018, 2037, 2048, 3001, 3044, 4010, 4014, and 4097. Well 2007 is located in the former production area, and Wells 2018, 2037, 3001, and 4010 are located inside of or directly downgradient from the waste storage area. Wells 2048 and 4014 are located in the vicinity of South Field. Well 3044 is located along the southwestern boundary of the FEMP property, and Well 4097 is located near the big band of the Great Miami River.

Detections of other organic compounds were generally low level and inconsistent. Detections of organic compounds with concentrations above the detection limits were found only in wells located in the waste storage area, the former production area, the South Plume, and downgradient from the local industries south of the FEMP property. Wells where groundwater contained above-detection limit concentrations of organic compounds include:

- Well 2007 - Phenol
- Well 2011 - Carbon disulfide, N-nitrosodiphenylamine, 3-nitroaniline
- Well 2015 - 1,1,1-trichloroethane
- Well 2022 - Aldrin, alpha-BHC, Heptachlor
- Well 2027 - Carbon disulfide
- Well 2037 - Carbon disulfide
- Well 2060 - 1,1,1-trichloroethane
- Well 2094 - Benzene, xylene (total)
- Well 2106 - 1,1,1-trichloroethane
- Well 3037 - Phenol

The pesticides aldrin, alpha-BHC, and heptachlor were found only in Well 2022, with concentrations ranging from 0.07 to 1.10 µg/L. Well 2022 is located between Pit 3 and Pit 4 in the waste storage area.

3.5 SOILS

Soils which were evaluated as part of Operable Unit 5 include all soils on the FEMP property which are not specifically included within source-control Operable Units 1, 2, and 4 (Figure 1-3). Therefore, Operable Unit 5 includes all soils both inside and outside the former production area, in addition to those soils found within the nine previously defined suspect areas (Figure 1-11). Contaminated soils outside the FEMP boundary are also within the framework of Operable Unit 5.

For the purpose of this discussion, uranium concentrations of primary concern in soil defined for this operable Unit 5 report consists of a concentration equal to or greater than 35 pCi/g. The text also uses "above the PRG level" to describe contamination. The PRG level for uranium in soil is 35 pCi/g.

In general, uranium concentrations in soils outside the former production area are not above 35 pCi/g. Soils inside the former production area contain elevated levels of uranium in many locations between 35 and 135 pCi/g, or greater. The lower end of this range was established by the NRC in its 1981 NRC Branch Technical Position Paper. In this paper, the NRC determined that 35 pCi/g of uranium activity in soils was a guideline for allowing public use of land. Based on the specific activity of uranium in soils at the FEMP, 35 pCi/g of uranium activity is approximately equal to 50 micrograms per gram (µg/g). The upper limit in this range originated during the initial RI/FS site characterization efforts when OU3 personnel developed a strategy to delineate uranium concentrations in soils in the former production area (soils in the former production area were part of the OU3 scope prior to the Amended Consent Agreement of December 19, 1991 when these soils were incorporated into the OU5 scope). Based on soil sampling data, contour lines were generated to pinpoint high and low levels of uranium in soil. Through the results of these contouring efforts, a conclusion was made that most uranium levels fell below 200 µg/g, which based on the activity of uranium at the FEMP, converts to 135 pCi/g. In essence, 135 pCi/g came to be OU3's method of delineating "hot spots" by serving as an upper bound for most uranium concentrations in soils in the former production area.

This strategy and its results served as a method of presenting uranium in soil for OU3's ISA and RI reports. Once these soils in the former production area became part of the OU5 scope, it was decided to incorporate OU3's method and results for defining uranium in soil in the former production area into the OU5 ISA report. Hence, this report will also use 135 pCi/g as an upper bound for uranium in soil, consistent with the past OU3 philosophy. The 135 pCi/g level will merely be a tool in qualitatively defining the level of uranium contained in soils in the former production area and in presenting the data. It is not in any way regulatory driven. At the present time, formal EPA or DOE standards have not been established for uranium in soil.

3.5.1 Former Production Area and Suspect Area Soils

An examination of the RI data collected from sampling activities in the former production area reveals that the majority of soils containing uranium at levels exceeding 35 pCi/g are from the uppermost 1.5 feet of surficial material. With respect to surface area, approximately 50 percent of the former production area soils contain uranium concentrations exceeding 35 pCi/g. Table A-15 details locations (Figure 3-10), depths, and levels of uranium concentrations in the former production area.

As was previously described, the RI/FS soil sampling program includes the analysis of a number of samples for several radionuclides in addition to total uranium. Table A-16 presents the maximum detected concentration of each of these constituents in each of the quadrants, as well as in the fire training area, incinerator/sewage treatment plant area, and along the Clearwell K-65 slurry lines. Samples were analyzed for isotopes of uranium, thorium, radium, plutonium, cesium, technetium, strontium, and neptunium. Background values for each of these constituents are also presented in Table A-16. Each of the isotopes included in the analysis was detected at least once in the former production area. In all but a few instances, the maximum detected concentration in each area exceeds the background concentration of that radionuclide.

A more detailed description of radionuclides in soils is presented in Table A-17. The maximum detected concentration of Uranium-234, -235/236 and -238, Thorium-230 and -228, and Radium-226 and -228 is presented for each specific area within a given quadrant. These results indicate that each of these isotopic radionuclides is widely distributed throughout the former production area. The remaining radionuclides presented in Table A-16, including Cesium-137, Technetium-99, Strontium-90, Neptunium-237, Plutonium-238, and Plutonium-239/240, are not as prevalent across the site, nor do they generally occur at such high concentrations and, therefore, are not included in Table A-17. In addition, uranium isotopes are so pervasive throughout the former production area and suspect areas that each of the areas of concern identified in Table A-17 is also considered an area of concern with respect to total uranium.

Table A-18 presents the range of detected concentrations of metals in the production and suspect areas. These data are the summary results of the 1988 and 1989 RI/FS Soil Sampling Program. Beryllium and lead are the metals with maximum detected concentrations in excess of PRGs in soil, established to protect human health (Section 3.2). Several of the metals included in the analysis, including aluminum, calcium, cobalt, iron, magnesium, potassium, and sodium, are naturally occurring elements. Because no adverse health effects have been demonstrated with exposure to high concentrations of these metals, no health-based corrective action levels exist. Maximum detected concentrations are, therefore, compared to naturally occurring background concentrations in order to interpret the relative levels of these constituents in the environment. In a few instances, for example, calcium, iron, and magnesium had detected concentrations which were slightly above background levels.

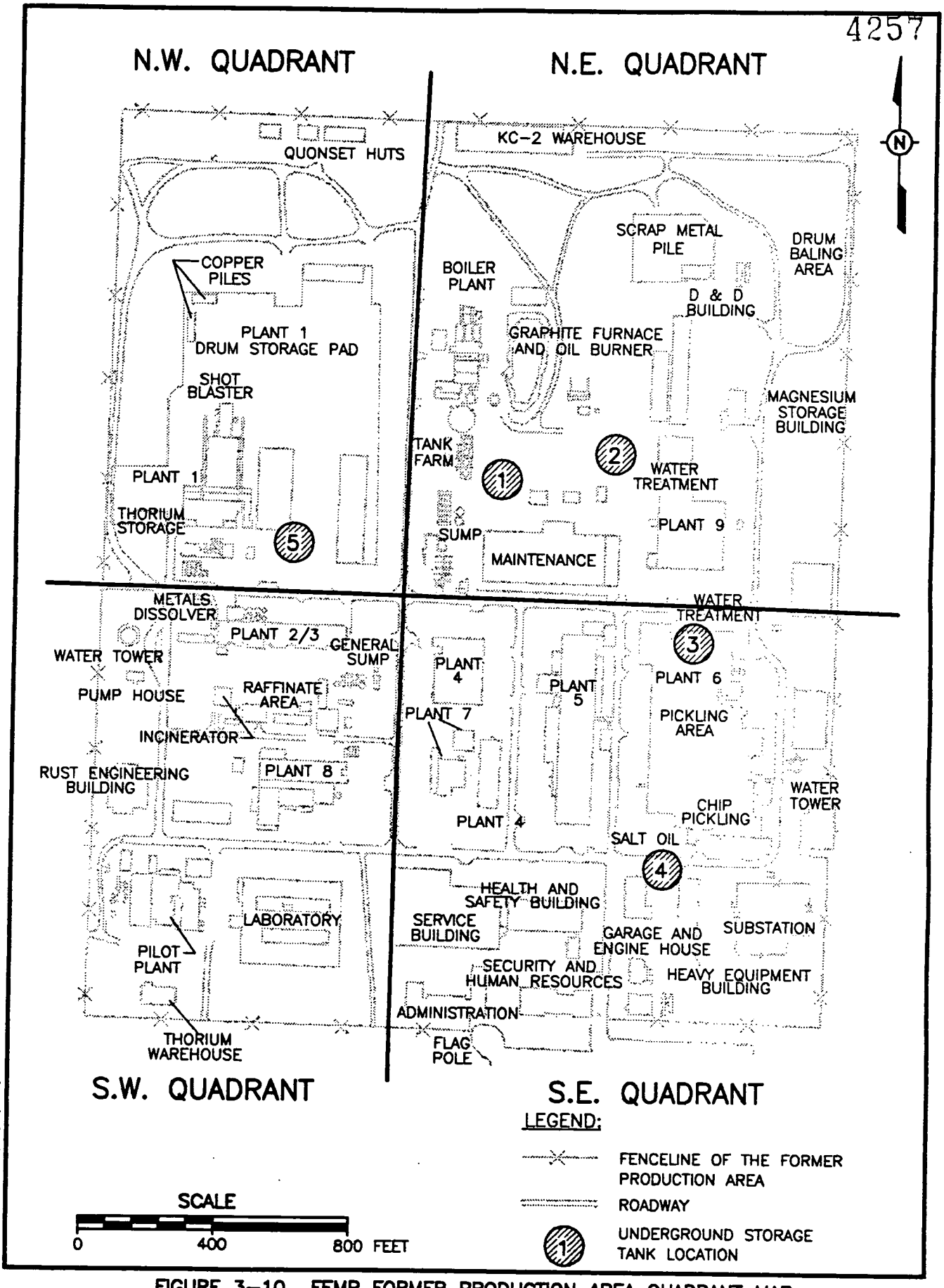


FIGURE 3-10 FEMP FORMER PRODUCTION AREA QUADRANT MAP

The results of the organic analysis of soil samples collected as part of the 1988 and 1989 RI/FS sampling program are presented in Table A-19. Unlike metals, organic chemicals are not naturally occurring, and background concentrations are considered to be zero. Maximum concentrations are, therefore, compared only to the PRG concentration which has been established to protect the health of the public (Section 3.2). Those organic constituents found at high concentrations (relative to the established PRG) include tetrachloroethene, trichloroethene, and benzo(a)pyrene.

Specific areas of nonradiological constituents in soil have been identified on a quadrant basis. Sampling locations with constituent concentrations in excess of their respective soil PRGs were identified and reported in relation to the facility nearest that location. Tables A-20 through A-22 present the nonradiological constituents identified as being above PRG concentrations in the southwest, northeast, and northwest quadrants, respectively. No constituent concentrations were found to be in excess of the PRGs in the southeast quadrant.

In the southwest quadrant, samples were collected in the Plant 2/3 area, the pilot plant area, and the laboratory area (Figure 3-10). Beryllium was detected above the PRG concentration in all areas (Table A-20). Concentrations of lead in excess of the PRG level were also detected in the Plant 2/3 area and the pilot plant area. The latter area also had benzo(a)pyrene, in addition to tetrachloroethene, above PRG levels. Contamination in these three areas extends from the soil surface to a depth of 10.5 feet. Table A-23 presents the depth of sampling associated with each sampling location.

Sampling locations in the northeast quadrant were located in the vicinity of the maintenance building, Plant 9, and the graphite furnace and oil burner area (Figure 3-10). The sampling depths associated with each location are presented in Table A-23. Beryllium was detected at concentrations above the PRG level in both the maintenance building and the graphite furnace and oil burner areas (Table A-21). Concentrations in excess of the PRG level for trichloroethene and benzo(a)pyrene were also identified in the maintenance building area. No constituents were detected in the Plant 9 area at concentrations that exceed the established PRGs. The majority of constituents above their respective PRG levels found within northeast quadrant soils were detected between the (soil) surface and a depth of one foot.

Nonradiological chemical soil sampling in the northwest quadrant was conducted in the shot blaster area (Figure 3-10). Soils were sampled to a depth of two feet. Beryllium was the only chemical constituent which had maximum detected concentrations greater than its PRG (Table A-22).

Soil sampling was also conducted in two of the suspect areas associated with Operable Unit 5, the fire training area and the area along the Clearwell K-65 slurry lines. Soil samples were collected at eight locations in the fire training area (Figure 1-11). Samples were collected at a depth of 2.0 to 2.5 feet.

Beryllium was the only constituent detected at concentrations higher than the associated PRGs (Table A-24). Beryllium was also found at concentrations in excess of the PRG in a sample collected along the Clearwell K-65 slurry lines. This sample was collected at a depth of 14 feet.

Additional RI/FS soil sampling was conducted in the northeast quadrant of the former production area in 1991. The locations that were sampled were concentrated in three areas north of the maintenance building (Sampling Locations 1581 through 1592, excluding 1587), southeast of the maintenance building (Sampling Locations 1601 through 1605), and southeast of Plant 9 (Sampling Locations 1565 through 1570, excluding 1566 and 1567) (Figure 3-10). The samples collected from these locations were analyzed for pesticides, inorganics (northwest and southeast of the maintenance building only), and organic compounds (both volatiles and semivolatiles).

Table A-25 presents the range of detected concentrations for those chemical constituents found in excess of the established PRGs. Beryllium levels above the PRG were found northwest and southeast of the maintenance building. Samples were collected to a depth of 10 feet and 4.5 feet northwest and southeast of the maintenance building, respectively. Areas with concentrations of beryllium above the PRG extended to the maximum depth sampled, while the remaining constituents included in Table A-25 were detected in only the first foot or two of soil. There were no detected concentrations of volatiles, semivolatiles, or pesticides in soils collected to a depth of 16 feet southeast of Plant 9.

The remainder of this section presents a quadrant-based discussion of specific areas within the former production area and suspect areas which, by virtue of the activities in these areas, contain contaminated soils. Total uranium is the major constituent of concern, although other potential chemicals of concern have already been identified. Each specific area of concern within the former production area is discussed in the context of the quadrant (southeast, southwest, northeast, or northwest) in which it is found. Each discussion presents, where possible, the identified contaminant(s) of concern, possible sources of the contamination, area and volume of contamination, level of contamination, and potential access to contaminated soils. Volumes of soils containing compounds above their PRG level and established within this section are utilized throughout the remainder of this document in support of the evaluation of process options and technologies, and in the development, evaluation, and costing of the remedial action alternatives.

In calculating the volumes of uranium impacted soils (Tables A-26 to A-30), those soils with detected uranium concentrations less than 35 pCi/g are not carried forward in the calculations. Those soils having detected uranium concentrations in excess of 35 pCi/g are further divided (for the purpose of calculating soil volumes) into those having detected concentrations below or above 135 pCi/g. In addition, the following quadrant-based discussions of uranium in the former production area present actual data concentration ranges. To clarify where an actual range might fall into the < 35, > 35,

< 135, or > 135 range description, the maximum of the range was used. For example, when the text states that uranium concentrations are between 21 and 72 pCi/g, the maximum of the range, 72 pCi/g, falls between the > 35 and ≤ 135 range. For this example, Table A-26 would indicate uranium levels at a certain depth with a concentration of > 35, and ≤ 135, and this would then be carried forward in the volume calculations. An actual concentration range of 18-33 pCi/g would not be carried forward into the volume calculations. Similarly, a concentration of 73 to 302 pCi/g would be indicated in the tables in Appendix A as an area containing uranium > 135 pCi/g. The basis for this range of uranium concentrations between 35 and 135 pCi/g was explained earlier in Section 3.5.

For the purposes of the following discussions, access will refer to the relative ease of removing contaminated soil materials for treatment and/or disposal. The placement of surrounding facilities, such as plant buildings, roadways, and other structures may limit the volumes of soil that can be safely excavated from a specific location, unless the structure is removed or structurally modified. The potential for unintentional human contact with these contaminated soils is remote because all hazardous waste management units have strict access restrictions (i.e., fencing, posting, etc.).

3.5.1.1 Southeast Quadrant

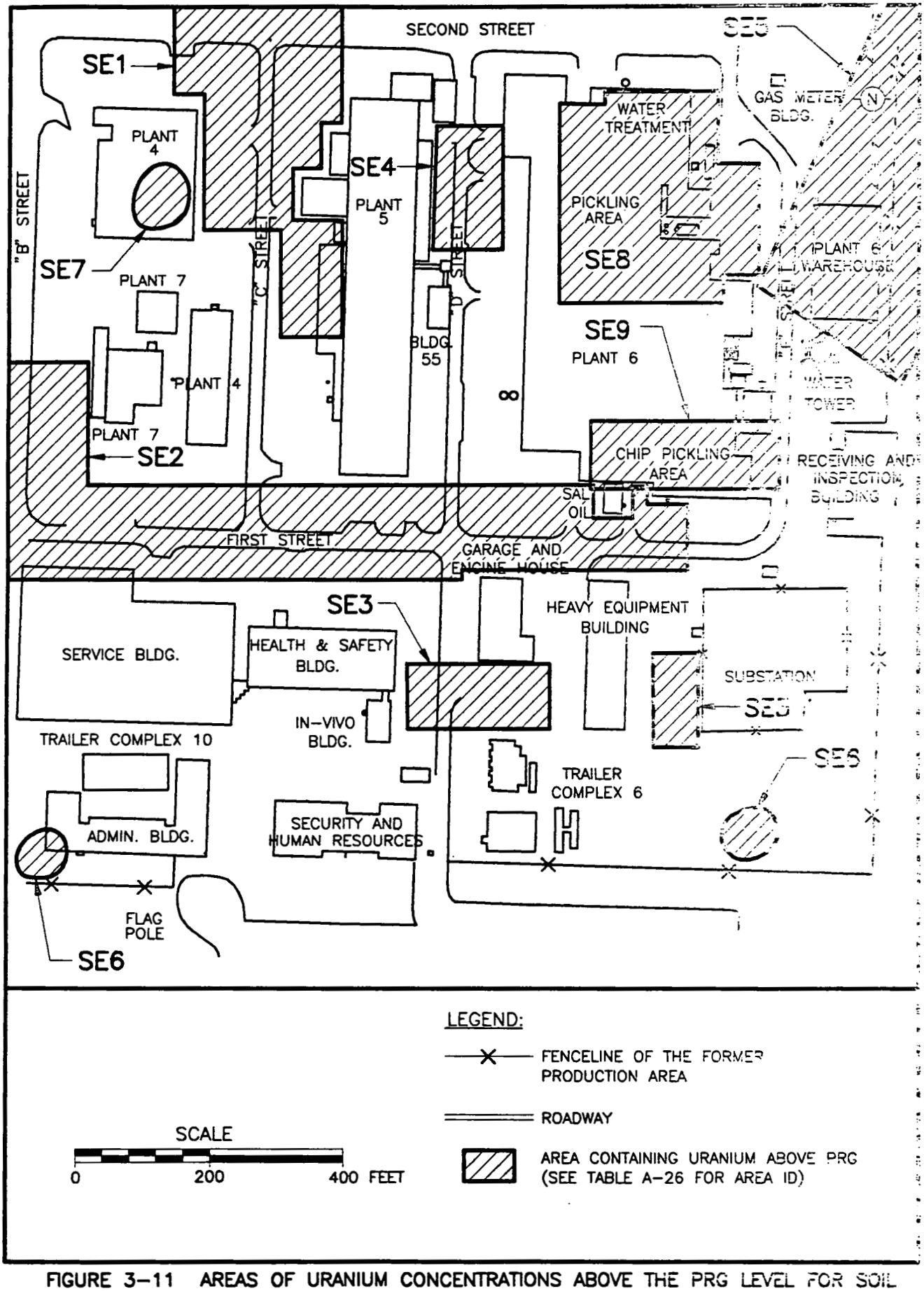
Figure 3-11 illustrates the southeast quadrant areas. The area identification numbers on the figures (i.e., SE1, SE2, etc.) are also referenced in Table A-26 and below, in the area description. Table A-26 lists the areas and volumes of soils containing concentrations of uranium above 35 pCi/g. The volumes in this table were calculated by taking the sum of the volumes at various depths. For example, the volume of soil in the area along First Street (Area SE2) was calculated by taking the sum of the volumes at 0 to 1.5 feet, 1.5 to 3 feet, 3 to 5.5 feet, 5.5 to 10 feet, 10 to 15 feet, and 15 to 20 feet (Table A-26). Thus, the calculation looks like this:

Total Volume = (1550' x 200' x 1.5') + (400' x 100' x 1.5') + (150' x 50' x 2.5') + (150' x 50' x 4.5') + (π [75']^2/4 x 5') + (2'[{50'}^{2}/4 x 5']) = 619,200 cubic feet = 23,000 cubic yards.

It should be noted that these volume calculations of soil impacted by uranium concentrations do not take into account any overburden soil. They are used only to calculate volumes of soil affected by uranium concentrations above 35 pCi/g and do not include soil at lesser concentrations.

3.5.1.1.1 Area Between Plant 4 and Plant 5 (Area SE1, Figure 3-11)

Uranium concentrations in soil above 35 pCi/g appear to have developed in this region from rainwater and air emissions from Plants 4 and 5. Total uranium concentrations between 21 and 72 pCi/g exist in soils at a depth of 0.0 to 1.5 feet. There is one area approximately 50 feet in diameter between 3.0 and 3.5 feet in depth with a uranium concentration of 128 pCi/g. The total volume of soil in this area



409195-A58 (ISA/OU5) (PGH)

FIGURE 3-11 AREAS OF URANIUM CONCENTRATIONS ABOVE THE PRG LEVEL FOR SOIL IN THE SOUTHEAST QUADRANT

that demonstrates uranium concentrations above the PRG level is approximately 7000 cubic yards. This location is an open field area, with limited access to this soil due to surrounding facilities. A note should be made that Table A-15 of this report indicates uranium levels greater than 135 pCi/g in this area. However, Table A-26 does not show such elevated concentrations. A discrepancy as to the actual uranium level in this area presently exists. However, this discrepancy will be resolved in the Operable Unit 5 RI report.

3.5.1.1.2 Area Along First Street (Area SE2, Figure 3-11)

This area encompasses portions of both the southeast and southwest quadrants. The source of the uranium levels above PRG concentrations could be leakage from the sump and trench in the chip pickling room and the catch basin for the salt oil, storm water runoff from the adjacent roadways, and air deposition from Plants 4, 5, 7, and 8 (WMCO 1989b). This area begins south of Plant 6 and continues to south of Plant 8. Uranium does not reach any facilities, but follows both sides of First Street. Although the area is open, soil access is limited due to surrounding structures. Total uranium concentrations between 35 and 2107 pCi/g were detected at a depth of 0.0 to 1.5 feet for soils in this area. Uranium also extends vertically into the subsurface soil, possibly due to leaching from surface soils or leakage from buried pipelines in the area. For soil at depths between 1.5 to 3.0 feet, total uranium concentrations ranged from 13 to 55 pCi/g. Uranium concentrations of 22 to 57 pCi/g were detected in soil located at 4.5 to 6.0 feet in depth. Levels of uranium above the PRG extend further where soil concentrations reach 19 to 44 pCi/g at 9.0 to 10.5 feet in depth and 42 to 46 pCi/g for soil 15 feet below the surface. The total volume of soil containing uranium above 35 pCi/g in this area is approximately 23,000 cubic yards. Isotopes of thorium, radium, cesium, plutonium, strontium, and technetium were also detected at levels in excess of background concentrations in this area.

3.5.1.1.3 Areas South of Garage and East of Heavy Equipment Building (Area SE3, Figure 3-11)

Uranium in soil exists in the open areas south of the garage and engine house and east of the heavy equipment building. Sampling activities in this area show total uranium levels of 40 to 213 pCi/g for soil at depths of 0.0 to 1.5 feet. Soil borings also show vertical migration of uranium where levels range from 48 to 52 pCi/g between 2.0 and 2.5 feet in depth. The total volume of soil containing uranium in both locations is approximately 2,800 cubic yards. Elevated concentrations of thorium, radium, cesium, and technetium have also resulted in these areas. Access to these soils is limited by the surrounding facilities.

3.5.1.1.4 Area East of Plant 5, Metals Production Plant (Area SE4, Figure 3-11)

Uranium from storm water runoff and air emissions is found around and beneath the pad immediately east of Plant 5 (and west of Plant 6). A surface soil sample in this region demonstrated a total uranium concentration of 436 pCi/g. A soil boring at this same location showed that uranium migrated into the subsurface soil with a uranium concentration of 43 pCi/g between 5.0 and 5.5 feet

and 45 pCi/g at depths between 15.0 to 15.5 feet. The total calculated volume of soil with uranium levels in excess of 35 pCi/g is approximately 2,600 cubic yards. Although this is an open field area, surrounding facilities limit access to these soils.

3.5.1.1.5 Buffer Zone and Area East of Plant 9 (Area SE5, Figure 3-11)

Soil containing uranium above the PRG level in this area occurs east of Plant 9 and includes a portion of the buffer zone. The area in the buffer zone, with uranium concentrations ranging from 11 to 40 pCi/g for soils at 0.0 to 1.5 feet in depth, extends east past the FEMP former production area fence line. The total volume of soils with uranium in excess of 35 pCi/g is approximately 20,000 cubic yards. This entire area has been characterized as an open field without restricted access to these soils.

3.5.1.1.6 South and West Fence Line Areas (Area SE6, Figure 3-11)

This area includes scattered regions of uranium in soils from the southern half of the former FEMP production area. Concentrations of total uranium range between 33 and 42 pCi/g for soils at 0.0 to 1.5 feet in depth. The total volume of soil with uranium concentrations above 35 pCi/g is approximately 230 cubic yards. This volume also consists of soil from Area SW9. Access to these soils is not limited by surrounding structures.

3.5.1.1.7 Plant 4, Green Salt Plant (Area SE7, Figure 3-11)

Uranium is suspected to have leaked into the underlying soil from the Plant 4 sump and the tank farm sump (WMCO 1989b). A soil boring in the southern portion of Plant 4 showed a total uranium concentration of 272 pCi/g at the surface (0.0 to 0.5 feet in depth). The concentration decreased dramatically with depth. At 2.0 feet, the total uranium concentration was 9 pCi/g. The total volume of soil having uranium concentrations above the PRG level for this area is approximately 440 cubic yards. Surrounding structures may impede access to these soils.

3.5.1.1.8 Plant 6 Pickling Area (Area SE8, Figure 3-11)

This region consists of the pickling area and the wastewater treatment area in Plant 6. The sump on the east side of the pickling area and the sump in the waste water treatment area appear to be sources of uranium (WMCO 1989b). Soil sampling activities at a 0.0- to 1.5-foot depth show total uranium levels ranging from 35 pCi/g to 60,435 pCi/g. Uranium is also present at 1.5 to 3.0 feet below the surface with concentrations ranging from 50 to 333 pCi/g. Migrating vertically, uranium reached levels of 73 to 302 pCi/g at depths of 5.0 to 7.0 feet and 20 to 178 pCi/g, 10.0 to 10.5 feet in depth. Total uranium also exists at 15.0 to 15.5 feet in depth, with concentrations ranging between 37 and 320 pCi/g. The total volume of soils containing uranium levels above the PRG concentration is 74,600 cubic yards. Soils in this area underlie facilities and structures, thereby greatly restricting access to them.

3.5.1.1.9 Plant 6 Chip Pickling Area (Area SE9, Figure 3-11)

Uranium in this region has spread from the chip pickling area through the salt oil area. Documented concentrations of uranium have been reported between 16 and 5391 pCi/g for soils at 0.0 to 1.5 feet in depth. At a depth of 2.0 to 3.0 feet, total uranium levels ranged from 13 to 11,290 pCi/g. Sampling activities have also revealed uranium in the 5.0- to 6.0-foot depth range where concentrations were 41 to 3186 pCi/g. This accounts for 3400 cubic yards of soil that contains uranium levels above 35 pCi/g. This uranium is suspected to have leaked from the sump and trench in the chip pickling room and the catch basin for the salt oil (WMCO 1989b). These soils lie underneath facilities, preventing easy access for remedial activities.

3.5.1.2 Southwest Quadrant

This section presents a discussion of specific areas of soil containing uranium above 35 pCi/g in the southwest quadrant of the former production area (Table A-27, Figure 3-12).

3.5.1.2.1 Area Between Plant 2/3 and Plant 4 (Area SW1, Figure 3-12)

The soils in this area that have uranium in excess of the PRG concentration appear to be a result of rainwater runoff from Plant 2/3 and Plant 4 and air emissions from Plants 4 and 8. A soil boring shows a uranium concentration of 102 pCi/g at a depth of 0.0 to 1.5 feet. This results in a total volume of soil containing uranium concentrations above 35 pCi/g of 830 cubic yards which lies in an open field area with limited access due to surrounding facilities.

3.5.1.2.2 Area West of Plant 8 Hydrochloric Acid Metals Dissolver (Area SW2, Figure 3-12)

This area was originally a site where uranium and magnesium scrap metals were dissolved. On this diked pad, two 1000-gallon wooden tanks containing hydrochloric acid were used to dissolve the metals prior to separation in Plant 8. The source of uranium in this area appears to be leakage from the pad into the soil (WMCO 1989b). Total uranium concentrations in this area range between 5 and 25 pCi/g for soils 0.0 to 3.5 feet in depth. Slightly higher levels of uranium exist further below into the subsurface soil where uranium concentrations were found to be 12 to 51 pCi/g at depths of 5.0 to 6.0 feet. This uranium migrated further into soils with concentrations ranging from 11 to 70 pCi/g at 10.0 to 11.5 feet below the surface and 11 to 59 pCi/g at depths between 15.0 and 15.5 feet. The total volume of soils with uranium above the PRG level in this area covers approximately 4100 cubic yards. Thorium, radium, and strontium were also detected at elevated concentrations in these soils. Facilities in the area limit access to these soils.

3.5.1.2.3 Area Along First Street (Area SW3, Figure 3-12)

This area encompasses portions of both the southeast and southwest quadrants. A description of uranium concentrations in the eastern region of this area is provided in Section 3.4.1.1.2.

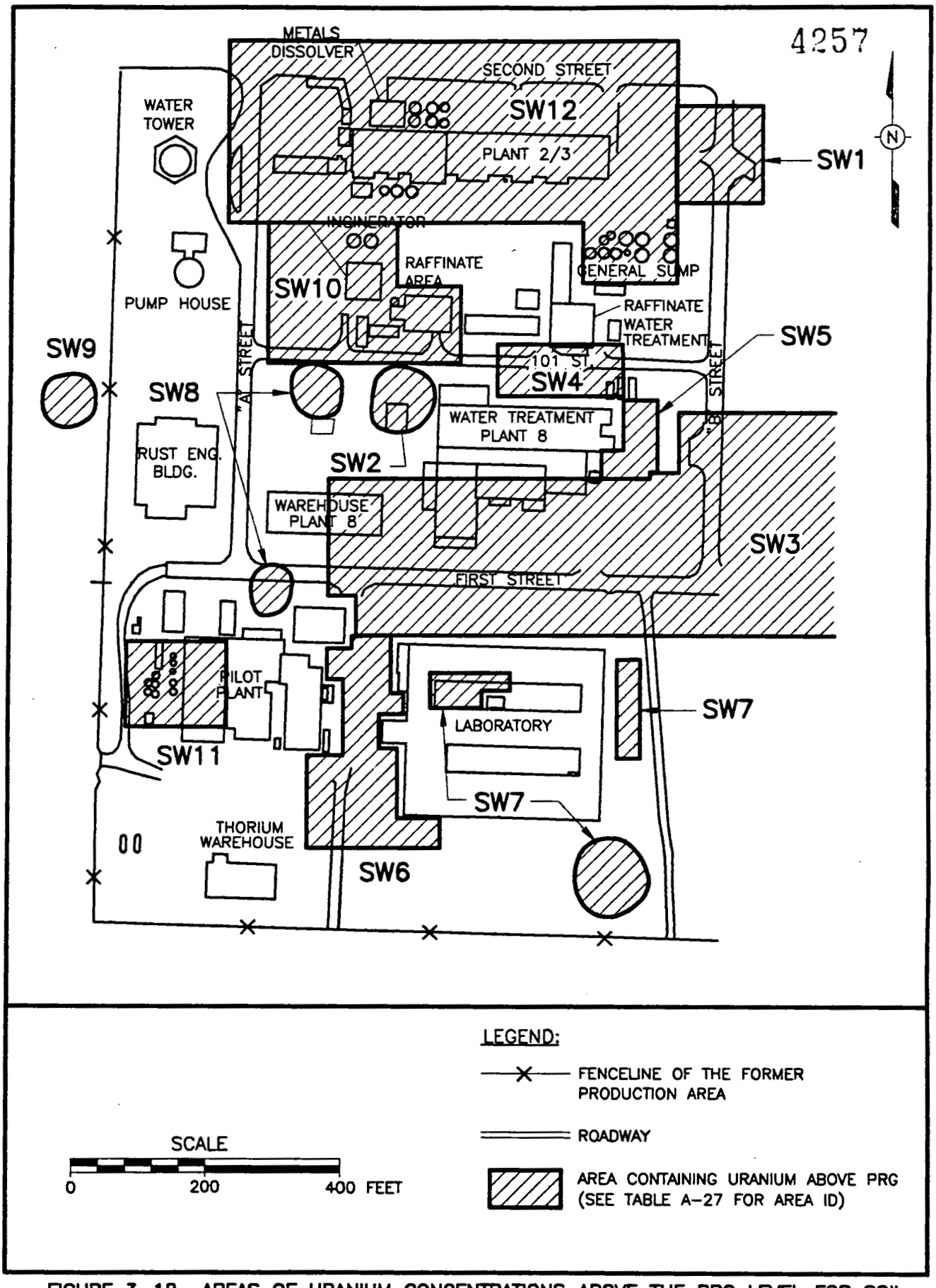


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FIGURE 3-12 AREAS OF URANIUM CONCENTRATIONS ABOVE THE PRG LEVEL FOR SOIL IN THE SOUTHWEST QUADRANT

The western region of this area falls in the southwest quadrant. Total uranium concentrations range from 15 to 298 pCi/g for soils at 0.0 to 1.5 feet in depth. Uranium also exists below the surface soils where concentrations at depths of 1.5 to 2.5 feet fall between 92 and 95 pCi/g. The total volume of soils containing uranium levels in excess of 35 pCi/g is accounted for in Area SE2 of the Southeast Quadrant (23,000 cubic yards).

3.5.1.2.4 Area North of Plant 8 (Area SW4, Figure 3-12)

Soils in this area with uranium levels exceeding 35 pCi/g are just west of the sump at the northeast corner of Plant 8. This area has most likely been affected by rainwater runoff from the adjacent roadways, air deposition from Plants 2/3 and 8, and leakage from the adjacent sump. Concentrations of total uranium in soils 0.0 to 1.5 feet in depth are between 4 and 379 pCi/g. Soil borings also demonstrate that uranium migrated vertically into subsurface soil with concentrations of 106, 241, and 37 pCi/g at depths of 3.0 to 3.5, 5.0 to 6.5 and 10.5 to 11.0 feet, respectively. This results in 2,800 cubic yards of soil affected by uranium concentrations above the PRG level. Even though this is an open field area, access to these soils is limited by surrounding structures.

3.5.1.2.5 Plant 8 Loading Dock (Area SW5, Figure 3-12)

This area is located underneath the concrete loading pad east of Plant 8 and appears to have been impacted by uranium concentrations from rainwater which washed radioactive material into the soil around and beneath the pad. Most of the uranium in this area exists below surface soils. Total uranium concentrations are 66, 25, and 12 pCi/g for depths between 0.0 and 1.5 feet, 1.5 and 2.0 feet, and 5.0 and 6.5 feet, respectively. However, uranium concentrations have reached levels of 196 and 91 pCi/g for subsurface soils at 10.5 to 11 feet and 15.0 to 15.5 feet in depth. Due to the vertical migration of the uranium, the total volume of soils containing uranium is calculated at 4,200 cubic yards. Soils in this area were also found to contain Thorium-230. Surrounding structures prevent easy access to these soils.

3.5.1.2.6 Area Between Laboratory and Pilot Plant (Area SW6, Figure 3-12)

This open area includes a former waste solvent drum storage site between the pilot plant and laboratory and an open field south of the laboratory.

Levels of uranium range from 6 to 14,114 pCi/g for sampling at a 0.0- to 1.5-foot depth. Analyses to delineate uranium levels below 1.5 feet reveal concentrations to be very low; i.e., between 2 and 9 pCi/g. This indicates that total uranium appears to exist relatively close to the surface, with approximately 2,500 cubic yards of soil having uranium levels above 35 pCi/g. This uranium seems to be the result of rainwater washing radioactive material into the soil around and beneath the drum storage pad. Other radionuclides, including isotopes of thorium, radium, cesium, plutonium, strontium, and technetium were also detected. Additionally, concentrations of beryllium, cadmium and

benzo(a)pyrene have also been detected in this area. Access to these soils is limited by surrounding structures. Fernald Environmental Restoration Management Corporation (FERMCO) is currently conducting a removal action in this area. Any contaminated material will be placed in storage boxes and maintained on site pending final disposition.

3.5.1.2.7 Areas Around Laboratory (Area SW7, Figure 3-12)

Uranium in this area occurs south and east of the laboratory. Also, included is a small section within the laboratory, approximately 50 feet in diameter, which contains uranium at a concentration of 649 pCi/g. Outside the laboratory, total uranium levels range between 28 and 70 pCi/g. This uranium appears in soils at a depth of 0.0 to 1.5 feet, resulting in 1,100 cubic yards of soils containing uranium levels above the PRG level. Structures in the vicinity of this open field area restrict access to these soils.

3.5.1.2.8 Area North of Pilot Plant (Area SW8, Figure 3-12)

Uranium in soils appears at two separate locations, as shown in Figure 3-12. One area is directly north of the pilot plant and the other area is further north and due west of Plant 8. Both open field areas are approximately 75 feet in diameter. Two sample borings, one in each area, at a depth of 0.0 to 1.5 feet, adequately describe uranium levels in these areas. The concentrations of these two samples are both 39 pCi/g, resulting in a total volume of soils containing uranium above 35 pCi/g of approximately 490 cubic yards. Concentrations of thorium, radium, and strontium were also detected in these soils. Surrounding facilities limit the access to these soils.

3.5.1.2.9 South and West Fence Line Areas (Area SW9, Figure 3-12)

This region is located at the west fence line of the former production area, next to the Rust Engineering building. A sample at this location shows a uranium concentration at 35 pCi/g for soils at a depth of 0.0 to 1.5 feet. The total volume of soil in this area affected by uranium levels above the PRG concentration was combined with Area SE6, as described in Section 3.4.1.1.6, of the Southwest Quadrant. Open access to these soils is clear with little or no restriction.

3.5.1.2.10 Building 39A, Incinerator (Area SW10, Figure 3-12)

Building 39A contains two separate incinerators used for the destruction of solid and liquid wastes: a Kelly incinerator and a Trane incinerator. Uranium occurring in soils between 0.0 and 1.5 feet in depth had a concentration range of 3 to 456 pCi/g. Vertical migration of the uranium caused elevated concentrations to appear in subsurface soils. For example, total uranium levels between 25 and 50 pCi/g and 26 to 77 pCi/g occur at depths of 3.0 to 3.5 feet and 5.0 to 6.5 feet, respectively. At 15.0 to 15.5 feet below the surface, the concentration range of uranium is 18 to 37 pCi/g. A total volume of 13,100 cubic yards of soil having uranium levels above 35 pCi/g resulted from the

uranium permeating through subsurface soils. Access to these soils is limited due to surrounding structures.

3.5.1.2.11 Pilot Plant and Pilot Plant Tank Farm (Area SW11, Figure 3-12)

At the western edge of the pilot plant main building, sampling shows uranium that extended under the pilot plant main building and tank farm structures. A small rectangular area adjacent to the south side of the main building of the pilot plant was identified as an underground tank storage site. Uranium levels in this area range from 23 to 381 pCi/g for soils at depths of 0.0 to 1.5 feet. This area is also characterized by uranium in the subsurface soils. Concentrations of total uranium range from 13 to 52 pCi/g at 2.0 to 3.5 feet in depth. Uranium also exists at greater soil depths of 5.0 to 6.5 feet and 10.5 to 11.0 feet, where concentrations are 12 to 114 pCi/g and 16 to 255 pCi/g, respectively. This appears to be attributable to liquids leaking into the soil from the tank storage area (WMCO 1989b). The total volume of soil containing uranium in excess of 35 pCi/g in this area is approximately 5,200 cubic yards. A number of additional constituents, including arsenic, beryllium, cadmium, tetrachloroethene, PCBs, polycyclic aromatic hydrocarbons (PAH), thorium, radium, cesium, and plutonium have also been detected in this area. The facilities associated with this area limit access to the underlying soils.

3.5.1.2.12 Plant 2/3, Refinery (Area SW12, Figure 3-12)

This area is contained within the boundaries of Plant 2/3, the general sump, and the raffinate area. Uranium seems to be extensive in this area, possibly from sumps in three areas: southeast of Plant 2/3, southwest of Plant 2/3, and northwest of Plant 2/3 (WMCO 1989b). Other possible sources of uranium may be the aboveground tanks in the area or airborne particulates and surface water runoff from process plants in the former production area. Total uranium concentrations for soils at the surface to 1.5 feet below the surface range from 40 to 2595 pCi/g. For subsurface soils at 1.5 to 3.0 feet in depth, the concentration levels of uranium decrease, ranging from 29 to 72 pCi/g. At 4.5 to 5.5 feet below the surface, uranium concentrations fall into a range of 11 to 190 pCi/g. This uranium continues at depths of 10 to 10.5 feet where concentrations are between 11 and 150 pCi/g and are between 16 and 102 pCi/g for subsurface soils between 15.0 and 15.5 feet in depth. Due to the fact that uranium in this area extends large distances both horizontally and vertically, a total volume of 37,700 cubic yards of soil has been affected by uranium concentrations above the PRG level. Arsenic, beryllium, cadmium, lead, PCBs, thorium, and radium have also been detected in samples collected in this area. Access to these soils is limited due to surrounding buildings and structures.

3.5.1.3 Northeast Quadrant

Specific areas of soil containing uranium levels above 35 pCi/g and identified in the northeast quadrant of the former production area are presented in this section (Table A-28, Figure 3-13).

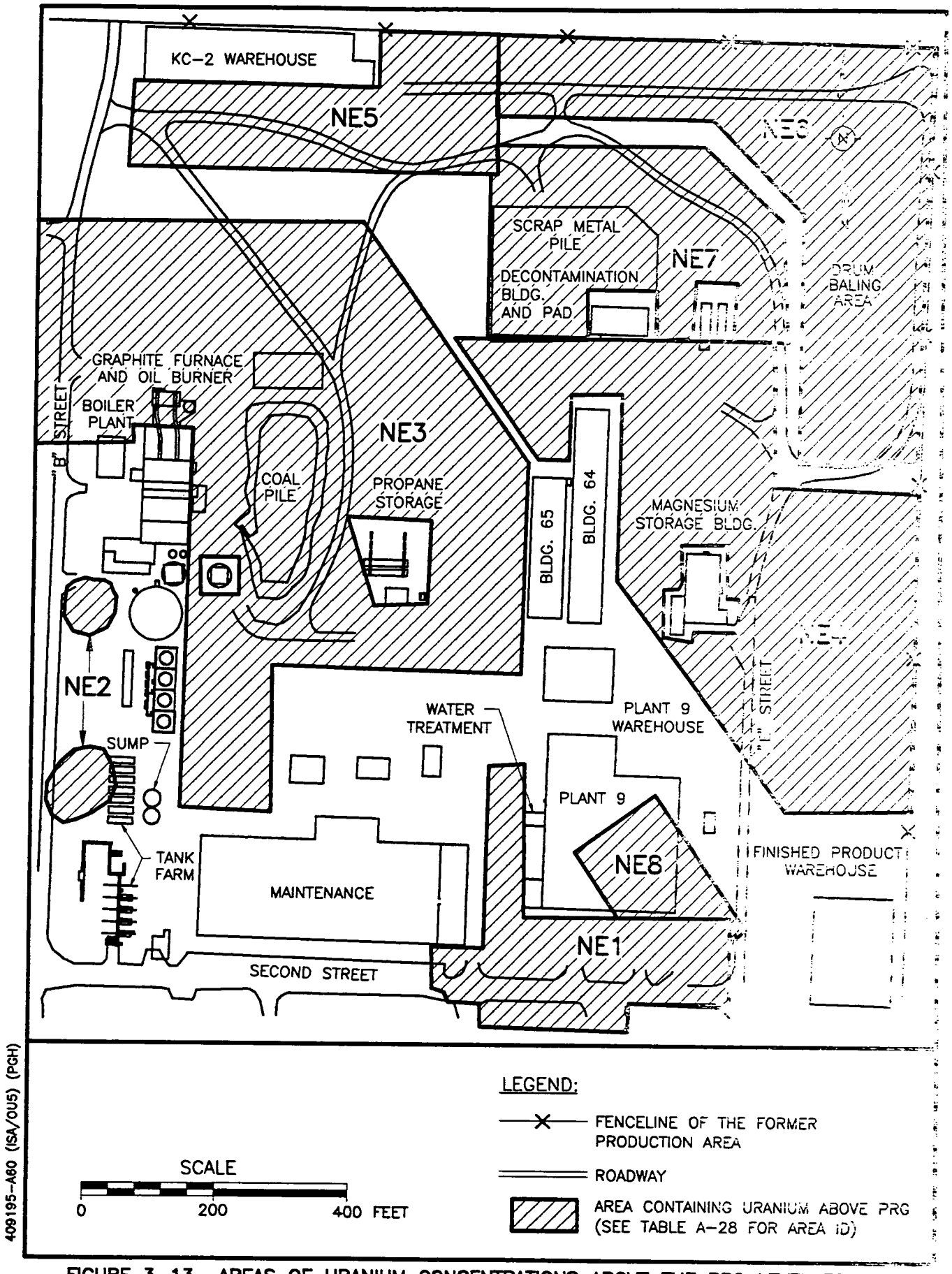

FIGURE 3-13 AREAS OF URANIUM CONCENTRATIONS ABOVE THE PRG LEVEL FOR SOIL IN THE NORTHEAST QUADRANT

3.5.1.3.1 Area South of Plant 9 (Area NE1, Figure 3-13)

Uranium in this area appears to have developed from rainwater runoff and air emissions from Plants 5 and 9. Total uranium concentrations for soils between 0.0 and 1.5 feet in depth range from 1 to 140 pCi/g. At further depths, between 5.0 and 6.5 feet, a soil boring was analyzed with a uranium concentration of 37 pCi/g; and, at 15.0 to 15.5 feet, the uranium concentration was 10 pCi/g. The total volume of soil in this area with uranium concentrations greater than 35 pCi/g is approximately 7400 cubic yards. This is an area of concern because mobile forms of uranium contamination are moving from Plants 6 and 9 into the perched groundwater. In addition, concentrations of arsenic, beryllium, cadmium, lead, PCBs, PAHs, thorium, radium, and cesium have been detected in these soils. Although these are open field areas, access is limited by facilities located nearby.

3.5.1.3.2 Area West of Tank Farm and Sump (Area NE2, Figure 3-13)

Uranium concentrations above 35 pCi/g appear in two separate areas. One area is west of the tank and sump along "B" Street, where the uranium appears to be the result of rainwater runoff to the storm sewer system. The other area just north of the tank farm seems to contain uranium as a result of rainwater runoff from the boiler plant. Three soil borings in these areas indicate uranium concentrations ranging from 27 to 45 pCi/g at soil depths between 0.0 and 1.5 feet. This accounts for approximately 540 cubic yards of soils affected by uranium levels above the PRG level. This volume also consists of soil containing uranium concentrations in excess of 35 pCi/g from Area NW3. Access to these soil areas is limited by surrounding facilities.

3.5.1.3.3 Graphite Furnace and Oil Burner Area (Area NE3, Figure 3-13)

This area includes the graphite furnace/oil burner area and the areas north of the maintenance building and boiler plant. Levels of uranium range between 8 and 312 pCi/g for the soils at depths of 0.0 to 1.5 feet. This uranium is believed to have migrated further into the subsurface soils, at a depth of 3.5 feet, and is responsible for 24,200 cubic yards of soils with levels of uranium above 35 pCi/g. In addition, sampling results also indicate the presence of arsenic, beryllium, cadmium, lead, trichloroethene, PCBs, PAHs, thorium, and radium in this area. These areas have been characterized as open fields with good access to these soils.

3.5.1.3.4 Area South of the Northeast Scrap Metal Pile (Area NE4, Figure 3-13)

This open area between the scrap metal pile and Buildings 64 and 65 appears to receive uranium from rainwater runoff from the scrap metal pile (Northeast Quadrant). Uranium concentrations range from 37 to 145 pCi/g in this area. The contamination is contained in the top 1.5 feet of soil, with a total volume of 11,300 cubic yards. Isotopes of thorium, radium, and cesium have also been detected in soils collected in this area. Access to these soils appears to be open.

3.5.1.3.5 Area South of KC-2 Warehouse (Area NE5, Figure 3-13)

Soils with uranium levels above the PRG concentration are located south of the KC-2 warehouse. Uranium concentrations range from 24 to 80 pCi/g in this area. The total volume of these soils is calculated at 4,600 cubic yards, of which there are no limitations or restrictions to the accessibility to the soils.

3.5.1.3.6 Drum Bailing Area (Area NE6, Figure 3-13)

The drum baling area previously consisted of discarded scraps, material, and structures. Uranium in this area is a result of rainwater runoff directly to the soil beneath the discarded scrap pile. Uranium concentrations in the top 0.0 to 1.5 feet of soil fall into a range of 39 to 160 pCi/g. Uranium is also evident at a depth of 6.0 to 6.5 feet, where the concentration is 177 pCi/g at an isolated sample location. A total volume of 11,300 cubic yards of soil has been affected by uranium levels in excess of the PRG concentration. These soils lie in a open field where access is not limited by surrounding facilities. Thorium and radium have also been detected within this area.

3.5.1.3.7 Scrap Metal Pile Area (Area NE7, Figure 3-13)

The FEMP currently has three separate piles of metallic scrap with uranium concentrations above background levels. One pile of material is stored on a controlled curbed pad in the Northeast Quadrant of the former production area. This scrap metal pile consists primarily of ferrous material which contributes uranium to the soils underlying a portion of this area. A minimum sample concentration of 46 pCi/g and a maximum of 1518 pCi/g describe the uranium concentration range for soils at 0.0 to 1.5 feet in depth. This uranium appears to have migrated vertically into the subsurface soil because uranium also exists in the 1.5- to 3.0-foot depth range. Sampling results also indicate the presence of Cesium-137 in this area. The total volume of soils with uranium concentrations greater than 35 pCi/g is approximately 5,700 cubic yards with unrestricted access.

3.5.1.3.8 Plant 9, Special Products Plant (Area NE8, Figure 3-13)

Plant 9 is a metal production plant which has been designated for demolition. Uranium found in the soil seems to be located primarily near the sump at the southeast corner of Plant 9 (WMCO 1989b). The total volume of this soil is approximately 3,200 cubic yards. This is due to uranium concentrations ranging from 89 to 160 pCi/g for soils at depths of 0.0 to 1.5 feet and also includes uranium that is believed to have migrated 15 feet further into subsurface soils.

3.5.1.4 Northwest Quadrant

This section presents a discussion of areas and locations of soil containing uranium in the northwest quadrant of the former production area (Table A-29, Figure 3-14).

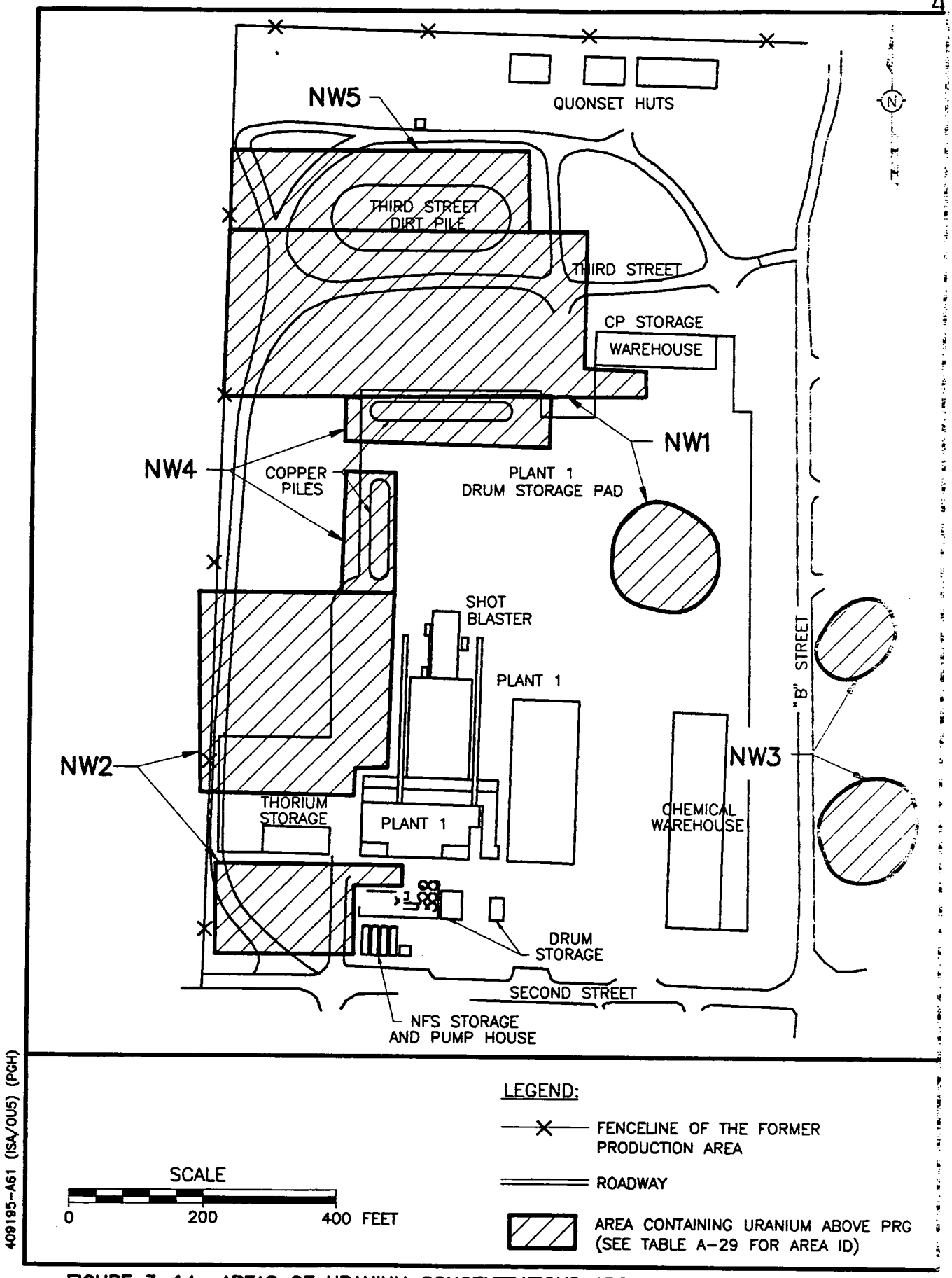

FIGURE 3-14 AREAS OF URANIUM CONCENTRATIONS ABOVE THE PRG LEVEL FOR SOIL IN THE NORTHWEST QUADRANT

3.5.1.4.1 Plant 1 Drum Storage Pad and Storage Areas (Area NW1, Figure 3-14)

The Plant 1 storage pad is used to hold drummed low-level radioactive materials and contaminated copper scrap awaiting further processing or shipment off site. Approximately 68,000 drums and containers were located on site in 1990. Approximately 32,000 drums contained uranium residue, approximately 5,000 drums contained mixed waste, and approximately 13,000 containers (the equivalent of approximately 7,500 fifty-five-gallon drums) were used for thorium storage. An additional 18,000 drums containing uranium residue were suspected to contain mixed waste (WMCO 1990b). Most of the drums stored on the pad exhibited evidence of corrosion and deterioration and were overpacked. The site had undertaken removal actions on the Plant 1 pad that include concrete surface repair, storm water management, and a planned phase A/B storage facility. The repair of cracked or leaking surfaces will be achieved through a process of scarifying existing concrete, placing an impermeable membrane, and pouring new concrete over the membrane.

Uranium in this area exhibits a wide range of concentration values. A minimum of 23 pCi/g and a maximum of 4,107 pCi/g in 0.0 to 1.5 feet of soil exemplify this range. Uranium appears to have developed in this area from rainwater runoff from the Plant 1 area and the drums stored on the pad. This uranium also seems to have migrated vertically into the subsurface soil at depths between 3.0 and 5.5 feet in depth. The total volume of soil containing levels of uranium above 35 pCi/g is calculated at 7,600 cubic yards. Thorium and radium have also been detected at above-background concentrations in samples collected in this area. Access to these soils is somewhat limited by structures and facilities located in the vicinity.

3.5.1.4.2 Thorium Storage Area (Area NW2, Figure 3-14)

Uranium levels appear to have developed in this region from rainwater runoff from the Plant 1 area. Total concentrations of uranium in the soil range from 19 to 307 pCi/g at 0.0 to 1.5 feet in depth. Uranium has also penetrated to the subsurface soil at 15.0 to 15.5 feet, where a soil boring shows a uranium concentration of 45 pCi/g. Because uranium has migrated to the lower depths of the subsurface soil, the volume impacted by uranium is approximated at 6,900 cubic yards. Although this is an open field area, surrounding facilities limit access to these soils.

3.5.1.4.3 Area West of Tank Farm and Sump (Area NW3, Figure 3-14)

Uranium in this area was mainly presented as part of the northeast quadrant, Section 3.5.1.3.2. Two other borings not in that section add to the description of uranium in this area. The samples collected at 0.0 to 1.5 feet in depth show total uranium concentrations of 43 and 66 pCi/g. Because Areas NW3 and NE2 are considered a single volume and character of soil, the total volume of soil impacted by concentrations of uranium exceeding the PRG for Area NW3 was indicated in Section 3.5.1.3.2 (540 cubic yards). Access to the soils is once again limited by surrounding facilities.

3.5.1.4.4 Scrap Metal Pile Area (Area NW4, Figure 3-14)

Two of the three FEMP scrap metal piles are located in the northwest quadrant of the former production area on the north end of the Plant 1 storage pad. Concentrations of uranium in soil range from a maximum of 141 pCi/g at 0.0 to 1.5 feet in depth to 49 pCi/g at 5.0 to 5.5 feet in depth. This uranium has impacted 10,200 cubic yards of soil in this area. In addition to uranium, data based on the 1990 OU3 RI indicate samples from two locations in the shot blaster area, south of the scrap metal piles, which had detected concentrations of arsenic, beryllium, cadmium, calcium, cobalt, copper, iron, magnesium, manganese, mercury, nickel, thallium, and zinc. Beryllium was the only constituent above the PRG level. Access to these soils is open in most cases, but may be somewhat limited in a few instances where the Plant 1 drum storage pad lies above the soils.

3.5.1.4.5 Construction Rubble Mound (Area NW5, Figure 3-14)

This is a large mound of soil, sometimes referred to as the Third Street dirt pile, excavated during construction activities at the FEMP. At present, limited RI/FS data are available for this area. However, because this area was established in accordance with WEMCO's standard operating procedures for soils management, uranium levels are expected to range from 35 to 135 pCi/g. The total volume of soil beneath the rubble mound that contains concentrations of uranium above 35 pCi/g is approximately 3300 cubic yards. Access to the soils is limited by the actual aboveground rubble mound.

3.5.1.5 Suspect Areas

Specific areas of soil impacted by levels of uranium greater than 35 pCi/g have been identified in two of the suspect areas: the fire training area and the sewage treatment plant/incinerator area (Table A-30, Figures 3-15 through 3-17).

3.5.1.5.1 Fire Training Area (Area SA1, Figure 3-15)

The fire training area is located 50 feet north of the buffer zone fence. The area consists of a burn-house, tank, a 30-foot-diameter pond, and a steel burn trough. A security fence lines the south side of this area. Total uranium concentrations ranging from 4 to 45 pCi/g were found in soil samples taken from borings located within the fire training area. The borings were sampled at 0.0 to 1.5 feet in depth. The total volume of soil containing levels of uranium in excess of the PRG concentration is approximated at 440 cubic yards. There is also evidence from sampling activities in this area that arsenic, beryllium, cadmium, and PCBs are present. Radionuclide data also indicate the presence of Thorium-230, Radium-228, Cesium-137, and Strontium-90. Access to these soils is not restricted by any structures.

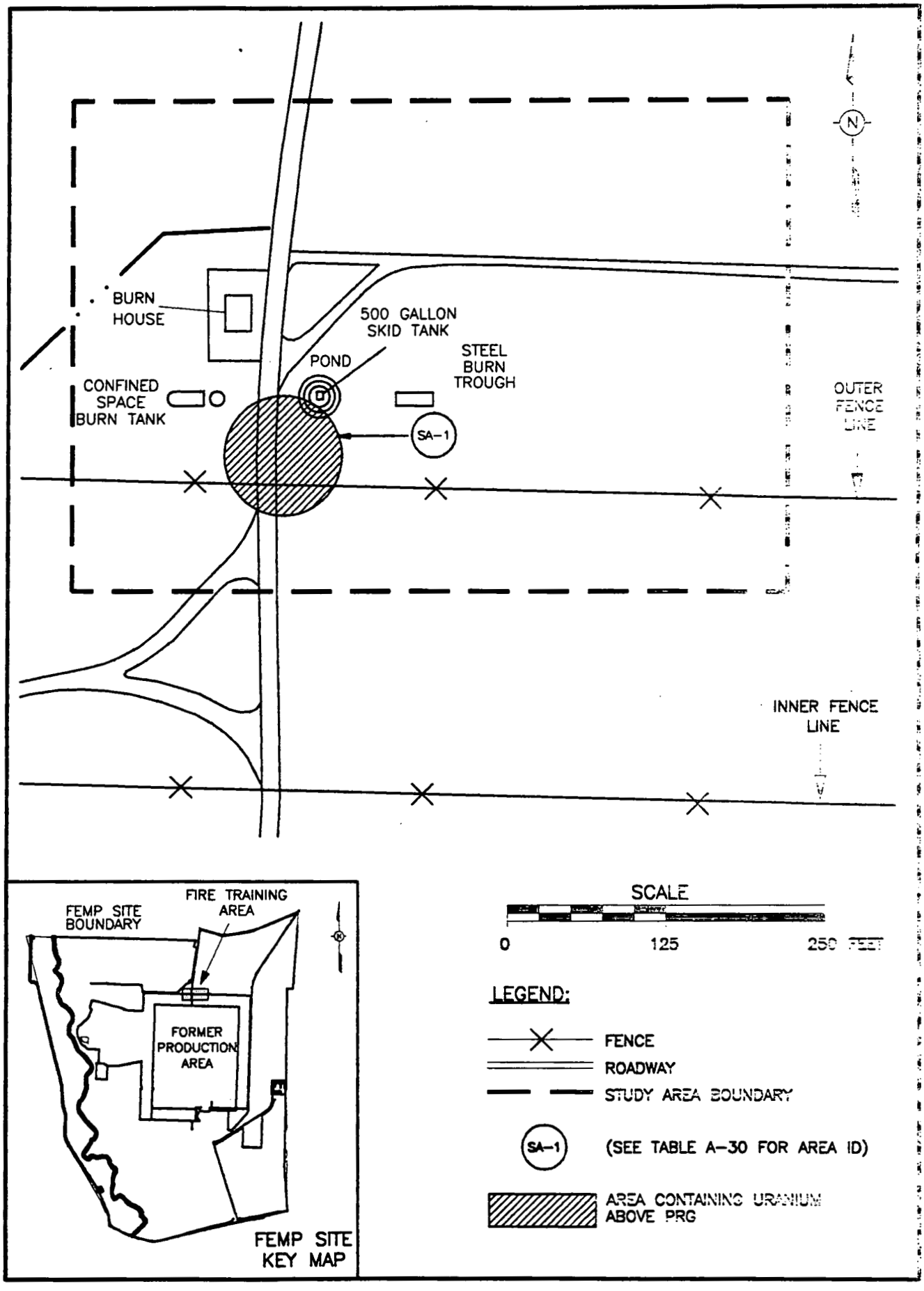

FIGURE 3-15 FIRE TRAINING AREA OF THE FEMP

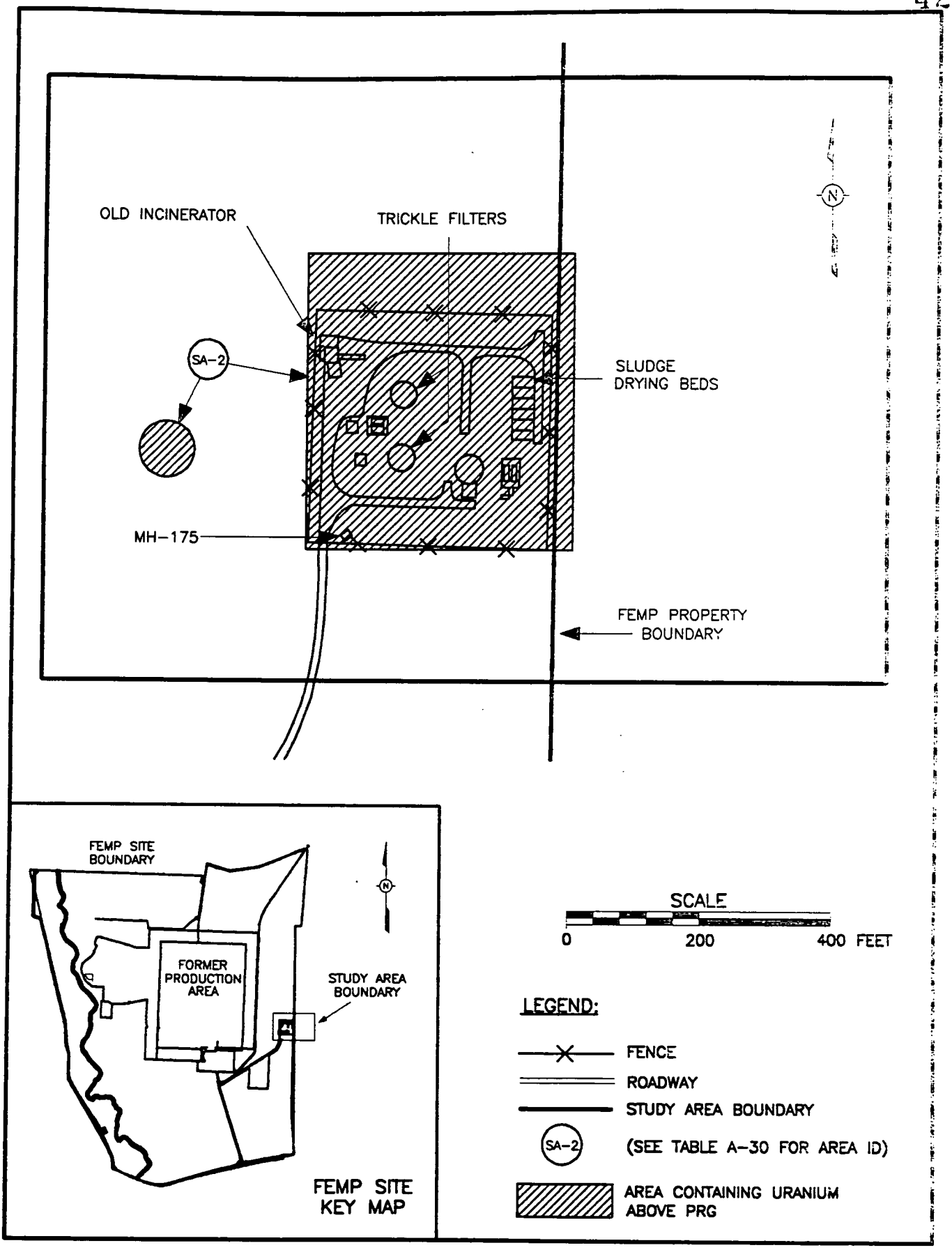

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FIGURE 3-16 SEWAGE TREATMENT PLANT/INCINERATOR AREA OF THE FEMP

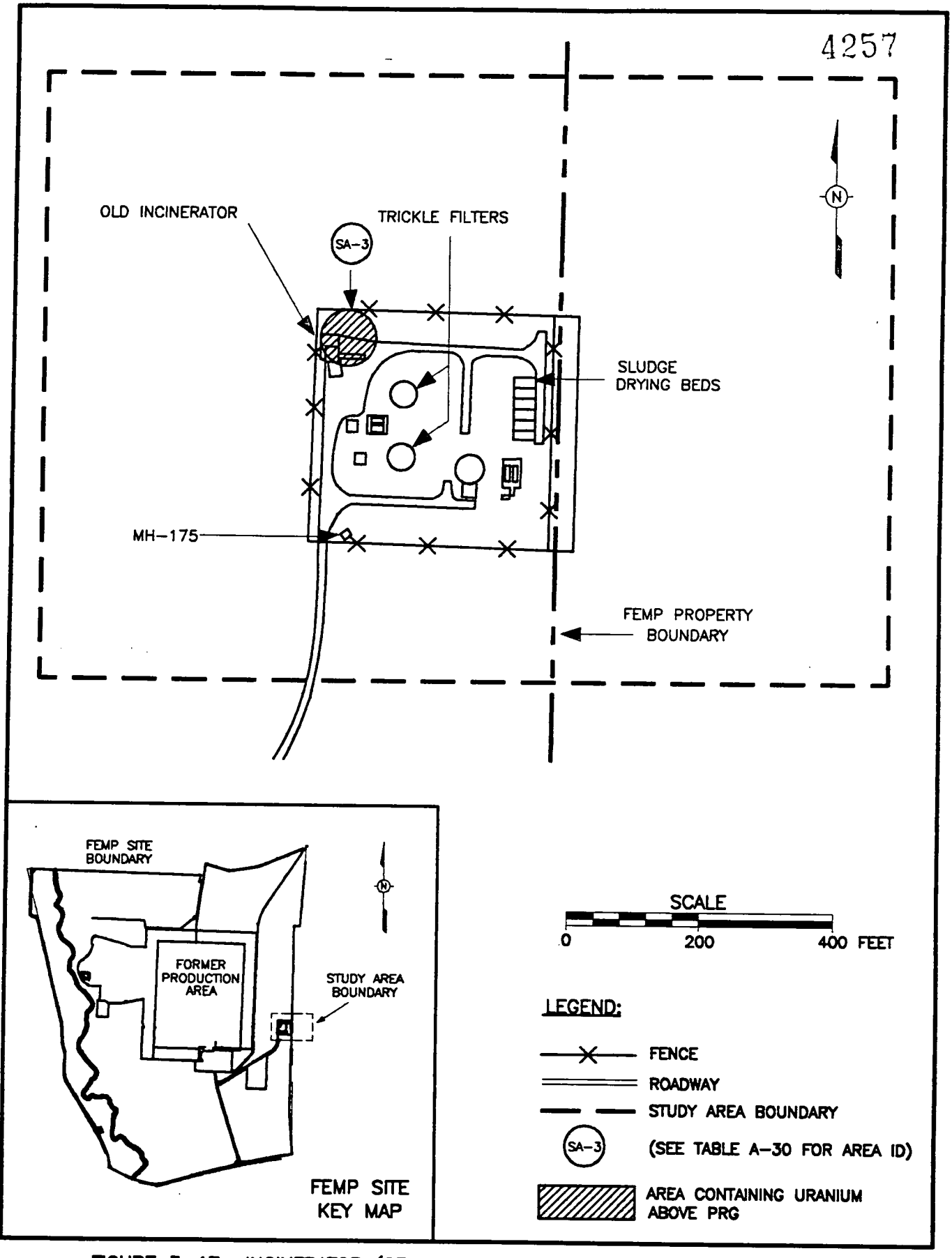

FIGURE 3-17 INCINERATOR (SEWAGE TREATMENT PLANT AREA) OF THE FEMP

3.5.1.5.2 Sewage Treatment Plant/Incinerator Area (Areas SA2 and SA3, Figures 3-16 and 3-17)

The sewage treatment plant/incinerator area is located east of the former production area. Areas of total uranium contamination in soil at depths of 0.0 to 1.5 feet display a concentration range of 8 to 3,365 pCi/g. Subsurface penetration of uranium has also been found in samples from two locations in the sewage treatment plant/incinerator area. Total uranium concentrations of 224 and 70 pCi/g were found at depths of 1.5 to 3.0 feet and 3.0 to 5.5 feet, respectively. A sample taken at 10 to 15 feet in depth showed a total uranium concentration of 53 pCi/g, indicating that leaching and migration of contaminants has occurred. Preliminary estimates indicate that total uranium contamination in this area has impacted at least 14,000 cubic yards of soil. Removal actions in the area suggest that this soil will require off-property remediation. Access to off-property locations will require easements and agreements with landowners.

The incinerator building is approximately 75 feet long and 25 feet wide. It is located in the northwest corner of the sewage treatment plant/incinerator area. Samples with the highest concentrations of uranium are located around and under the old incinerator (3,365 pCi/g and 2,796 pCi/g). The total volume of soils under the building that contain uranium concentrations in excess of 35 pCi/g is approximately 440 cubic yards. Access to underlying soils is restricted due to the presence of the incinerator.

3.5.1.6 Transfer Lines

This section discusses any transfer lines within or on the perimeter of the former production area, including slurry lines and effluent lines.

3.5.1.6.1 Effluent Lines

Effluent lines currently under investigation include the line from the Clearwell to Manhole 175 via the general sump and the main effluent line from Manhole 175 to the Great Miami River (Figure 1-11). No sampling tests have been conducted on the effluent line from the Clearwell to the general sump. The main effluent line is a 16-inch-diameter cast iron pipe that runs 4,650 feet from Manhole 175 to the Great Miami River. There are seven concrete manholes located along the line for access and maintenance purposes. The effluent line is a permitted discharge for wastewater. The wastewater conveyed by the main effluent line comes from treated effluent from the general sump, treated effluent from the sanitary wastewater treatment plant, and storm water runoff from the storm water retention basin. Soil sampling along the effluent line will be conducted as an Operable Unit 5 RI/FS Addendum activity. Therefore, the level and extent of uranium within the soils in the vicinity of the effluent line have not been established. Access to surrounding soils is good, with the exception of isolated congested areas within the former production area. Those off-property portions of the effluent line will require access and easement agreements with property owners if remediation is warranted.

Although this may be viewed as a limitation, most access and easement agreements will be obtained through negotiation with the property owners, or by having the court intercede.

3.5.1.6.2 K-65 Slurry Line (Area SA4, Table A-30)

The K-65 slurry line is a sealed pipe placed in a 1,500-foot-long, 2.5-foot-wide covered concrete trench. It extends from the K-65 silos to the general sump by way of the hot raffinate building located in the former production area. Sampling data indicate that the actual slurry line and the surrounding soil are contaminated. During December 1990, an exploratory trench 50 feet in length was excavated 30 feet south of and parallel to the K-65 pipe trench. Subsurface soil samples were taken from locations in the trench. The samples showed low levels of total uranium with concentrations ranging from 2 to 5 pCi/g. Under the former production and additional suspect areas' (PASA) systematic boring program, a piezometer was drilled near the point of exit from the trench. Total uranium concentrations ranged from a maximum detect of 208 pCi/g to nondetect. The total volume of soil impacted by uranium in this area is approximately 2,800 cubic yards. Also, analyses of soil samples collected adjacent to the slurry line showed concentrations of beryllium, cadmium, total thorium, Strontium-90, and Plutonium-239/240 in excess of background concentrations. Access to these soils is limited by surrounding structures and facilities.

3.5.1.7 Underground Storage Tanks

As part of this ISA document for Operable Unit 5, soil data from the RCRA, RI/FS and post-excavation sampling programs are presented to characterize the extent of contamination possibly associated with five areas of underground storage tanks in the former production area at the FEMP. The following discussion presents only volatile, semivolatile, and metal data. Radionuclide data are well-documented in the quadrant-based discussions in Sections 3.5.1.1, 3.5.1.2, 3.5.1.3, and 3.5.1.4. It should also be noted that contamination in the vicinity of these underground storage tanks (UST) is not easily distinguishable between the UST as the source of contamination or the other sources of contamination within the former production area. Consequently, the concentrations of constituents presented below may have been a result of an UST, but may have also resulted from or been contributed to by another source. In addition, the locations of the USTs overlap areas of uranium in soil in the former production area (Figures 3-11, 3-12, 3-13, 3-14). These areas were used to calculate volumes of soil containing levels of uranium above 35 pCi/g in the production area; therefore, volumes of soil to be remediated as a result of leakage from USTs have been covered in these prior discussions.

3.5.1.7.1 Tank Area 1 (Northeast Quadrant, Maintenance Building 12, Tank 6)

Tank Area 1 (Tank 6) was located about 1 foot north of maintenance Building 12 (Figure 3-10). It was a 1,000-gallon steel tank which previously held gasoline. The tank was removed in the fall of 1990 under the RCRA program. Soil samples in and around the excavation were collected following

tank removal. The analytical results show only single detections of toluene (5.48 micrograms per kilogram (µg/kg) and total xylenes (11.8 µg/kg), both substantially below the PRG level established for these constituents in Table 3-3 of this document. Lead was detected at each of the three soil sampling locations, with concentrations ranging from 5.98 to 8.85 milligrams per kilogram (mg/kd), which are also below the PRG soil concentration for lead. Based on the analytical results, clean closure of this tank location was granted by the Ohio State Fire Marshal, with subsequent backfilling of the excavation with clean gravel.

3.5.1.7.2 Tank Area 2 (Northeast Quadrant, Railroad Engine House Building 24A, Tank 3)

Tank Area 2 (Tank 3) was located about 25 feet northeast of Building 24A (Figure 3-10). It was a 12,500-gallon steel tank which was formerly used to store diesel fuel. The tank was removed as part of the RCRA program at the FEMP. Soil samples were taken around the perimeter of the excavation. The analytical results show single detected concentrations of benzene at 66.7 µg/kg and ethylbenzene at 747 µg/kg, which are below PRG levels. Detected concentrations of toluene, total xylenes, and total petroleum hydrocarbons (TPH) ranged from 38.9 to 794 µg/kg, 320 to 6,180 µg/kg and 1,270 to 23,600 mg/kg, respectively. Concentration ranges of toluene and total xylenes are below their respective PRG level. TPH is a general parameter which does not have a PRG. Lead was detected in all three of the soil samples, with a concentration range of 8.43 to 13.3 mg/kg. This is also below the PRG level established for lead in soil. A clean closure of this tank location has also been granted by the Ohio State Fire Marshal.

3.5.1.7.3 Tank Area 3 (Southeast Quadrant, Plant 6, Tank 14)

Tank Area 3 (Tank 14) is located underneath the exterior foundation wall of Plant 6, in the scrap melting area (Figure 3-10). It previously contained water soluble machine lubricating oils used to cool process equipment. Under the RI/FS soil sampling program, samples taken in the vicinity of Tank 14 show single detections of 1,2-dichloroethylene (0.055 mg/kg) and trichloroethene (0.2 mg/kg) which are well below PRG levels for these constituents. 1,1-Dichloroethene was detected in two analyses with a concentration range of 0.009 to 0.025 mg/kg which is also below its PRG level. Metals detected in this tank area include cadmium, magnesium, molybdenum, nickel, and silver with concentration ranges of 5.2 to 6.2 mg/kg, 29,500 to 34,500 mg/kg, 3.7 to 4.5 mg/kg, 17.0 to 17.7 mg/kg, and 5.6 to 5.9 mg/kg, respectively. Once again, these concentrations are well below the PRG levels established for metals in Table 3-2. It is the goal of the FEMP to close the tank by abandonment in place under RCRA, as removal of the tank would threaten the structural integrity of the building. If the tank cannot be closed under the RCRA program, Tank 14 will be incorporated into the CERCLA Remedial Action program at the FEMP.

3.5.1.7.4 Tank Area 4 (Southwest Quadrant, Garage Building 31, Tanks 1, 2, 8, 9, and 10)

Tank area 4 consisted of five USTs located on the east side of the garage (Building 31) (Figure 3-10). These USTs include:

- Tank 8, a 1,000-gallon steel tank which was used to store gasoline located approximately 12 feet northeast of the garage.
- Tank 9, a 1,000-gallon steel tank which was used to store diesel fuel located approximately 8 feet from the northeast corner of the garage.
- Tanks 1, 2, and 10 were located in a common tank pit.
  - Tanks 1 and 2, 1,500-gallon fiberglass tanks which were used to hold unleaded gasoline were located 51 feet east of the garage.
  - Tank 10, a 3,000-gallon gasoline tank which was located 43 feet east of the garage.

As part of the PASA investigations, a soil boring (1172) was drilled in the garage UST area. Benzene (0.002 µg/kg), toluene (0.001 µg/kg), ethylbenzene (0.018 µg/kg), and total xylenes (0.082 µg/kg) were all detected in this sample. All detections were below PRG levels. In addition, typical laboratory contaminants including acetone, methylene chloride, 2-butanone, and 4-methyl-2-pentanone were also detected in this soil sample, with all concentrations below PRG levels.

These tanks were removed in September 1990. After removal, the soils from each of the three excavations were sampled in December 1990. Analytical results show benzene detections ranging from 14.1 to 1,210 µg/kg, toluene detections with a range of 5.96 to 382 µg/kg, detections of ethylbenzene ranging from 18.1 to 44,70 µg/kg, and total xylene detections of 11.4 to 11,300 µg/kg. Each of these concentration ranges fall below the PRG level for that particular constituent. In addition, detections of lead ranged from 4.24 to 35.6 mg/kg which is also below its PRG concentration. TPH concentrations had a range of 19 to 656 mg/kg. However, no PRG for TPH has been established. In the summer of 1991, additional excavation sampling activities for this tank area showed a single detection of tetrachloroethene at 12 µg/kg, which is below the PRG concentration for tetrachloroethene. Additional soil sample collection and analysis will be required to address the impact of petroleum residuals in this area. These tank locations are scheduled to be closed as part of the CERCLA Remedial Action at the FEMP. Specific tank removal and closure requirements are covered in RCRA Subtitle I and 40 CFR 280 which has been identified as an ARAR for the FEMP.

3.5.1.7.5 Tank Area 5 (Northwest Quadrant, Plant 1 Truck Dock, Tanks 11, 12, and 13)

Tank Area 5 (Tanks 11 and 12) were located south of Plant 1 and approximately 6 feet east of the Plant 1 truck dock. Tank 13 was located approximately 25 feet east of the truck dock and 40 feet

south of the dock (Figure 3-10). All three tanks had a 3,000-gallon capacity and were used to store gasoline. Tanks 11 and 13 were also used to store kerosene.

As part of the RI/FS sampling program, borings in the vicinity of the Plant 1 truck dock were taken in 1989 and analyzed to determine if detected petroleum contaminants may be attributed to leakage from these USTs. The results indicate that 1,1-dichloroethane was detected once at 0.046 mg/kg; toluene was detected at 0.021 mg/kg; and total xylenes were detected at a concentration of 0.017 mg/kg. All of these concentrations were below their respected PRG concentrations. Metals which were detected as part of the RI/FS program include arsenic, beryllium, cadmium, lead, magnesium, molybdenum, nickel, and silver. The maximum concentrations for constituents were 8.4, 2.4, 6.9, 440, 38,600, 2.9, 38, and 17.2 mg/kg. Beryllium and lead are the only two constituents with maximum concentrations above the PRG level. This may be attributed to operations conducted on the north side of the refinery building.

Removal of these tanks was completed in the fall of 1990. After the tanks were removed, soils from the excavations were sampled. Benzene had a detected concentration range of 67.2 to 342 µg/kg. Detections of toluene ranged from 70.4 to 519 µg/kg. Detections of ethylbenzene ranged from 652 to 2,920 µg/kg. Total xylenes had a detected concentration range of 3,850 to 11,400 µg/kg. No volatile constituent had a concentration detected above the PRG concentration for that constituent. In addition, lead detections ranged from 4.47 to 19.7 mg/kg, which is also below its PRG level. Detections of TPH ranged from 374 to 1,810 mg/kg. Additional sampling in the summer of 1991 show no detections of any Hazardous Substance List (HSL) constituent.

The nature and extent of contamination due to leaking USTs near the Plant 1 truck dock have not been defined sufficiently to provide for final remediation of the area. Additional soil characterization is necessary. This area is also expected to be closed as part of the CERCLA Remedial Action at the FEMP.

3.5.2 Areas Outside of the Former Production and Suspect Areas

Soils at and in the vicinity of the FEMP have been assessed primarily with respect to radiological constituents. A review of the available data indicates that, with the exception of uranium, radionuclides are generally not present in soils outside the PASA at levels above background. Background radionuclide levels for soils located outside the PASA are based on regional data and are not FEMP-specific. These data are presented in Appendix A, Table A-31. There are widespread areas, both inside and outside the FEMP boundary, where uranium levels exceed background. Naturally occurring Uranium-238 in Ohio soils ranges in concentration from approximately 1 to 2 pCi/g (Myrick et al., 1983). Total natural uranium is approximately twice this concentration, since the two major isotopes

of uranium, Uranium-238 and Uranium-234, occur together naturally in about the same activity in the soil.

Soil samples were collected at 0 to 5 centimeters (cm) in depth both inside and outside the FEMP boundary as part of the routine sampling program for the FEMP Environmental Monitoring Program. Six locations were sampled along the boundary of the site from 1976 to 1980, with an additional location sampled beginning in 1981. Soil samples were collected outside the FEMP boundary at 8 locations from 1983 to 1985, 7 locations in 1986 and 1987, and 19 and 21 locations in 1988 and 1989, respectively. Figure 3-18 shows the locations of soil samples outside the FEMP boundary, and Table 3-5 indicates the corresponding years of the sampling events.

The RI sampling program (1987 and 1988) also included the collection of soils both inside and outside the FEMP boundary. Soils were collected in the 0- to 6-inch zone for most on-property samples, and in the 0- to 2-inch zone for most off-property samples. In general, RI sampling was concentrated downwind (north and east) of the site.

Summaries of routine soil data from the FEMP Environmental Monitoring Annual Reports are presented in Table A-32 (Appendix A). In general, the data collected as part of the FEMP Environmental Monitoring Program indicate that the Operable Unit 5 soils sampled along the FEMP boundary had uranium concentrations ranging from 0.42 to 16 pCi/g from 1976 to 1989. However, above-background uranium concentrations have been observed during this time interval at a soil sampling location adjacent to the sewage treatment plant and the incinerator. This sampling location accounts for the maximum uranium concentrations observed for the soil samples collected inside the FEMP boundary (Table A-32). Soils sampled outside the FEMP boundary had uranium concentrations which ranged from 0.35 to 16 pCi/g from 1983 to 1989 (Table A-32). During the summer of 1984, 105 additional nonroutine soil samples from locations outside the FEMP boundary were collected to construct a surface map, which showed the uranium concentration profile in the top 5 cm of soil. The results indicated that above-background uranium concentrations were present in soils immediately east of the FEMP. Similar to the on-property soil samples, the highest off-property soil uranium levels were adjacent to the incinerator area (43.6 pCi/g). These levels are probably from the former operation of the incinerator adjacent to the sewage treatment plant. Another elevated soil uranium concentration east of Ross (14.3 pCi/g) was caused by the large amount of coal cinders present in the sample. Coal typically contains higher amounts of uranium than would the ambient soil, and its presence is not related to FEMP operations.

Twenty-five of these nonroutine soil samples were also analyzed for the following radionuclides: Thorium-228, Thorium-230, Thorium-232, Plutonium-238, Plutonium-239, Plutonium-240, Neptunium-237, and Technetium-99. Plutonium isotopes and neptunium were not detected in any of

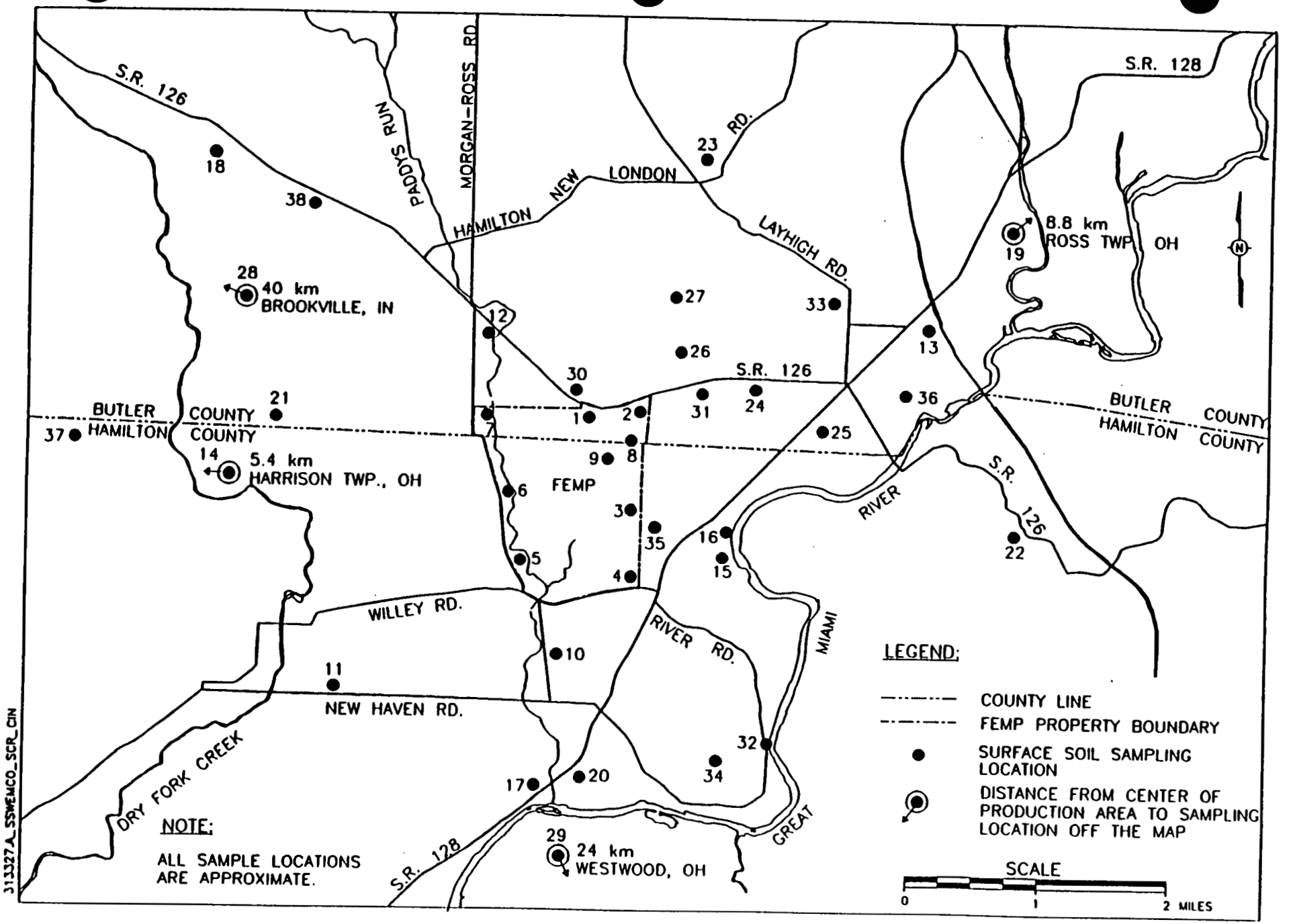

FIGURE 3-18 SURFACE SOIL SAMPLING LOCATIONS – FEMP ENVIRONMENTAL MONITORING PROGRAM 1985-1990

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TABLE 3-5

SURFACE SOIL SAMPLING EVENTS[a] AT NOTED LOCATIONS
FEMP ENVIRONMENTAL MONITORING PROGRAM 1985 - 1990

Sampling Location (corresponds with the numbered locations in Figure 3-18)	1985 Location	1986 Location	1987 Location	1988 Location	1989 Location	1990 Location
1-7	1-7	1-7	1-7	1-7	1-7	1-7
8				8	8	8
9				9	9	9
10				10	10	10
11				11	11	11
12					12	12
13				13	13	13
14				14	14	14
15	12	12	12	15	15	15
16			16			
17	14	14	14	17	17	17
18				18	18	18
19				19	19	19
20			17	20	20	20
21	15	15	15	21	21	21
22	13	13	13	22	22	22
23	8	8	8	23	23	23

See footnotes at end of table.

TABLE 3-5
(Continued)

Sampling Location (corresponds with the numbered locations in Figure 3-18)	1985 Location	1986 Location	1987 Location	1988 Location	1989 Location	1990 Location
24				24	24	24
25				25	25	25
26				26		
27				27		
28				28	28	28
29				29	29	29
30					30	30
31					31	31
32					32	
33	9	9	9		33	33
34						34
35	11	11	11			
36	10	10	10			
37			18			

[a]Sampling locations for the FEMP Environmental Monitoring Program have been numbered during the 1985-1990 time period. This table indicates which sample locations were renumbered and the year these renumberings occurred.

the samples. Technetium-99 was detected in four samples ranging from 0.8 to 4 pCi/g. Each of the three thorium isotopes were detected in all of the soil samples. The detected ranges were as follows: Thorium-228 (0.3 to 1.6 pCi/g); Thorium-230 (0.4 to 2.0 pCi/g); Thorium-232 (0.4 to 1.7 pCi/g). These data are significant in that they demonstrate that any off-property radionuclide soil contamination is primarily due to uranium. Other radionuclides are not as significant a concern in off-property soils because of low or undetectable concentrations and these isotopes were not regularly analyzed in later years under the Environmental Monitoring Program. The analytical results of these 25 nonroutine soil samples are presented in Table A-33.

The 1988 RI soil data indicate that areas exceeding the 35 pCi/g criterion for uranium are largely limited to locations within the former production area, which deals with controlled access areas and other suspect areas. Figure 3-19 identifies those specific soil locations exceeding 35 pCi/g within Operable Unit 5 which are outside the PASA. As shown in the figure, there are five specific locations within the property boundary that exceed 35 pCi/g. Each of these five specific locations is indicated by a single point, since each represents the results of only one sample analysis. Concentrations for 1988 at these locations were 53.1, 36.5, 35.6, 35.6, and 36.5 pCi/g of uranium. The values represent the sum of isotopic uranium activities for Uranium-234, Uranium-238, and Uranium-235/236. All other samples analyzed for uranium were below these levels. Nearby sample locations had concentrations below 35 pCi/g. This provides evidence that the observed areas with uranium concentrations above 35 pCi/g are local and do not represent significant areas of contamination. In addition to uranium, isotopes of thorium, radium, strontium, technetium, and cesium were detected in Operable Unit 5 soils outside the production and suspect areas. The average concentration of thorium isotopes were near background values. Background values for Thorium-228, Thorium-230, and Thorium-232 are 1.0 pCi/g, 1.4 pCi/g, and 1.0 pCi/g, respectively (Myrick et al., 1983). The average detected soil concentration of Radium-226 was slightly less than the average background value of 1.5 pCi/g. Radium-228 values ranged from 0.6 to 1.5 pCi/g. The background level for Radium-228 is 1.0 pCi/g.

The Cesium-137, Strontium-90, and Techentium-99 isotopes are fission products and are globally present in soils due to residual fallout from early nuclear weapons testing. Cesium-137 was detected in nearly all analyzed soil samples. Background values for this isotope calculated for the FEMP range from 0.15 to 0.71 pCi/g (DOE 1992c). The upper tolerance limit observed for background soil samples is 0.71 pCi/g. A possible source of the diffuse, low-level Cesium-137 concentrations observed in the area could result from a residual fallout from weapons testing.

Strontium-90 was detected in approximately half of all analyzed soil samples, at levels ranging from 0.5 pCi/g to 5.2 pCi/g. All background soil sample concentrations for Strontium-90 were less than 0.5 pCi/g. Technetium-99 was detected in only six of 131 samples analyzed, at an average

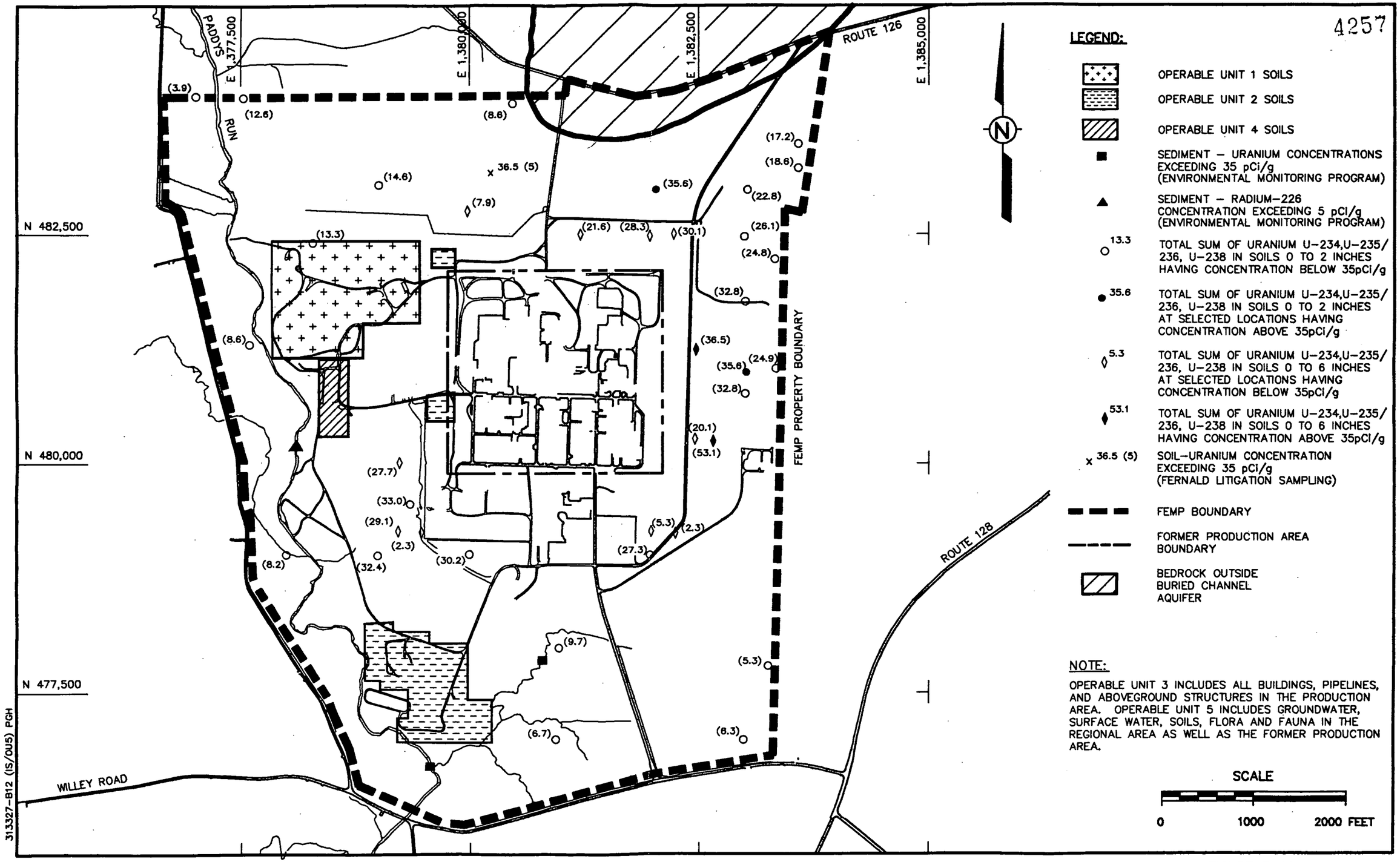


FIGURE 3–19
URANIUM SUM ACTIVITIES
U–234, U–235/236 AND U–238 IN SOIL
AT THE FEMP

concentration of 1.9 pCi/g. Background soil sample concentrations for Technetium-99 were less than 0.90 pCi/g. For risk assessment and site characterization purposes, the low-level Cesium-137 detections will be considered to be background conditions, while all Strontium-90 and Technetium-99 detections will be considered to be attributable to the processing of used fuel assemblies at the FEMP.

Additional soil samples were collected in 1991 outside the PASA as part of the RI/FS sampling program. A total of 13 locations were sampled south and west of the former production area, with 4 samples being collected outside the FEMP boundary (south of Willey Road). Sampling depths ranged from 1.5 to 96.5 feet. The resulting samples were analyzed for radionuclides. Table A-31 presents the results of this analysis. There were no detected concentrations of Cesium-137, Neptunium-237, Plutonium-238, Plutonium-239/240, Ruthenium-106, Technetium-99, or Uranium-235/236. The maximum detected concentrations for all of the remaining radionuclides, including the isotopes of radium, thorium, uranium, and strontium are greater than the reported background concentrations (Table A-31). Detected concentrations of total thorium and total uranium ranged from 1.6 to 10.0 and 1.3 to 11.5 µg/g, respectively, at these sampling locations during 1991.

Soil samples were also collected along with vegetation samples from the same location, as part of the FEMP Environmental Monitoring Program (Table A-34). In 1985, uranium levels ranged from 1.08 to 64.32 pCi/g, with the highest detection along the western boundary. Samples collected in 1987 ranged from 1.2 to 23.8 pCi/g, with the highest detection along the southern boundary. In 1988, the routine soil sampling program was combined with the parallel soil and vegetation sampling program. Soil samples were still collected at four sampling locations, which were part of the parallel soil and vegetation sampling program in 1988 and 1989. These samples were collected at locations outside the FEMP boundary, northeast of the site. The total uranium concentrations measured at these locations, in addition to the locations sampled outside the FEMP boundary in 1988 and 1989, were relatively low, ranging from 1.4 to 9.1 pCi/g.

3.6 SURFACE WATER

The SSOD, Paddys Run, and the Great Miami River are the principal surface water bodies potentially impacted by operations at the FEMP. Surface water at and in the vicinity of the FEMP has been sampled and analyzed to determine the concentration of a variety of radionuclides. Summaries of these data obtained from the FEMP Environmental Monitoring Reports and the RI sampling program are provided in Tables A-35, A-36, A-37, and A-38. It should be noted, however, that surface water concentrations are not directly comparable over time due to different states of dilution as a result of varying flow rates.

Uranium has been identified as the primary constituent of concern for all three surface water bodies at the FEMP because it has routinely been detected at both low (slightly above the detection limit) and

above the PRG level (20 µg/L; the PMCL for uranium in drinking water) (Tables A-35, A-36, and A-37). However, since uranium is naturally occurring, it is not unusual for it to be detected in samples of surface water. Other radionuclides, including Technetium-99 and Radium-228, were also detected at concentrations above the PRG level. Technetium-99 was observed at estimated levels below the contract required quantitation limit (CRQL), at low concentrations, and at elevated concentrations in the Great Miami River. Radium-228 was occasionally detected at low concentrations (less than 1.0 pCi/L) in both Paddys Run and Great Miami River samples. One unfiltered Great Miami River sample, however, had a detected concentration of 5.0 pCi/L, which is equal to the MCL for drinking water. Other radionuclides which were detected only at low concentrations include Radium-226, Strontium-90, Thorium-228, and Thorium-230 (Tables A-35 and A-36).

The SSOD has historically conveyed runoff from the former production area and other areas within the FEMP to Paddys Run and ultimately to the Great Miami River. During the period of 1956 to 1986, an estimated 28,000 pounds of uranium was discharged with excess surface water to the SSOD (Table 3-6). This amount is based on both calculated and recorded losses. In 1986, a retention basin was constructed to hold excess surface water for solids removal. A second basin was added in 1988. Water is pumped from the basins to the FEMP-permitted effluent line. The basin system has the capacity to contain the 10-year, 24-hour rainfall event. Thus, at the present time, the potential for uranium to enter the SSOD has been severely limited. An evaluation of the impacts on environmental pathways associated with surface water discharged from the FEMP, including overflows from the storm water retention basin, is being included in the RI report. During the 1989 RI sampling, surface water samples were collected from the SSOD and analyzed for uranium. The range of concentrations observed in four unfiltered samples was 2 to 24 µg/L (1.3 to 16 pCi/L) and in four filtered samples 2 to 44 µg/L (1.3 to 29 pCi/L) (Table A-36).

This apparent overlap of filtered and unfiltered uranium concentration ranges may indicate that the uranium is primarily in a soluble, nonfilterable form. The samples collected for filtered and unfiltered samples were not collected on the same dates, which might explain why the highest dissolved uranium value exceeds the highest total (unfiltered) uranium concentration.

Concentrations of uranium in Paddys Run have been monitored at selected locations since 1975. Sampling locations have been situated upstream of the FEMP, upstream of the confluence with the SSOD, near the confluence, and downstream of the confluence (Figure 3-20). All sampling locations show evidence of the presence of uranium, either historically or at the present time. Historically, samples collected from Paddys Run within the FEMP boundary both above and at the confluence with the SSOD had measured total uranium concentrations greater than 20 µg/L (13.4 pCi/L). However, elevated concentrations were not consistently found at these locations. Average annual uranium concentrations at four sampling locations in Paddys Run have ranged between 1.2 to 351.5 µg/L

TABLE 3-6

FERNALD RI/FS OPERABLE UNIT 5, SOUTH PLUME GROUNDWATER STUDY ESTIMATED URANIUM LOSS TO STORM SEWER SYSTEM AND STORM SEWER OUTFALL DITCH

Year	Recorded Annual Uranium Loss to Storm Sewer System (lbs)	Recorded Annual Loss to Storm Sewer Outfall Ditch (lbs)	Assumed Annual Loss to Storm Sewer Outfall Ditch[a] (lbs)	Source
1956	1,800		393	b
1957	2,600		568	b
1958	5,400		1,180	b
1959	6,300	1,400	1,400	b
1960	11,200	2,000	2,000	b
1961	11,800	2,600	2,600	b
1962	14,760		3,225	c
1963	12,180		2,661	d
1964	9,600		2,098	c
1965	7,070		1,545	c
1966	9,490[e]	2,400[f]	2,400	c
1967	4,190		916	c
1968	4,080		892	c
1969	5,568		1,217	c
1970	2,976		650	c
1971	4,184		914	c
1972	2,584		564	c
1973	2,605		567	c
1974	1,752		497[g]	c
1975	1,584[h]		965[i]	c
1976		98.5	98.5	j
1977		157.6	157.6	j
1978		46.0	46.0	j
1979		75.5	75.5	j
1980		16.4	16.4	j

See footnotes at end of table.

TABLE 3-6
(Continued)

Year	Recorded Annual Uranium Loss to Storm Sewer System (lbs)	Recorded Annual Loss to Storm Sewer Outfall Ditch (lbs)	Assumed Annual Loss to Storm Sewer Outfall Ditch[a] (lbs)	Source
1981		4.3	4.3	j
1982		42.7	42.7	j
1983		98.5	98.5	j
1984		124.8	124.8	j
1985		85.4	85.4	k

[a]The assumed annual uranium loss to the Storm Sewer Outfall Ditch (SSOD) is calculated, if not recorded, as 21.85 percent of the annual loss to the Storm Sewer System (SSS). The 21.85 percent figure is the average fraction of the total loss to the SSS that the recorded loss to the SSOD represents for Years 1959, 1960, 1961, and 1966.

[b]NLO Report of the FMPC Ground Contamination Study Committee, September 30, 1962.

[c]NLO Aquifer Contamination Control Reports dated January 21, 1965 to October 1, 1975.

[d]Data for 1963 is not available. Value presented is average of 1962 and 1964 data.

[e]Value presented is calculated based on a loss of 8,700 pounds for the period January 1 to November 30, 1966.

[f]Value presented is calculated based on a loss of 2,200 pounds for the period January 1 to November 30, 1966.

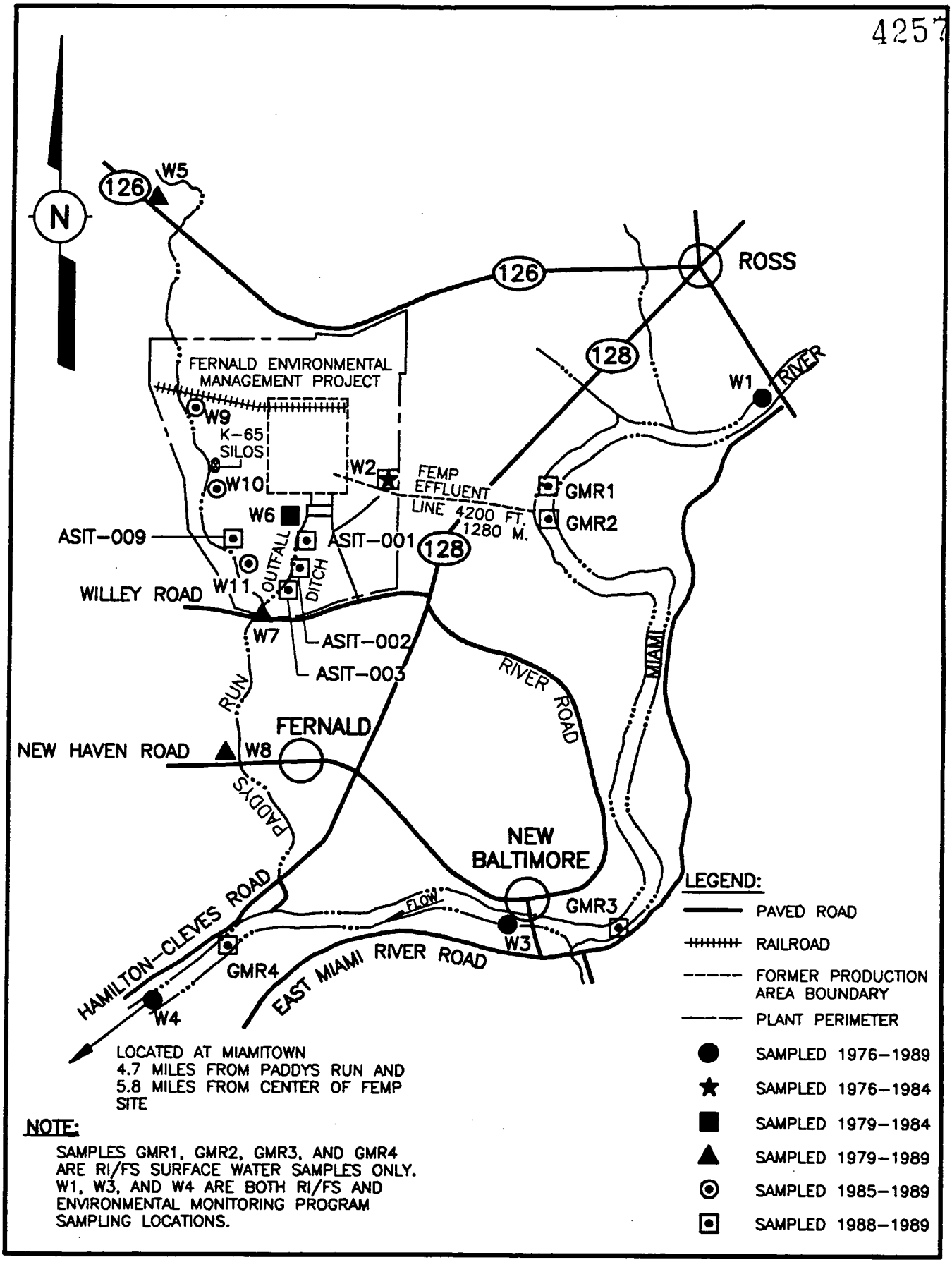
[g]For January through November 1974, uranium loss to the SSOD was 21.85 percent of the loss to the SSS. For December 1974, the uranium loss to the SSOD was 100 percent of the loss to the SSS. Value presented is calculated accordingly.

[h]Value presented is calculated based on a loss of 132 pounds per month for the first four months of 1975.

[i]For January through June 1975, uranium loss to the SSOD was 100 percent of the loss to the SSS. For July through December 1975, the uranium loss to the SSOD was 21.85 percent of the loss to the SSS. Value presented is calculated accordingly.

[j]NLO FMPC Environmental Monitoring Report for 1976 through 1984. Values presented are converted from Ci to lbs by 1 Ci = 3283.5 lbs.

[k]WMCO FMPC Environmental Monitoring Report for 1985. Value presented is converted from Ci to lbs by 1 Ci = 3283.5 lbs.



NOTE:

SAMPLES GMR1, GMR2, GMR3, AND GMR4 ARE RI/FS SURFACE WATER SAMPLES ONLY. W1, W3, AND W4 ARE BOTH RI/FS AND ENVIRONMENTAL MONITORING PROGRAM SAMPLING LOCATIONS.

313327-A112 (ISA) (PGH)

FIGURE 3-20 SURFACE WATER SAMPLING LOCATIONS AT THE FEMP

(0.8 to 236 pCi/L) during the period 1975 through 1989. Concentrations over the last three years (1987, 1988, and 1989) have averaged from 1.2 to 12 µg/L (0.8 to 8 pCi/L), with the exception of one location sampled and analyzed in 1988 (Table A-37). This sampling location had an average of 58.2 µg/L (39 pCi/L) due to a single high reading which was included in the average. Overall, detected concentrations were lower in samples collected upstream of the northern boundary of the FEMP.

Surface waters in the Great Miami River have been sampled and analyzed for uranium for many years. The three sampling locations are situated upstream of the FEMP discharge point (W1), between the effluent discharge and the point of confluence with Paddys Run (W3), and downstream of Paddys Run (W4) (Figure 3-20). Concentrations of uranium at these locations, as reported in the annual Environmental Monitoring Reports 1984 to 1988 (Tables A-35 and A-38), have ranged from a low of 0.9 µg/L (0.61 pCi/L) to a high of 38.4 µg/L (25.7 pCi/L). The average annual concentration has not exceeded 2.8 µg/L (1.9 pCi/L); the high value of 38.4 µg/L (25.7 pCi/L) was reported as the maximum in 1984 at one location. No readily apparent pattern of increased uranium concentrations in the vicinity of FEMP-influenced outfalls was apparent in the data. Data collected in 1987 from 11 locations on the Great Miami River between the Ross Bridge and one mile downstream of the FEMP outfall indicated uranium concentrations ranging from less than detection limits to 5.0 µg/L (3.4 pCi/L) (IT 1988). FEMP RI samples collected at seven locations (GMR1 to GMR4, W1, W3 and W4) in 1988 and 1989 indicate concentrations ranging from below detection limits to 6.1 µg/L (4.1 pCi/L) (Figure 3-20).

Table A-39 provides a summary of detected radionuclides from the RI/FS surface water sampling program. The laboratory results consist of 199 water samples that were taken in 1988 and 1989 at eight main sampling locations (Figure 3-20). The Great Miami River (above the effluent discharge) had the lowest total uranium concentrations, ranging from less than detected to 1.0 µg/L. Some of the highest concentrations were found in Manhole 175 and miscellaneous ditches that lead to Paddys Run. Manhole 175 had a range of 715 µg/L to 1021 µg/L, but the highest total concentration of uranium was 9,318 µg/L in a ditch southwest of Pit 5. As stated previously, these concentrations are a function of the flow rates and dilution factors present at the time of sample collection. The data show that the total uranium concentrations in both filtered and unfiltered samples collected from the waste pit drainageways are essentially the same, and that little, if any, uranium is bound up in suspended solids in the storm waste runoff.

Tables A-40 and A-41 (Appendix A) contain the chemicals (organic compounds and heavy metals) identified in the surface waters of Paddys Run and the Great Miami River, respectively. Figure 3-20 shows the locations of the sampling points on the Great Miami River and Paddys Run that were listed in Footnote a of Tables A-40 and A-41. The results indicate that none of the three organic

constituents detected in Paddys Run and none of the identified metals exceed the MCL drinking water standards. However, concentrations of the metals cadmium, copper, lead, and mercury exceeded the AWQC based on a chronic exposure to aquatic species. These compounds were detected in the surface waters of both Paddys Run and the Great Miami River.

The AWQCs for cadmium, copper, lead, and mercury are 1.1 µg/L, 12 µg/L, 3.2 µg/L, and 0.012 µg/L, respectively. Mercury was the only compound that exceeded the State of Ohio Water Quality Standards, based on a 30-day average concentration of 0.02 µg/L.

Additional surface water sampling was conducted in the drum baling area in the northeast quadrant of the former production area. Radiological data were obtained from 15 locations (Figure 3-21) during a one-time sampling of storm water runoff from the drum baling area. The analytical results of this sampling are listed in Table A-42. Total uranium concentrations ranged from 700 µg/L to 16,100 µg/L.

3.7 SEDIMENTS

Sediments in the SSOD, Paddys Run, and the Great Miami River have been assessed primarily with respect to radiological constituents, although chemical data (organics and metals) have also been analyzed. Two constituents of potential concern, uranium and Radium-226, have been identified. A review of the available data indicates that concentrations of radionuclides are present in the sediments at levels above background. Elevated levels in the sediments could represent a continuing source of contamination to surface waters and may have potential adverse impacts on aquatic life. The ecological risk assessment, which will be conducted in conjunction with the Operable Unit 5 RI, will address this issue. No final cleanup levels have yet been established for radiological constituents in sediments. This will be completed in conjunction with the risk assessment. Until that time, the 35 pCi/g uranium limit used for delineation of soils of concern will also be applied to the sediments. The PRG level of 5 pCi/g was selected for Radium-226, since this has been established as an action level for soils at sites where radiological contamination was remediated under other federal programs.

During the 1987 and 1988 Environmental Monitoring Program, sediments were sampled in the SSOD at 8 locations and in Paddys Run at 43 locations (Tables A-43 and A-44). Samples were collected from each bank and from the center of the stream at each location. The samples were analyzed for 12 radionuclides. Based on this sampling, 3 areas above preliminary remediation levels of concern have been identified. Uranium has been detected in the sediment of the SSOD, and in the sediment at the confluence of Paddys Run and the SSOD. Radium-226 has been identified in the sediment of Paddys Run. Figure 3-19 indicates the approximate location of these areas. It is noted that the area of concern in all cases has been identified on the basis of a high concentration at only one of the three sampling locations across the width of the channel (Table A-45). It is also noted that concentrations

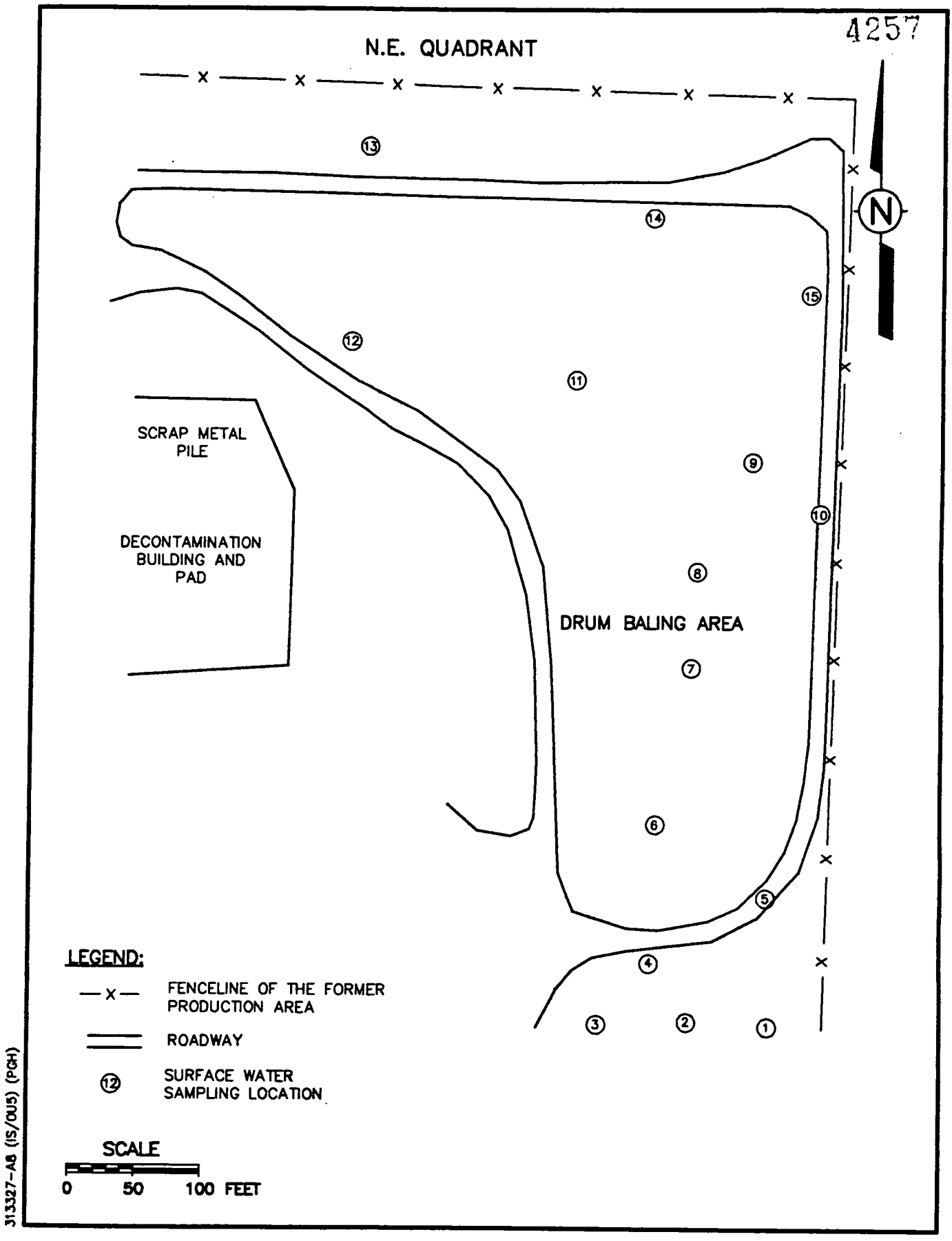


FIGURE 3-21 SURFACE WATER SAMPLING LOCATIONS FOR THE DRUM BALING AREA AT THE FEMP

were below the levels of concern at sampling locations immediately upstream and downstream of the locations shown in Figure 3-19. Furthermore, the scouring of Paddys Run and the SSOD during periods of heavy flow prevents contaminants from concentrating in a specific location for a significant amount of time. The sum of uranium isotope concentrations of 14 RI sediment samples collected at seven locations along the Great Miami River in 1988 and 1989 ranged from less than detection limits (< 0.6 pCi/g) to 2.5 pCi/g, with Uranium-234 and Uranium-238 contributing approximately 51 and 49 percent, respectively (Table A-46.) These concentrations, which are much lower than the specified action level (35 pCi/g), are consistent with those measured during the Environmental Monitoring Program from 1984 to 1988 (Tables A-43, A-44, and A-47). Concentrations from the latter program ranged up to 2.96 pCi/g during this period.

The organic compounds and metals identified in the sediments of Paddys Run (above and below the confluence of the SSOD with Paddys Run) and at the SSOD are presented in Tables A-48, A-49, and A-50, respectively. One constituent of potential concern, aluminum, has been identified.

The RI/FS database for sediment samples consists of 142 samples that were taken in 1988 and 1989 (Table A-51). The total uranium concentration was lowest in the Great Miami River (above and below the effluent discharge) (Figure 3-20). It ranged from less than detected to 3.0 µg/g (dry weight). The highest concentration of total uranium in sediment was found in Manhole 175. It ranged from 595 µg/g to 614 µg/g (dry weight).

The total volume of sediment impacted by radionuclide constituents, such as uranium and Radium-226, was estimated to be 140 cubic yards. The calculations for this estimate are shown below:

- FEMP Storm Sewer Outfall - 10 feet wide x 300 feet long x 6 inches deep x 1/3 effective width (total of 500 cubic feet (ft^3) or approximately 20 cubic yards (yd^3)
- Paddys Run - 15 feet wide x 600 feet long x 6 inches deep x 1/3 effective width (total of 1,500 ft^3 or approximately 60 yd^3)
- Paddys Run near FEMP Storm Sewer Outfall Confluence - 15 feet wide x 600 feet long x 6 inches deep x 1/3 effective width (total of approximately 1500 ft^3 or 60 yd^3)

3.8 AIR

Measurable concentrations of radionuclides have been present at times in air, at and in the vicinity of the FEMP. These occurrences have been primarily associated with site stack emissions and fugitive emissions from waste areas and have been shown not to result in unacceptable doses to off-site populations. Source control represents the only valid action for addressing this environmental condition. While fugitive dust emissions will be addressed during implementation of remedial actions,

site stacks are not included within the scope of Operable Unit 5. Available air data will be documented as part of the Operable Unit 5 RI and will be considered as a pathway within the risk assessment.

3.9 BIOTA

Terrestrial and aquatic biota have been sampled to determine whether any radiological or hazardous substances released to the FEMP environs have been transferred to wildlife habitats, including wetlands, or to agricultural produce and milk. The data can then be used to determine if any such transfers represent a significant hazard to human beings or to threatened or endangered wildlife species. These evaluations will be performed in the ecological risk assessment.

Local produce, including green peppers, okra, tomatoes, cucumbers, squash, potatoes, alfalfa, and corn, had uranium concentrations no higher than those in produce from an upwind control area in Brookville, Indiana (Table A-52). This indicates that local produce is probably not a significant pathway for human exposure to uranium derived from FEMP operations, although this pathway will be evaluated in the risk assessment that is yet to be performed. Exposure to other FEMP-derived radionuclides through agricultural products does not appear to be significant. Neither Cesium-137 nor Strontium-90 was detected in any of the produce sampled. These two radionuclides were selected as key parameters due to their high bioaccumulation potential.

Milk samples were collected from cows grazing both in the vicinity of the FEMP and from dairy farms approximately 30 kilometers (km) away as part of the 1983 to 1988 FEMP Environmental Monitoring Programs. Only 3 of 62 samples collected at the FEMP and control locations had detectable levels of uranium (Table A-53). In 1983, one of the four samples collected had a detectable concentration of uranium in milk from both the FEMP location cows as well as the control cows. Both locations had uranium concentration ranges of < 0.7 to 1.35 pCi/L. In 1988, one of 12 milk samples collected at the FEMP had a uranium concentration above the detection limit, at 1.0 pCi/L. Milk samples from cows at the control location were all below the uranium detection limit of 0.7 pCi/L.

Vegetation sampling at the FEMP included the collection and radiological analysis of the roots and shoots of both grasses and forbs. All samples were collected inside the FEMP boundary, but outside the former production area. Total uranium concentrations in vegetation ranged from nondetectable (< 0.6 pCi/g) to 35.5 pCi/g, and occurred at detectable levels in about 62 percent of the samples. Uranium concentrations in soil and vegetation exhibited high spatial variability. Cesium-137 and Strontium-90 concentrations were consistently low, occurring at detectable levels in only 27 and 7 percent of the samples, respectively (Table A-54).

No detectable radionuclides were found in mammal samples, except for uranium in a composite sample of small mammal organs (including liver, kidney, and gonads) collected adjacent to waste pit 5 (Table A-55). This could indicate a potential exposure pathway to receptors feeding in the waste storage area. However, their wide feeding ranges should limit their exposure to radionuclides from the FEMP. The composite carcass sample from which the organs were taken had no detectable radionuclides.

Aquatic organisms could be exposed to FEMP-derived radionuclides in wetlands, Paddys Run, and the Great Miami River. The radiological analysis of aquatic vegetation (cattail, sedge, and grass leaf and root samples) revealed total uranium concentrations ranging from nondetectable (< 0.6 pCi/g) to 31.3 pCi/g. Uranium occurred at detectable levels in 44 percent of the samples. Strontium-90 was detected in only one algae sample (0.9 pCi/g), and Technetium-99 was detected in one leaf sample (1.9 pCi/g). All other concentrations were below detection limits. Cesium-137 was below detection limits in all samples (Table A-56). The potential ecological impacts associated with radionuclides detected in the aquatic vegetation samples will be examined in the ecological risk assessment.

Benthic macroinvertebrate samples collected from both Paddys Run and the Great Miami River had detectable Uranium-234 and Uranium-238 concentrations. Detected total uranium concentrations ranged from 1.5 to 6.5 pCi/g. Cesium-137, Strontium-90, and Technetium-99 were below detection limits in all samples (Table A-57). The detected concentrations indicate that uranium may be entering the aquatic food chain. Fish collected from Paddys Run had detected levels of uranium (0.6 to 3.7 pCi/g) in 30 percent of the samples analyzed (Table A-57). Cesium-137, Strontium-90, and Technetium-99 were not detected in any of the samples. No detectable radionuclides were found in fish samples collected from any site on the Great Miami River as part of the RI/FS investigation. Because whole-body fish samples did not have radionuclide concentrations higher than macroinvertebrates, there is no evidence of biomagnification of radionuclides by fish in Paddys Run or the Great Miami River.

Biological samples, including grass, fish, and mammal tissues, were also analyzed for priority pollutant base, neutral, and acid extractable organic compounds as well as pesticides and PCBs. None of these compounds were detected in any sample.

There is no evidence that threatened or endangered species are currently at risk from radionuclides or hazardous substances released by the FEMP.

3.10 CONTAMINANT TRANSPORT AND FATE

As indicated in the preceding sections, radiological contaminants which may adversely affect human health and the environment are present in various environmental media at the FEMP. The transport

pathways, potential receptors, and risk to receptors will be thoroughly evaluated as part of the baseline risk assessment, which will be an integral component of the RI for Operable Unit 5. Section 3.10.1 provides an overview of the role of environmental media in the transport of contaminants and the associated potential exposure of receptors. The environmental fate of contaminants is discussed in Section 3.10.2.

3.10.1 Contaminant Migration Pathways and Receptors

3.10.1.1 Groundwater

The contamination in the regional aquifer south of the FEMP is believed to be largely the result of historical releases of radioactive materials from the FEMP that entered Paddys Run by way of the SSOD and other overland pathways, and subsequently infiltrated into the aquifer through the streambed. The addition of the storm water retention basin and the implementation of other surface water management practices have minimized the loading of contaminants associated with this pathway to the aquifer. The observed contamination of the regional aquifer immediately beneath the waste storage area is likely the result of vertical migration of uranium originating in the waste pits through the till.

The regional aquifer provides water supplies to a large number of private and industrial users in the FEMP vicinity. Part 4 of the South Plume Removal Action expanded the existing groundwater monitoring program to include more frequent monitoring of private wells located near areas of known contamination. The off-property well monitoring program provides the environmental data necessary to reduce the potential exposure of off-property well water consumers to groundwater in excess of the 20 µg/L preliminary remediation goal. Alternate water supply wells for two affected industrial users have been developed. This program of alternate water supply system installation, combined with well monitoring minimizes the chance of people using contaminated groundwater. Currently, uranium from the FEMP into the regional aquifer does not pose an immediate health risk or substantial endangerment to known users of the groundwater from the aquifer. However, because a possibility of future human exposure to this groundwater does remain, the OU5 Risk Assessment will evaluate the most probable human and environmental exposure pathways; those being direct ingestion, indirect ingestion via watering of plants and livestock, inhalation, and dermal contact.

The long-term migration of the plume underlying the Waste Storage Area is dependent on the continued pumping of the three SOWC wells or other wells in the area. The nearest SOWC well is located approximately 3,500 feet east of the FEMP property boundary. The other two SOWC wells are located approximately 4,000 feet and 5,200 feet east of the property boundary, near the Big Bend Area of the Great Miami River. Continued pumping will cause an eastward plume migration. In the absence of pumping, the plume would migrate southward along the natural gradient. This long-term

migration scenario will be further evaluated as part of the Operable Unit 5 modeling study and risk assessment.

3.10.1.2 Surface Water

As previously indicated in Section 3.6, concentrations of uranium in surface waters of the SSOD and Paddys Run are relatively low and have significantly decreased with time. The major sources of contamination to these surface water bodies have been surface runoff from the former production area and other areas within the FEMP. Projects to control these sources have been completed; others are planned.

Uranium concentrations in the Great Miami River are only slightly elevated above background levels. Specifically, the average uranium concentration in the Great Miami River for samples collected at Locations W3 (downstream from the effluent discharge) (Figure 3-20) and W4 (located approximately 7.6 km downstream from the confluence of Paddys Run with the Great Miami River) is approximately 1.6 pCi/L; the average background concentration is 1.2 pCi/L (collected upstream from the main effluent line at Sampling Location W1). Uranium is discharged to the river by the FEMP under the authority of DOE Order 5400.5. Earlier studies, as presented in the "Hydrogeologic Study of the FMPC Discharge to the Great Miami River" (IT 1988), have demonstrated that any contribution of uranium from the main effluent line into the river does not result in measurable effects on uranium concentrations in nearby production wells. Surface water runoff from the site via the SSOD and Paddys Run does not significantly contribute to uranium concentrations in the river.

The primary human exposure pathway relating to surface water of Paddys Run and the SSOD is dermal contact. At the present time, direct ingestion is not considered a possible exposure pathway because neither Paddys Run nor the outfall ditch is used as a drinking water supply nor does either support a viable commercial or recreational fishery. Environmental exposure pathways in surface waters of the Great Miami River include the direct ingestion of water by organisms and the transfer of contaminants up the food chain through ingestion at various trophic levels. Ultimately, this pathway can affect human health.

3.10.1.3 Soils and Sediments

As discussed in Section 3.5, there are extensive areas within the FEMP where concentrations of uranium in soil exceed the preliminary remediation goal (Figure 3-19). There are also widespread areas within and outside the FEMP boundary where concentrations are above background but below the preliminary remediation goal. The overall pattern of above-background levels of uranium is due primarily to airborne release and the deposition of uranium-contaminated particulates historically emitted from numerous stacks. Local areas with uranium concentrations exceeding the preliminary remediation goal of 35 pCi/g are typically linked to specific operations (i.e., the historic use of the

incinerator) or previous spills. Human exposure pathways to contaminated surface soils include direct ingestion, dermal contact, inhalation, and ingestion of agricultural crops grown in soil.

Sediments in the SSOD, Paddys Run, and the Great Miami River generally have concentrations of contaminants at levels below PRGs (Section 3.7). The sources of contaminants in these sediments are the same as those for surface water. The primary potential exposure pathway for humans is direct ingestion of the sediments with a secondary human exposure pathway being dermal contact of contaminated sediments. Environmental exposure pathways include both the consumption of sediments by bottom feeding organisms and subsequent transfer into the food chain. The release of contaminants from the sediments to the water column is also a potential exposure pathway, but the lack of observed surface water concentrations exceeding preliminary remediation goals would negate the need to consider this pathway.

3.10.1.4 Ambient Air

Transport of radionuclides and chemicals via the air can occur as a consequence of mechanical disturbances of soil or sediment or from particulate resuspension by local winds. Subsequent transport and dispersion to receptor locations and specific receptor groups will be calculated as part of the risk assessment.

3.10.1.5 Biota

Biota can be receptors of radionuclides and chemicals dispersed through air, surface water, sediments, or groundwater pathways. Biota will be evaluated in the ecological risk assessment as both intermediate receptors for final exposure by humans and as end-point environmental receptors.

3.10.2 Contaminant Fate

Uranium is radioactive and will decay over time to become other radioisotopes, and ultimately stable lead. The half-lives of U-238, -235, and-234 are 4.5×10^9, 7.04×10^8, and 2.5×10^5 years, respectively. Relative to these half-lives, the uranium has been present at and near the site for a very short time and will remain in its present forms with little change over the life of the Fernald project; i.e., the next 30 years. If no action is taken, uranium in the groundwater will migrate from the area and will ultimately be discharged into the Great Miami River. Once in the Great Miami River, the uranium will be transported downstream. Some uranium could be lost to the sediments, but surface water runoff data collected in the spring of 1989 as part of the RI indicate that the uranium is in a soluble, nonfilterable form. The data show that the total uranium concentrations in both filtered and unfiltered samples collected from within drainageways in the waste pit area are essentially the same, and that little, if any, uranium is bound up in suspended solids in the storm water runoff.

Uranium in soils and sediments will either remain in place and be slowly transformed through the decay process, undergo erosion or leaching and enter the hydrologic system, or be physically transported to other areas by wind or rain in the case of soil and resuspension in the case of sediments.

A more detailed description of the fate and transport of contaminants at the FEMP is presented in Appendix O (Groundwater Fate and Transport Modeling) of the Sitewide Characterization Report (DOE 1992a).

3.11 CONTAMINANTS OF CONCERN

Not all chemicals identified during site sampling pose significant health risks. The first step in the baseline risk assessment involves the identification of constituents considered to be potential concerns. These constituents are then carried through the risk assessment process to evaluate exposure pathways and to ascertain present and future impacts on human health. Since the risk assessment for Operable Unit 5 has not been performed, a list of preliminary potential contaminants of concern has been identified for the site as a whole. The preliminary potential contaminants of concern are listed in Tables 3-1, 3-2, and 3-3. Each contaminant detected is noted in these tables. Tables 3-7, 3-8, 3-9, 3-10, and 3-11 present the list of contaminants detected at or above their respective PRGs in each media. This list of contaminants is used to identify applicable technologies for remediation.

3.11.1 Exposure Routes and Receptors

The transport media, transport mechanisms, and corresponding exposure pathways applicable to Operable Unit 5 are summarized below:

Transport Medium	Transport Mechanism	Exposure Pathway
Air	Mechanical disturbance or resuspension; transport and dispersion by local winds	Inhalation; dermal contact indirect ingestion via deposition on soil or vegetation and subsequent uptake by plants and livestock
Surface Water	Sediment release into surface water; ingestion by aquatic organisms; release of surface water to other surface water courses; release to underlying aquifer	Direct ingestion; indirect ingestion via uptake by plants or fish; indirect ingestion via watering of plants and livestock; dermal contact
Groundwater	Discharge to surface water course; extraction by pumping; phreatophytes (e.g., willow trees)	Direct ingestion; indirect ingestion via watering of plants and livestock; dermal contact; inhalation

Transport Medium	Transport Mechanism	Exposure Pathway
Soils	Release into surface water course (erosion); resuspension into air; uptake by vegetation; and bioaccumulation in food chain	Direct ingestion; inhalation; indirect ingestion via uptake by plants and livestock; dermal contact
Sediment	Sediment release into surface water; ingestion by aquatic organisms	Direct ingestion; indirect ingestion via uptake by plants or fish; dermal contact

TABLE 3-7
GREAT MIAMI AQUIFER CONSTITUENTS DETECTED ABOVE PRELIMINARY REMEDIATION GOALS (PRG)[a]

Constituents	2000-, 3000-, 4000-Series Wells Maximum Concentration	PRG
Organics (mg/L)		
Benzene	0.160	0.005 (MCL[b])
Methylene chloride	0.047	0.005 (PMCL[b])
Trichloroethene	0.009	0.005 (MCL)
N-nitrosodiphenylamine	0.021	0.007 (CSF-based[c])
Phenol	11.50	4 (RfD-based[d])
Bis(2-ethylhexyl)phthalate	0.05	0.003 (CSF-based)
Radionuclides (pCi/L)		
Strontium-90	38.5	8 (MCL)
Technetium-99	5510	3750 (MCL)
Thorium-232	2.3	2 (4 mrem dose)
Uranium-234	149.675	7 (PMCL)
Uranium-235/236	7.365	0.3[e] (PMCL)
Uranium-238	156.675	7 (PMCL)
Total uranium (µg/L)	575	20 (PMCL)
Metals (mg/L)		
Barium	5.224	2 (MCL)
Beryllium	0.002	0.001 (PMCL)
Cadmium	0.643	0.005 (MCLG[f])
Chromium (total)	4.781	0.1 (MCLG)
Lead	0.725	0.005 (MCL)
Manganese	354.699	0.7 (RfD-based)
Mercury	0.02513	0.002 (MCLG)
Molybdenum	0.058	0.03 (RfD-based)
Nickel	2.009	0.1 (PMCLG[f])

See footnotes at end of table.

TABLE 3-7
(Continued)

Constituents	2000-, 3000-, 4000-Series Wells Maximum Concentration	PRG
Selenium	0.203	0.05 (MCLG)
Silver	3.886	0.05 (MCL)
Thallium	0.002	0.0005 (PMCLG)
Vanadium	2.612	0.05 (RfD-based)
Zinc	2.3	1 (RfD-based)

[a]Based on data available in the Fernald database as of December 1, 1991.

[b]MCL/PMCL - Chemical-specific "maximum contaminant levels/preliminary maximum contaminant levels" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[c]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

[d]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

[e]This PRG applies to uranium-235 only.

[f]MCLG/PMCLG - Chemical-specific "maximum contaminant level goals/preliminary maximum contaminant level goals" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

NOTE: Maximum uranium concentrations are not representative of a single sample, but represent individual maximum isotopic concentrations observed at the FEMP.

TABLE 3-8
PERCHED GROUNDWATER CONSTITUENTS DETECTED ABOVE PRELIMINARY REMEDIATION GOALS (PRG)[a]

Constituents	1000 Series Wells Maximum Concentration	PRG
Organics (mg/L)		
Benzene	0.014	0.005 (MCL[b])
1,1-Dichloroethane	2.5	0.7 (RfD-Based[c])
1,2-Dichloroethane	0.086	0.005 (MCL)
1,1-Dichloroethene	0.49	0.007 (MCL)
Cis-1,2-Dichloroethene	1.5	0.07 (MCLG[d])
Methylene chloride	0.028	0.005 (PMCL[b])
Tetrachloroethene	0.35	0.005 (MCL)
1,1,1-Trichloroethane	2.9	0.2 (MCL)
Trichloroethene	6.4	0.005 (MCL)
Vinyl chloride	0.016	0.002 (MCL)
Radionuclides (pCi/L)		
Technetium-99	6130	3750 (MCL)
Thorium-230	23.3	10 (4 mrem dose)
Thorium-232	23.1	2 (4 mrem dose)
Radium-228	53.9	5, 20 (CSF[e])
Uranium-234	50,553	7 (PMCL)
Uranium-235/236	7494	0.3 (CSF[f])
Uranium-238	59,924	7 (PMCL)
Total uranium (µg/L)	568,100	20 (PMCL)
Inorganics (mg/L)		
Ammonia	188.5	7.1 (RfD-Based)
Arsenic	0.113	0.05 (MCL)
Beryllium	0.072	0.001 (PMCL)

See footnotes at end of table.

TABLE 3-8
(Continued)

Constituents	1000 Series Wells Maximum Concentration	PRG
Cadmium	0.040	0.005 (MCLG)
Chromium (total)	2.11	0.1 (MCLG)
Cobalt	0.245	0.02 (RfD-Based)
Manganese	35.425	0.7 (RfD-Based)
Mercury	7.55	0.002 (MCLG)
Molybdenum	0.491	0.03 (RfD-Based)
Nickel	0.271	0.1 (PMCLG[d])
Silver	0.824	0.05 (MCL)
Thallium	0.003	0.0005 (PMCLG)
Vanadium	0.670	0.05 (RfD-Based)

NOTE: Maximum uranium concentrations are not representative of a single sample, but represent individual maximum isotopic concentrations observed at the FEMP.

[a]Based on data available in the Fernald database as of December 1, 1991.

[b]MCL/PMCL - Chemical-specific "maximum contaminant levels/preliminary maximum contaminant levels" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[c]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

[d]MCLG/PMCLG - Chemical-specific "maximum contaminant level goals/preliminary maximum contaminant level goals" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[e]CSF - Chemical-specific "cancer slope factor," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS), used with a 10^{-6} risk level.

[f]This PRG applies to uranium-235 only.

TABLE 3-9
SOIL CONSTITUENTS DETECTED ABOVE PRELIMINARY REMEDIATION GOALS (PRG)[a]

Constituents	Maximum Concentration	PRG
Organics (mg/kg)		
Tetrachloroethene	17	10 (CSF-based[b])
Trichloroethene	150	60 (CSF-based)
Benzo(a)pyrene	24	0.06 (CSF-based)
Radionuclides (pCi/g)		
Total uranium	90,350	35 (TBC[c])
Uranium-234	13,262	35 (TBC)
Uranium-235/236	1730	35 (TBC[d])
Uranium-238	25,670	35 (TBC)
Thorium-228	315	0.006 (CSF-based)
Thorium-230	2749	5 (TBC)
Thorium-232	283	5 (TBC[e])
Radium-226	2720	5 (TBC[e])
Radium-228	546	5 (TBC[e])
Cesium-137	14.4	0.02 (CSF-based)
Strontium-90	26.3	10 (CSF-based)
Plutonium-238	6.1	0.5 (CSF-based)
Plutonium-239/240	1.5	0.5 (CSF-based)
Metals (mg/kg)		
Beryllium	2.4	0.2 (CSF-based)
Lead	440	90 (RfD-based[f])

See footnotes at end of table.

TABLE 3-9
(Continued)

NOTE: Maximum uranium concentrations are not representative of a single sample, but represent individual maximum isotopic concentrations observed at the FEMP.

[a]Based on data available in the Fernald database as of December 1, 1991.

[b]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

[c]TBC - Chemical-specific guidance "to be considered" refers to pertinent suggested, nonregulatory concentration levels that represent health-based, recommended levels to be evaluated in the absence of applicable ARARs.

[d]This PRG applies to uranium-235 only.

[e]Includes progeny products.

[f]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

TABLE 3-10
SURFACE WATER CONSTITUENTS DETECTED ABOVE PRELIMINARY REMEDIATION GOALS (PRG)[a]

Constituents	Maximum Concentration			PRG
Organics (mg/L)				
Bis(2-ethylhexyl)phthalate	0.004 (PR[b])			0.003 (CSF[c])
	Max. Conc. Paddys Run	Max. Conc. GMR[d]	Max. Conc. Other SW[e]	PRG
Radionuclides (pCi/L)				
Uranium-234	f	f	653	7 (PMCL[g])
Uranium-235/236	<1.0	<1.0	51.5	0.3 (CSF-based[h])
Uranium-238	f	f	2840.0	7 (PMCL)
Radium-228	f	f	127.2	20 (PMCL)
Technetium-99	f	f	21,887	3750 (MCL[g])
Thorium-232	f	f	4.7	2 (4 mrem dose)
Total uranium (µg/L)	20.00	f	9318	20 (PMCL)
	Max. Conc.			PRG
Metals (mg/L)				
Beryllium	0.0012 (PR)			0.001 (PMCL)
Cadmium	0.005 (GMR)			0.0011 (FAWQC/Chronic[i])
Copper	0.0147 (PR)			0.012 (FAWQC/Chronic[j])
Lead	0.014 (GMR)			0.0032 (FAWQC/Chronic)
Mercury	0.001 (GMR)			0.000012 (FAWQC/Chronic[j])

NOTE: Maximum uranium concentrations are not representative of a single sample, but represent individual maximum isotopic concentrations observed at the FEMP.

[a]Based on data available in the Fernald database as of December 1, 1991.

[b]PR - Maximum concentration was detected in Paddys Run.

[c]CSF - Chemical-specific "cancer slope factor," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS), used with a 10^{-6} risk level.

TABLE 3-10
(Continued)

[d]GMR - Maximum concentration was detected in the Great Miami River.

[e]SW - Surface water

[f]Maximum concentration detected is less than the PRG.

[g]MCL/PMCL - Chemical-specific "maximum contaminant levels/proposal maximum contaminant levels" are regulatory chemical concentration levels established in the Safe Drinking Water Act (40CFR Parts 141-142).

[h]This PRG applies to uranium-235 only.

[i]FAWQC - Chemical-specific "federal ambient water quality criteria" are regulatory chemical concentration levels established in the U.S. EPA guidance document "Quality Criteria for Water, 1986."

[j]Insufficient data to develop criteria; value presented is the lowest observed effect level (LOEL).

TABLE 3-11

SEDIMENT CONSTITUENTS DETECTED ABOVE PRELIMINARY REMEDIATION GOALS (PRG)[a]

Constituents	Max. Conc.[b] Paddys Run	Max. Conc. GMR[c]	Max. Conc. Other SW[d]	PRG
Organics (mg/kg)				
None		N/A		
Radionuclides (pCi/g)				
Uranium-234	e	e	174	35 (TBC[f])
Uranium-238	e	e	244	35 (TBC)
Radium-226	10.6	e	10.6	5[g] (TBC)
Radium-228	21.7	e	24.5	5[g] (TBC)
Technetium-99	e	e	692	290 (CSF-based[h])
Thorium-228	<0.6	<0.6	32	0.006 (CSF-based)
Thorium-230	e	e	28.2	5 (TBC)
Total uranium	e	e	411.4	35 (TBC)
Metals (mg/kg)				
Beryllium	0.5	NA[i]	0.4	0.2 (CSF-based)

[a]Based on data available in the Fernald database as of December 1, 1991.

[b]Max. Conc. - Maximum detected concentration.

[c]GMR - Great Miami River.

[d]SW - Surface water.

[e]Maximum concentration detected is less than the PRG.

[f]TBC - Chemical-specific guidance "to be considered" refers to pertinent suggested, nonregulatory concentration levels that represent health-based, recommended levels to be evaluated in the absence of applicable ARARs.

[g]Includes progeny products.

TABLE 3-11
(Continued)

[h]CSF - Chemical-specific "cancer slope factor," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS), used with a 10^{-6} risk level.

[i]NA - Not available.

NOTE: Maximum uranium concentrations are not representative of a single sample, but represent individual maximum isotopic concentrations observed at the FEMP.

4.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

4.1 INTRODUCTION

This section discusses the development and screening of the technologies and process options used to assemble the preliminary remedial action objectives (RAO) for Operable Unit 5. The steps involved in this screening include:

- Developing preliminary RAOs specifying the contaminants and media of interest, exposure pathways, and preliminary remediation goals that permit a range of treatment and containment alternatives to be developed. The preliminary remediation goals are developed on the basis of chemical-specific ARARs, when available; other available information (e.g., reference doses [RfDs]); and site-specific, risk-related factors.

- Developing general response actions for each medium of interest defining containment, treatment, excavation, pumping, or other actions, singly or in combination, that may be taken to satisfy the preliminary RAOs for the site.

- Identifying volumes or areas of media to which general response actions might be applied, taking into account the requirements as identified in the preliminary RAOs, and the chemical and physical characterization of the site.

- Identifying and screening the technologies and process options applicable to each general response action to eliminate those that cannot achieve the preliminary RAOs or be implemented technically at the site.

These tasks were initially completed as part of the sitewide Development of Alternatives Report. The refinement of these initial tasks for Operable Unit 5 is presented in the following sections.

4.2 PRELIMINARY REMEDIAL ACTION OBJECTIVES

Preliminary RAOs consist of medium-specific or operable unit-specific goals for protecting human health and the environment. In general, preliminary RAOs aimed at protecting human health and the environment must consider:

- The contaminant(s) of concern
- Exposure route(s) and receptor(s)
- An acceptable contaminant level or range of levels for each exposure route (i.e., a PRG).

EPA guidance requires that preliminary RAOs be developed in the initial phase of the FS and used as the framework for developing the detailed remedial alternatives. The specificity of these objectives may vary depending on the availability and quality of site information, conditions, and complexity.

4.2.1 Summary of Operable Unit 5 Preliminary RAOs

Preliminary RAOs for relevant media associated with Operable Unit 5 are summarized in Table 4-1. The preliminary RAOs established for the Operable Unit 5 FS focus on pathways and receptors. Continuing or existing sources of contamination to these pathways are the subject of other operable units. Based on the existing data, the media addressed in this report that potentially require direct remediation include groundwater, soils, and sediments. Remediation of the surface water, air, floral and faunal receptors/pathways will be addressed by removing the source(s) of contamination. These actions are evaluated for the following four media: perched groundwater, Great Miami Aquifer, soils, and sediments.

4.3 IDENTIFICATION OF GENERAL RESPONSE ACTIONS

General response actions are identified for contaminants of concern to satisfy the preliminary RAOs. Response actions represent classes or groups of technologies which have characteristics in common. The response actions considered for Operable Unit 5 are as follows:

- No Action: Represents no further remedial action on environmental media beyond what is currently proposed as part of other operational or regulatory compliance programs
- Institutional Actions: Represent minimum activity and includes additional monitoring and/or use access restrictions
- Control/Containment: Includes primarily physical measures to restrict contaminant migration or waste movement
- Removal: Involves the removal of contaminated material to a treatment or disposal facility
- Treatment (on and off site): Includes physical, chemical, and biological measures which will reduce the toxicity, mobility, or volume (TMV) of a contaminant or waste by altering the physical or chemical properties of the containment and/or media
- Disposal (on and off site): Includes the removal of the treated or untreated material and placement in a temporary or permanent pre-engineered environment which will restrict contaminant migration and thus eliminate exposure routes
- Discharge: Includes the release of treated or untreated groundwater to the environment.

Each of these response actions is applicable to groundwater with the exception of disposal. Disposal is, however, an ancillary operation associated with groundwater treatment. Treatment residuals may require disposal. Also, with the exception of the discharge action, each is considered applicable to the soil and sediment media.

TABLE 4-1
OPERABLE UNIT 5 PRELIMINARY REMEDIAL ACTION OBJECTIVES

Media	Preliminary Remedial Action Objective
Solids: • Soils • Sediments	Prevent direct contact with thorium-230, thorium-232, radium-226, and radium-228 above 5 picocuries per gram (pCi/g) in sediments or in the first 15 cm of soil, and 15 pCi/g at lower depths where there is a less chance of direct contact.
	Prevent inhalation/direct contact/ingestion of chemicals from exceeding a 1×10^{-6} cancer risk and/or a hazard index of 1.
	Prevent direct contact with soils or sediments containing total uranium at levels greater than 35 pCi/g (Tables 3-9 and 3-11).
	Prevent erosion of soil that would contribute to inorganic and organic chemical surface water concentrations exceeding risk levels of a 1×10^{-6} cancer risk and/or a hazard index of 1.
	Prevent migration of contaminants which would result in groundwater concentrations in the Great Miami Aquifer exceeding the maximum contaminant level (MCL) or a 1×10^{-6} cancer risk and/or a hazard index of 1 (Table 3-7).
	Prevent erosion of soils and release from sediments that would contribute to surface water concentrations of chemicals greater than ambient water quality criteria a 1×10^{-6} cancer risk and/or a hazard index of 1 (Table 3-10).
	Prevent excessive uptake of uranium contamination in soils and sediments by terrestrial and aquatic flora and fauna.
Groundwater: • Perched • Great Miami Aquifer	Prevent the ingestion (direct or indirect) of groundwater exceeding the proposed MCL of 20 mircrograms per liter (ug/L) for total uranium, in addition to other standards for hazardous chemicals, or other risk-based criteria that may be developed (Tables 3-7 and 3-8).
	Prevent the migration of groundwater exceeding the proposed MCL for total uranium of 20 ug/L to potential additional receptors (Tables 3-7 and 3-8).
	Prevent release of radionuclides from perched groundwater to the Great Miami Aquifer resulting in levels exceeding 20 ug/L (Tables 3-7 and 3-8).
	Prevent migration of contaminants which would result in groundwater concentrations in the Great Miami Aquifer exceeding the MCLs or exceeding a 1×10^{-6} cancer risk and/or a hazard index of 1 (Table 3-7).

4.4 IDENTIFICATION AND INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

For groundwater, soils, and sediments, potentially feasible remedial technologies and process options have been identified for each of the relevant response actions. These technologies were compiled from various EPA documents as well as other applicable references. Each of these technologies and process options has undergone a refinement of the previously completed screening of technologies and process options in the Development of Alternatives Document (DOE 1988b). The goal of the screening process is to evaluate a large number of technologies to determine which are potentially technically implementable for the various media. In this step, both process options and entire technology types could be eliminated based on technical effectiveness and/or implementability. Information regarding site characterization, contaminant types, and contaminant concentrations was used to eliminate technology types and process options that are either not applicable or cannot be effectively implemented at the site. In some instances, the technology type or process option is not considered applicable as the primary remedial action for an individual media; however, it may have applicability during implementation in support of the primary process. These technologies are noted as support technologies in this section and are not carried forward at this time for further evaluation.

Tables in this section document the results of the technology types and processing options screening process for Operable Unit 5. Following is a list of technology types applicable to groundwater for Operable Unit 5:

- Monitoring
- Use/access restrictions
- Pumping wells (control/containment)
- Alter natural drainage system
- Vertical barriers
- Horizontal barriers
- Pumping wells (removal)
- Gravity drainage
- Biological treatment
- Physical treatment
- Physicochemical treatment
- Chemical treatment
- Discharge to surface water
- Pumping wells (injection)

Following is a list of technologies applicable to soils and sediments for Operable Unit 5:

- Access/use restrictions
- Capping
- Surface water/storm water control
- Extraction of source
- Biological treatment

- Physical treatment
- Physicochemical treatment
- Solidification/stabilization
- Microencapsulation
- Vitrification
- Thermal treatment
- Storage facility
- Engineered disposal facility

The rationale for the elimination of certain technology types for Operable Unit 5 media is presented in the following sections.

As mentioned in Section 1.0 of this report, the removal action proposed as the preferred alternative within the South Plume EE/CA (DOE 1990a) and subsequent addendum entitled "Explanation of Significant Differences Document" is considered as the baseline condition for this FS. This removal action includes the provision of an alternate water supply to the two currently affected industrial users in the area and application of institutional measures regarding the use of contaminated groundwater by potential receptors. Additionally, four or five recovery wells will be located near the center of the plume to extract contaminated groundwater from the aquifer. Additional interim treatment of the site waste streams will also be provided to compensate for the additional mass of uranium that will be extracted from the aquifer and discharged to the Great Miami River. Monitoring for compliance and the effectiveness of the extraction system is also part of this removal action.

For purposes of the initial screening of technologies and process options for the groundwater medium, the alternate water supply and associated institutional measures are considered part of the removal action and will not be reevaluated. On the other hand, the continuation, discontinuation, or expansion of the extraction and monitoring system components of the removal action are considered to be candidate options for the final remedial action alternatives for the groundwater medium and are reevaluated in this screening document.

The following sections provide a discussion of the screening process. The technologies and process options for groundwater are first identified and screened. The soils and sediments are discussed together since most of the technologies and process options are common to both media. Storm water runoff and surface water overlying the sediments are addressed either in other operable units (i.e., those that address contamination sources) or implicitly by addressing the soils and sediments in this operable unit.

4.4.1 Initial Screening: Groundwater Medium

The groundwater medium consists of both the perched groundwater and the regional aquifer (Great Miami Aquifer). The general response actions that are applicable to the medium include no action,

institutional actions, control/containment, removal, treatment, and discharge. Summaries of the technologies and process options are presented in Table 4-2; however, due to differences in the aquifer characteristics and the variation in the levels and the nature of the contaminants in the perched groundwater and the Great Miami Aquifer, the applicability of the technologies and process options for the two groundwater zones may vary and is noted in Column 6 of Table 4-2.

As summarized in Section 3.0, and presented in Table 3-8, the perched groundwater contains volatile organics, inorganics and radionuclides above PRGs. The Great Miami Aquifer contains volatile and semivolatile organics, radionuclides, and metals above PRGs (Table 3-7). Uranium is the most widespread contaminant in the Great Miami Aquifer. Several volatile and semivolatile organic compounds and pesticides were detected in 2000-series wells in the Great Miami Aquifer. These detections were limited to isolated areas in the vicinity of the Waste Storage Area and former production area. Elevated concentrations of various organic compounds were also detected in off-property wells near Paddys Run. The major source of the volatile and semivolatile organics observed in these off-property wells may be the industrial facilities on Paddys Run Road.

Based on this information, and for purposes of the Initial Screening Document, treatment technologies and process options proposed for groundwater will be evaluated for their effectiveness in treating volatile organics, radionuclides, and other inorganics. Volatile organics and semivolatile organic compounds are addressed for the Great Miami Aquifer based on their limited and isolated presence. The actual volume of groundwater to be treated is not known at this time. Any refinements to this assumption will be analyzed during the detailed analysis of alternatives. At present, treatment of the organics present in limited and isolated occurrences in the Great Miami Aquifer would be implemented either as a side stream to the perched groundwater treatment system or by secondary support technologies which would not be included as part of the primary technology/alternative screening.

4.4.1.1 No Action

The no-action response was retained for consideration during the development and analysis of alternatives as required by the NCP. The no-action response does not provide additional remediation, monitoring, or security activities at the site to further minimize risk to public health or the environment. The no-action response will be further evaluated as a baseline for comparison with other remedial action alternatives developed for this operable unit.

4.4.1.2 Institutional Actions

The institutional actions screened for the groundwater medium include both monitoring and groundwater access/use restrictions. Both of these are applicable for perched groundwater and the Great Miami Aquifer. Monitoring includes the use of existing wells or the installation of new wells. These well networks can be used to monitor the performance of collection/treatment systems for

TABLE 4-2
FEMP FEASIBILITY STUDY
OPERABLE UNIT 5 - ENVIRONMENTAL MEDIA
INITIAL SCREENING OF TECHNOLOGIES
AND PROCESS OPTIONS FOR GROUNDWATER
(GREAT MIAMI AQUIFER AND PERCHED GROUNDWATER)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class		Description	Applicability		Screening Comments
			Inorganics/ Radionuclides	Organics		GMA[a]	PGW[b]	
No action	None	Not applicable	X	X	No action is taken. The no-action alternative is used as a baseline for comparison with other alternatives.	X	X	NCP requires the no-action alternative to be carried through detailed analysis.
Institutional actions	Monitoring	Groundwater monitoring	X	X	Ongoing GW monitoring via sampling existing wells and/or installation and sampling of new wells.	X	X	Potentially applicable.
	Groundwater use/access restrictions	Land acquisition	X	X	Purchase properties affected by the contaminated portion of the aquifer.	X	X	Potentially applicable.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Institutional actions (continued)	Groundwater use/access restrictions	Deed restrictions	X	X	Deeds for property and water rights within contaminated areas would include restrictions on future development and domestic groundwater use.	X	X	Potentially applicable.
Control/containment	Pumping wells	Extraction wells	X	X	Modify hydraulic gradient via extraction wells to contain and/or redirect contaminated groundwater flow.	X		Potentially applicable.
		Injection wells	X	X	Modify hydraulic gradient via injection wells to contain and/or redirect contaminated groundwater flow.	X		Potentially applicable.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Control/containment (continued)	Alter natural drainage system	Pave natural drainage channels which contribute recharge to aquifer	X	X	Contain Paddys Run in constructed drainage channel to prevent infiltration/recharge of aquifer.	X		Potentially applicable.
	Vertical barriers	Cement-bentonite/soil-bentonite slurry wall	X	X	Construct cement-bentonite or soil-bentonite slurry wall to prevent horizontal migration of contaminated groundwater.		X	Potentially applicable to perched groundwater, but maximum practical depth is limited to 100 feet.
		Grout curtain	X	X	Drill holes in a regular, overlapping pattern, then pressure inject grout to prevent horizontal migration of contaminated groundwater.		X	Not applicable. Major application of curtain grouting is to seal porous/ fractured bedrock. Generally not applicable in soils or loose overburden. Difficulty in determining final integrity of barrier.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Control/containment (continued)	Vertical barriers (continued)	Sheet piling	X	X	Construct cutoff wall from interlocking steel sheet piles hammered into place with a pile driver.		X	Potentially applicable as a support technology. Depth limited to 40 feet (typical). Difficult to install in rocky soils.
		Vibrating beam wall	X	X	Vibration used to advance a steel beam into the ground then a relatively thin wall of cement or bentonite is injected as beam is withdrawn, to prevent horizontal migration of contaminated groundwater.		X	Not applicable due to difficulty in ensuring integrity of barrier.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Control/containment (continued)	Horizontal barriers	Grout injection	X	X	Install horizontal grout barrier to prevent vertical migration of contaminated groundwater.		X	Not applicable due to difficulties in determining integrity of barrier.
		Block displacement	X	X	Controlled injection of slurry in notched injection holes.		X	Not applicable due to difficulties in determining integrity of barriers.
Removal	Pumping wells	Extraction wells	X	X	Series of wells to extract contaminated groundwater.	X	X	Potentially applicable.
		Wellpoint system	X	X	Numerous closely spaced wells connected to a header and pumped by a suction pump.		X	Potentially applicable, but depth of wellpoints limited to approximately 22 feet.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Removal (continued)	Pumping wells (continued)	Jet-eductor system	X	X	Type of jet pump that uses the vacuum generated by expanding a fluid through a nozzle to create the pumping action.		X	Not applicable due to low pump efficiency when compared to submersible well pumps. Depth of well limited to approximately 22 feet.
	Gravity drainage	French drains and/or interceptor trenches	X	X	Trenches used to divert surface and/or groundwater flow around contaminated areas or collect contaminated leachates.		X	Potentially applicable. Limited to depths of 40 feet (typical).
		Vertical sand drains	X	X	Install sand to connect thin, permeable strata separated by zones of low permeability materials to increase permeability.		X	Potentially applicable as a support technology only.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Removal (continued)	Other	Electroosmosis	X		Technique for dewatering soils using the application of an electrical field to induce water flow.	X	X	Potentially applicable as a support technology. Applicable to ionized contaminants (metals and inorganics) only. Would require detailed site-specific testing.
Treatment	Biological	Aerobic/ anaerobic bioremediation		X	Degradation of organics using microorganisms.		X	Not applicable; biological activity would be adversely affected by co-occurring metals and halogenated organics that are the primary contaminants of concern.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Biological (continued)	Denitrification		X	The reduction of nitrates and nitrites to molecular nitrogen by dentrifying bacteria.		X	Not applicable. Nitrogen-containing compounds are not major contaminants of concern.
		Aeration		X	A water treatment process that uses an aerated lagoon to promote biological degradation of organic contaminants.		X	Not applicable; organic contaminant concentrations are too low to sustain biological activity. VOCs are stripped rather than degraded, contributing to air pollution problems.
	Physical	Belt filter press	X	X	Dewater sludges by forced flow through a cloth filter media.	X	X	Potentially applicable as a support treatment process (sludge dewatering) only.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Physical (continued)	Flocculation/ coagulation/ sedimentation/ clarification	X	X	Remove suspended solids via (chemically and/or physically enhanced) gravity settling.	X	X	Potentially applicable as a support treatment process.
		Dual media filtration	X	X	Forced flow of liquid stream through a media (e.g., sand and anthracite) to remove TSS.	X	X	Potentially applicable as a support treatment process.
		Equalization	X	X	Uses a large capacity tank to eliminate fluctuations in flow rate and/or contaminant concentrations before further processing.	X	X	Potentially applicable as a support technology, particularly when biotreatment options are being considered for subsequent treatment stages.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Physical (continued)	Centrifugation	X	X	Separates suspended solids from a liquid by centrifugal force.	X	X	Potentially applicable as a support treatment process (pretreatment or sludge dewatering).
		Air stripping		X	Passing large volumes of air through VOC-contaminated water in a packed column or through diffused aeration to promote transfer of VOCs to air for subsequent processing.		X	Potentially applicable. Also has a limited ability to oxidize inorganic contaminants. Exhaust air will need subsequent treatment.
		Reverse osmosis	X	X	High pressure pumps are used to force water through a membrane. Contaminants are eliminated as a reject stream.	X	X	Potentially applicable. Membranes require regular maintenance and periodic replacement. Fouling is a common problem.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Physical (continued)	Advanced membrane filtration or ultrafiltration	X	X	Low pressure pumps are used to force water through porous membranes to remove high molecular weight contaminants from water.	X	X	Potentially applicable. Membranes require regular maintenance and periodic replacement. Fouling is a common problem.
		Distillation		X	Heat is used to separate organics contaminants from groundwater based upon the relative differences in their boiling points.	X	X	Not applicable. Primary contaminants are uranium and other radionuclides. For low concentrations of organics, better alternatives (e.g., air stripping) exist.
		Freeze crystallization	X	X	Refrigeration is used to separate contaminants from groundwater based upon the relative differences in their freeze points.	X	X	Not applicable. Contaminants are present in concentrations that are too low for this technology to be very effective.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Physicochemical	Polymerization		X	Chemical catalysts/promoters are used to promote polymerization of contaminants which can then be removed by filtration or settling.	X	X	Not applicable to site-specific contaminants and conditions. Has been successfully applied to spills of organic monomers but this is not descriptive of the current conditions at the FEMP.
		Adsorption (various media)	X	X	Adsorption of low concentration contaminants onto a substrate media.		X	Potentially applicable to organics and some selected inorganics.
		Precipitation	X		Use chemical additives to reduce the aqueous solubility of contaminants. A floccing agent is added to promote rapid settling.	X	X	Potentially applicable. Metal precipitate sludges may present a disposal problem.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Physicochemical (continued)	Electrodialysis	X		Contaminated groundwater flows through a stack of alternating cations--permeable and anion--permeable membranes. An electric current applied across the membrane stack removes ionized contaminants.	X	X	Potentially applicable. An advanced membrane-separation technology.
		Ultraviolet (UV) radiation/ oxidation		X	Uses UV radiation to promote oxidation of organic contaminants. Ozone and/or hydrogen peroxide is used as the oxidizing agent.		X	Potentially applicable; however, presence of turbidity greatly reduces effectiveness of this option.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Physicochemical (continued)	Ion exchange	X		Contaminated water is passed through an ion exchange resin bed where contaminant ions are exchanged for harmless ions.	X	X	Potentially applicable to ionized contaminants (heavy metals and inorganic contaminants).
		Biosorption	X		Use of an algae-based ion exchange resin to remove heavy metals from water.	X	X	Potentially applicable. A developing ion exchange technology. Some heavy metal ions may not be amenable to biological sorption.
	Chemical	Neutralization/ pH adjustment	X	X	Addition of chemicals to adjust water pH.	X	X	Potentially applicable as a support technology.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Chemical (continued)	Solvent (liquid-liquid) extraction	X	X	An immiscible (in water) solvent is added to the contaminated groundwater. The contaminants have a greater affinity for the added solvent. The solvent (and dissolved contaminants) are removed from treated groundwater by phase separation.	X	X	Potentially applicable. Complete separation is rarely achieved so some form of posttreatment would be required.
		Supercritical water oxidation	X	X	Treatment of groundwater at high temperature and pressure to enhance oxidation of organics.		X	Not applicable due to low concentrations of organics and ineffective in treating highly halogenated organics.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Chemical (continued)	Hydrolysis		X	Lime or sodium hydroxide used to decompose organics by hydrolysis reaction (generation of water). Applicable if concentration of organics is high.		X	Not applicable due to low concentrations of organics. Acid hydrolysis as an in situ treatment must be performed carefully because of the potential to mobilize any inorganic contaminants present.
		Catalyzed wet air oxidation		X	High temperatures and pressures used to oxidize organic contaminants.		X	Not applicable for highly halogenated organics. Minimum and maximum COD concentrations for successful application of CWAO are 10,000 mg/L and 200,000 mg/L, respectively.

See footnotes at end of table.

TABLE 4-2
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganics/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: GMA[a]	Applicability: PGW[b]	Screening Comments
Treatment (continued)	Chemical (continued)	Oxidation/ reduction	X	X	Generalization for several process options that employ redox reactions to detoxify contaminants.		X	Potentially applicable as support technologies. These technologies are typically used for pre/post treatment.
Discharge	Discharge to surface water	Discharge to the Great Miami River via new pipeline currently under construction	X	X	Discharge water to the Great Miami River via pipeline currently under construction.	X	X	Potentially applicable.
		Discharge to Paddys Run	X	X	Discharge water to Paddys Run	X	X	Potentially applicable.
	Underground discharge	Injection wells			Reinject water to aquifer after treatment. May combine control/contaminant action for groundwater gradient control.	X	X	Potentially applicable.

[a]GMA - Great Miami Aquifer.

[b]PGW - Perched groundwater.

groundwater, for detecting changes in contaminant releases and migration from the site, and/or for compliance monitoring. Use/access restrictions over and above the institutional controls considered under the South Plume removal action include the purchase of property over the contaminated aquifer area and deed restrictions. Each of these actions is retained for further evaluation.

4.4.1.3 Control/Containment

The pathway control/containment measures screened for the groundwater medium include primarily physical measures that modify contaminant migration patterns and minimize impacts on potential receptors. The control/containment technologies evaluated include pumping wells, alteration of the natural drainage system by paving drainage channels, vertical barriers, and horizontal barriers.

Pumping wells are retained for further consideration as a viable technology for extracting uncontaminated groundwater from the regional aquifer to modify existing groundwater flow patterns or to provide water for injection to direct flow away from receptors. Another control/containment technology potentially applicable to the regional aquifer is to pave Paddys Run and the SSOD to prevent the infiltration or recharge of contaminated surface water to the underlying aquifer.

Vertical barriers were evaluated, including slurry walls, grout curtains, sheet piling, and vibrating beam walls. The use of vertical barriers is not considered applicable for the regional aquifer due to the depth of bedrock at the site which is approximately 180 to 230 feet below ground surface. Vertical barriers are best suited for depths up to 100 feet. The slurry wall option is retained for further evaluation for the perched groundwater. The other vertical barrier options were eliminated because of the difficulties in determining the integrity of the barrier. The method of placement of cement-bentonite or soil-bentonite walls allows much greater control of the barrier's integrity.

Steel sheet piling is considered potentially applicable for temporary use or as a support technology, but will not be subject to further remedial technology screening. It may, however, be included during the detailed analysis of alternatives for the complete conceptualization, costing, and evaluation of a groundwater treatment system. Horizontal barriers were eliminated from further consideration for this site due to the difficulty in determining the integrity of such barriers.

4.4.1.4 Removal

The technologies screened for groundwater removal are pumping wells, gravity drainage systems, and electro-osmosis. Two types of pumping well systems are retained for further evaluation: extraction wells, used for both the Great Miami Aquifer and the perched groundwater; and a wellpoint system, generally applicable to only shallow aquifers such as the perched groundwater. French drains and interceptor trenches are also retained as options for extracting the contaminated perched groundwater.

Electroosmosis is a technique for dewatering low-permeability active clay soils by application of an electric field to induce water flow (an electrolyte solution). The movement of contaminant cations toward the cathode is accelerated by the movement of the electrolyte solution toward the cathode. If the moisture content is maintained in the vicinity of the anode, contaminant anions will move toward the anode. Electroosmosis is potentially applicable as a support technology during remedial activities and will not be further evaluated as a technology retained in the ISA.

Vertical sand drains are used to increase the permeability of materials and are considered potentially applicable as a support technology and, therefore, will not be further evaluated. The jet-eductor system is eliminated from further consideration due to the low efficiency achieved with this pump.

4.4.1.5 Treatment

The treatment response action includes biological, physical, physicochemical, and chemical processes which reduce the volume, toxicity, or mobility of a contaminant. The most prevalent FEMP-contaminant in the Great Miami Aquifer is uranium. Since the largest volume of water requiring treatment will be extracted from this aquifer, the emphasis of this screening is on technologies that effectively remove radionuclides. Process options are evaluated for removal of volatile organic contaminants that are present in the perched groundwater.

The potentially applicable process options retained for removal of uranium and other radionuclides and metals include advanced membrane separation technologies (i.e., reverse osmosis (RO), ultrafiltration, and electrodialysis), precipitation, ion exchange (including biosorption), and (liquid-liquid) solvent extraction.

The potentially applicable process options retained for further evaluation for organic contaminants removal include, in addition to the technologies listed above, air stripping, adsorption, and ultraviolet (UV) oxidation.

Several treatment processes were found to be potentially applicable for pretreatment and/or post-treatment supporting technologies. These include belt filter press, flocculation/coagulation/sedimentation/clarification, dual media filtration, equalization, centrifugation, neutralization, and oxidation/reduction. These supporting process technologies are not carried through the ISA evaluation process and the assembly of alternatives. They may, however, be included during the detailed analysis of alternatives as necessary components for the complete conceptualization, costing, and evaluation of a groundwater treatment system.

Several processes were eliminated because these processes are not suitable to the primary contaminants of concern and/or the levels of contaminants are too low to provide effective treatment. The process

options eliminated for this reason include the biological treatment technologies, distillation, freeze crystallization, polymerization, hydrolysis, and in situ oxidation/reduction. Supercritical water oxidation and catalyzed wet air oxidation were eliminated because they are ineffective for treating highly halogenated organics.

4.4.1.6 Discharge

Discharge refers to the release of groundwater to either a surface water body via a permitted outfall or to the subsurface environment via deep well injection. The option for discharge to the Great Miami River via a newly constructed FEMP pipeline has been retained for further consideration, as well as the use of pumping wells for reinjection of treated groundwater back into the aquifer with or without the intention of groundwater gradient control. Each is considered potentially applicable for discharge of treated groundwater. The discharge of groundwater to Paddys Run and discharge of groundwater to the Great Miami River represent variations of the technology "Surface Water Discharge." The two discharge paths will be carried through in the ISA under Surface Water Discharge. The specific options (i.e., Option 1: Discharge to the Great Miami River, Option 2: Discharge to Paddys Run) will be evaluated separately.

4.4.1.7 Summary of Technology Screening for Groundwater

The previous sections provided a discussion of the rationale for eliminating numerous technologies and process options for remediation of the site groundwater. The technologies and related process options that have been retained for further evaluation and subsequent development of remedial action alternatives are presented in Table 4-3. The no-action response has also been retained as required by the NCP and will be considered throughout the FS process.

4.4.2 Initial Screening: Soils and Sediments

This section includes a discussion of the initial screening of technologies and process options considered potentially applicable for remediation of site soils and sediments. Summaries of each process for both soil and sediment are presented in Table 4-4, and are jointly discussed in the following sections. Most options were considered appropriate for both media. However, several options are noted in Table 4-4 as being applicable to only soil or only sediment.

4.4.2.1 No Action

The NCP requires that the no-action response be carried through the detailed analysis of alternatives; therefore, it will not be eliminated at this stage. The no-action response will be further evaluated as a baseline for comparison with other remedial action alternatives developed for the soils and sediments. The no-action response is applicable to the soils and sediments as required by the NCP.

TABLE 4-3
FEMP FEASIBILITY STUDY
OPERABLE UNIT 5
TECHNOLOGIES AND PROCESS OPTIONS RETAINED
FOR FURTHER EVALUATION - GROUNDWATER

General Response Action	Remedial Technology	Process Options	GMA[a]	PGW[b]
No action	None	Not applicable	X	X
Institutional actions	Monitoring	Groundwater monitoring	X	X
	Groundwater use/access restrictions	Land acquisition	X	X
		Deed restrictions	X	X
Control/containment	Pumping wells	Extraction wells	X	
		Injection wells	X	
	Alter natural drainage system	Pave drainage channels	X	
	Vertical barriers	Slurry wall		X
Removal	Pumping wells	Extraction wells	X	X
		Wellpoint system		X
	Gravity drainage	French drains and/or interceptor trenches		X
Treatment	Physical	Air stripping		X
		Reverse osmosis	X	X
		Ultrafiltration	X	X
	Physicochemical	Adsorption		X
		Precipitation	X	X
		Electrodialysis	X	X
		UV Oxidation		X
		Ion exchange	X	X
		Biosorption	X	X
	Chemical	Solvent (Liquid-Liquid) Extraction	X	X

See footnotes at end of table.

TABLE 4-3
(Continued)

General Response Action	Remedial Technology	Process Options	GMA[a]	PGW[b]
Discharge	Discharge to surface water	Pipeline currently under construction to the Great Miami River	X	X
		Discharge to Paddys Run	X	X
	Underground discharge	Injection	X	X

[a]GMA - Great Miami Aquifer.

[b]PGW - Perched Groundwater.

TABLE 4-4

FEMP FEASIBILITY STUDY
OPERABLE UNIT 5 - ENVIRONMENTAL MEDIA
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOILS AND SEDIMENTS

General Response Action	Remedial Technology	Process Option	Target Contaminant Class		Description	Applicability		Screening Comments
			Inorganic/ Radionuclides	Organics		Soils	Sediments	
No action	None	Not applicable	X	X	May include environmental monitoring, but excludes actions that would reduce the potential for exposure.	X	X	NCP requires the no-action alternative to be carried through detailed analysis.
Institutional actions	Access/use restrictions	Physical barriers	X	X	Erect perimeter fence to restrict access around affected areas, posted warning signs and long-term security oversight.	X	X	Potentially applicable in localized areas of soil and sediment contamination.
		Deed restrictions	X	X	All property deeds within potentially contaminated areas would include restrictions on future development.	X	X	Potentially applicable for areas of soil contamination.
Control/containment	Capping	Single-layer cap	X	X	Construct cap over affected areas using low permeability materials, including concrete, synthetic membranes, asphalt, clay, soil, etc.	X	X	Potentially applicable for affected soils and sediments.

TAB[illegible]4-4
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganic/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: Soils	Applicability: Sediments	Screening Comments
Control/containment (continued)	Capping (continued)	Multilayer cap	X	X	Construct low permeability overlying impermeable clay cover with membrane, drainage/filter layer, and topsoil to provide infiltration, erosion, and moisture control.	X	X	Potentially applicable to affected soils. Unsuitable for sediments deposited in drainage channels; may also be used in conjunction with on-site landfilling. Sediments may be excavated, dewatered, and then placed under the cap.
	Surface water/storm water control	Diversion/ collection	X	X	Construct drainage dikes, berms, channels, terraces, benches, chutes, seepage basins, and ditches to control run-on/runoff, erosion and infiltration.	X	X	Potentially applicable as a support technology.
		Grading	X	X	Recontour the land surface to limit surface water infiltration run-on/runoff, and erosion.	X		Potentially applicable as a support technology.
		Site revegetation	X	X	Establish a vegetative cover to stabilize site soils.	X		Potentially applicable as a support technology.

TABLE 4-4
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganic/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: Soils	Applicability: Sediments	Screening Comments
Control/containment (continued)	Surface water/storm water control (continued)	Channel relocation	X	X	Relocate surface water courses to expose clean sediments and allow the covering of contaminated sediments.		X	Not applicable due to site-specific conditions. Surface water courses are dry during summer and fall months and can be excavated during this time. Support technology to channel paving.
		Channel modification	X	X	Modify channel alignment or crosssection to control sediment deposition or resuspension.		X	Not applicable due to site-specific conditions. Surface water courses are dry during summer and fall months and can be excavated during this time. Support technology to channel paving.
Removal	Extraction of source	Mechanical excavation	X	X	Remove soils and/or sediments by excavation using conventional construction equipment.	X	X	Potentially applicable.
		Dredging	X	X	Mechanical or hydraulic excavation of sediments for subsequent treatment or disposal.		X	Not applicable due to site conditions. Conventional excavation methods can be used in place of dredging.

TAB[illegible] 4-4
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganic/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: Soils	Applicability: Sediments	Screening Comments
Treatment	Biological	In situ bioremediation		X	Oxygen and nutrients are injected into the contaminated soils to enhance biological degradation of organic contaminants.	X	X	Not applicable due to the presence of halogenated organic and heavy metal contaminants which may interfere with biological activity.
		Plant harvesting	X	X	Plants are seeded in contaminated soil/ sediment to remove radionuclides and other contaminants.	X	X	Not applicable. Does not satisfy the specific RAO to prevent uptake of uranium by flora and fauna. May introduce uranium into food chain.
		Soil aeration		X	Soils/sediments are aerated using tilling for surface soils and air injection wells for deeper subsoils to promote microbial biodegradation of organics and to strip volatile organics.	X	X	Potentially applicable for limited areas of volatile organic contamination.

TAB[illegible]4-4
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganic/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: Soils	Applicability: Sediments	Screening Comments
Treatment (continued)	Biological (continued)	Land farming		X	Contaminated soils/ sediments are isolated in a containment pad and supplemented with oxygen and nutrients to enhance biological degradation.	X	X	Not applicable due to the presence of halogenated organic and heavy metal contaminants.
	Physical	Soil vapor extraction		X	Organic contaminants are removed from soil matrix by applying negative pressure.	X		Potentially applicable for volatile organics. Effectiveness is determined by contaminant volatilities and soil permeabilities. Requires on-site pilot studies.
		Radio frequency heating		X	In situ radio frequency heating to volatilize VOCs from contaminated soil/sediment. Applicable for volatile organics.	X		Potentially applicable as a support technology to enhance soil vapor extraction.
		Gravimetric (density) separation	X	X	Gravimetric separation is used to concentrate contaminants into density-specific fractions.	X	X	Potentially applicable as a support technology.

TAB[illegible]4-4
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganic/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: Soils	Applicability: Sediments	Screening Comments
Treatment (continued)	Physico-chemical	Hydrocyclonic (particle-size) separation	X	X	Centrifugal force, imparted by a rotating fluid, is used to concentrate contaminants into particle-size specific fractions.	X	X	Potentially applicable as a support technology.
		Soil/sediment washing (liquid-solid extraction)	X	X	Contaminants are extracted from soil/sediments using a liquid extraction agent such as water, acids, solvents, or chelating agents.	X	X	Potentially applicable.
	Solidification/ stabilization	Cement-based/ pozzolanic-based fixation	X	X	Cement, quicklime, or other grouting materials are mixed with the soil/sediments to immobilize contaminants and reduce infiltration.	X	X	Potentially applicable.
	Microencapsulation	Thermoplastic	X	X	Contaminated soils/ sediments are mixed with a plastic matrix of asphalt, bitumen, paraffin, or polyethylene and heated to form a stable solid.	X	X	Potentially applicable.

TABLE 4-4
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganic/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: Soils	Applicability: Sediments	Screening Comments
Treatment (continued)	Microencap-sulation (continued)	Organic polymer	X	X	Contaminated soil/ sediments are mixed with a polymer and catalyst to form a stable solid.	X	X	Potentially applicable
	Vitrification	Batch vitrification/ glassification	X	X	Contaminated soils/ sediments are mixed with molten glass to form a stable solid.	X	X	Potentially applicable. Glass forms stable solid matrix.
	Thermal	In situ vitrification	X	X	A high current of electricity is passed through the contaminated soil/sediments in situ to melt the material into a glassy, solid matrix.	X	X	Potentially applicable. Glass forms a stable solid matrix.
		Thermal desorption		X	A process used to thermally desorb volatile organic contaminants from soil/sediment by increasing temperature.	X	X	Not applicable for inorganics, radionuclides or low levels of volatiles present.
		Mobile incinerator (rotary kiln)		X	Transportable rotary kiln incinerator to destroy wastes by on-site combustion.	X	X	Not applicable for inorganics, radionuclides or low levels of volatiles present.

TAB[illegible]4-4
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class: Inorganic/ Radionuclides	Target Contaminant Class: Organics	Description	Applicability: Soils	Applicability: Sediments	Screening Comments
Treatment (continued)	Thermal (continued)	Multiple hearth incineration		X	A series of solid flat furnaces which destroy organic contaminants in solid, liquid, or gaseous waste streams.	X	X	Not applicable for inorganics, radionuclides, or low levels of volatiles present.
		Circulating bed combustion incineration		X	A method of burning solid, liquid, sludge, or gaseous waste streams which recirculate fluidized materials within the system.	X	X	Not applicable for inorganics, radionuclides, or low levels of volatiles present.
		Plasma centrifugal furnace		X	Soils/sediments are detoxified through the use of heat to vaporize organic contaminants and immobilize metals in a nonleachable glassy matrix.	X	X	Potentially applicable for highly refractory organic contaminents. Metals and radionuclides are not likely to be detoxified by this technology although mobility may be reduced.
Storage	Engineered storage facility	Intermediate storage facility	X	X	A fall-back option if other "permanent" treatment alternatives cannot be immediately identified or implemented.	X	X	Potentially applicable.

TAB[illegible]4-4
(Continued)

General Response Action	Remedial Technology	Process Option	Target Contaminant Class		Description	Applicability		Screening Comments
			Inorganic/ Radionuclides	Organics		Soils	Sediments	
On-Site Disposal	Engineered	Disposal facility	X	X	Disposal of soils/ sediments in an approved on-site disposal facility.	X	X	Potentially applicable.
	On-site backfilling	On-site backfilling	X	X	Disposal of treated soils/sediments by backfilling on-site excavations with the treated materials	X	X	Potentially applicable.
	Engineered disposal facility	Engineered disposal facility	X	X	Disposal of soils/ sediments in an approved off-site disposal facility.	X	X	Potentially applicable.

The no-action response does not provide additional remediation, monitoring, or security activities at the site to further minimize risk to public health or the environment.

4.4.2.2 Institutional Actions

This general response action includes access/use restrictions for soils and sediments. The access/use restriction response includes physical barriers and deed restrictions and will minimize access to and use of the areas of concern. The implementation of this response will result in no changes to the existing site environment. Fencing may be applicable in localized areas of soil contamination and as a technology for sediments during implementation of other remedial technologies. Security systems and posted warning signs are applicable for long-term remedial activities. Deed restrictions are considered for soils only and will be retained for further evaluation.

4.4.2.3 Control/Containment

The control/containment response is applicable for both soils and sediments. Major control and containment remedial technologies evaluated for these media include capping and surface water/storm water control systems. Vertical and horizontal barriers are considered to be groundwater containment technologies.

Capping involves the installation of a barrier over the surface of the contaminated area. Capping is designed to control erosion, prevent the generation of leachate due to surface water infiltration, and alleviate or eliminate possible direct and indirect exposures to the contaminants via inhalation, ingestion, or dermal contact. Both single-layer and multilayer capping techniques are retained for further evaluation. The single-layer cap is potentially applicable to both the soils and sediments areas of concern. Single-layer caps may include the use of concrete, asphalt, high-density polyethylene (HDPE), clay, or soil, with the last two options being applicable only to soils. While the installation of a multilayer cap is more complex than the single-layer cap, it may be applicable to areas that require more complete confinement due to associated higher potential risks. In addition, the multilayer cap may be considered as an integral part of the design of an on-site landfill disposal facility.

Surface water/storm water control can be used to minimize contamination of surface waters by reducing the erosion and off-site transport of contaminated soils. This technology includes the use of diversion and collection systems, grading, and site revegetation. All of these technologies are considered as support actions. They will not be carried further in the evaluation of process options but will be included, as necessary, during the detailed evaluation of alternatives.

Two other surface water/storm water control measures were considered for sediments as support technologies to altering the natural drainage channels. These include channel relocation and changes in channel alignment. Neither technology is considered applicable to a major river system such as the

Great Miami River. Although channel relocation and/or modification is technically implementable for Paddys Run and the SSOD, the sediments can be easily removed and/or treated during the prolonged dry period from June to December with less disturbance to the surrounding environment; thus, these technologies are not applicable.

4.4.2.4 Removal

Complete or partial removal of contaminated material will reduce migration of contaminants toward potential receptors. This may be accomplished using either mechanical excavation equipment or, in the case of contaminated sediments, dredging equipment.

Mechanical excavation involves the use of common construction equipment, such as a backhoe or bulldozer, to remove the soil or sediments. These methods are potentially viable for soils and for sediments not in contact with surface waters (i.e., Paddys Run and the SSOD during the dry season). Mechanical excavation will be retained for further consideration.

Dredging of material from streambeds is a common technique for sediments in contact with surface waters. The process is generally applicable for the removal of large volumes of sediments in relatively deep and/or permanent bodies of water. In this case, the excavation of the sediments can be done during the dry season and the volume of sediments requiring possible remediation is small; therefore, this option will not be retained for further consideration.

4.4.2.5 Treatment

The treatment options include biological, physical, physicochemical, solidification/stabilization, and thermal measures. These reduce the volume, toxicity, or mobility of a contaminant by altering its physical or chemical properties. The contaminants of concern found above PRGs in soils are radionuclides, metals, and organics. The contaminants of concern found above PRGs in sediments are radionuclides and metals only.

The following biological treatment processes were screened for soils:

- In situ bioremediation
- Plant harvesting
- Soil aeration
- Land farming

The biological treatment options (in situ bioremediation, plant harvesting, and land farming) were eliminated from further consideration because they are ineffective in treating highly halogenated organics and the co-occurrence of heavy metal contaminants may interfere with the biological activity.

Soil aeration is retained for treatment of organic contaminants only because it is as effective as the other biological options considered, the easiest to implement, and the most cost effective.

Physical treatment technologies are applicable when the properties of the contaminant compounds make them amenable to separation, replacement, or volatilization. The following physical treatment technologies were screened for soils and/or sediments:

- Soil vapor extraction
- Radio frequency heating

Vapor extraction is applicable for volatile organics only and will be retained for further evaluation for the soil areas of concern that have these contaminants. Radio frequency heating may be applicable as a support technology for enhancing soil vapor extraction and will not be further evaluated at this time.

The physicochemical treatment process of soil (liquid-solid) washing was also evaluated for the treatment of soils/sediments. Soil washing involves the removal of organic and inorganic compounds from soils or sediments by leaching. Soil washing may be viable for the removal of soluble uranium compounds; metals, and organics and is retained for further evaluation for both the surface soils and sediments. Gravimetric (density) and/or hydrocyclonic (particle-size) separation may be applicable as supporting technologies to soil washing.

Solidification/stabilization involves techniques to seal the contaminated soils and sediments in a solid, stable mass that reduces the mobility of the contaminants in the environment. Some of these techniques physically encapsulate the contaminant particles with a thermoplastic or an organic polymer agent (microencapsulation). Others chemically fixate the contaminants by reaction with a binding agent. The following solidification/stabilization technologies were reviewed for insitu or exsitu treatment of the surface soils and sediments, unless it is specifically indicated:

- Cement-based/pozzolanic-based fixation
- Microencapsulation (thermoplastic and organic polymer)
- Batch vitrification/glassification
- In situ vitrification

All of the stabilization/solidification technologies are retained for further consideration.

Thermal treatment is a process in which molecular bonding of organic compounds is altered through thermal decomposition and oxidation. The end products of this process typically include carbon dioxide, elemental carbon, ionized halogen, phosphorus, sulfur, and other inorganics, depending upon

the original composition of the waste material. The following process options were evaluated for on-site thermal treatment of soils and sediments:

- Thermal desorption
- Rotary kiln incineration
- Multiple hearth incineration
- Circulating bed combustion incineration
- Plasma centrifugal furnace

The first four of these thermal treatment technologies have been deleted from further consideration. They are applicable only to organics, and other technologies are being retained for further consideration that are applicable to all contaminants of concern.

The plasma centrifugal furnace technology has been retained for further evaluation because mixed radioactive wastes can potentially be handled by this type of incinerator. The plasma centrifugal furnace uses the heat from a plasma torch to create a molten bath in which the organic contaminants are vaporized and react at 3000°F temperature to form innocuous products. Metals and radionuclides are not likely detoxified by this technology, but their mobility would be limited by being incorporated into the final residue which is a glass matrix.

4.4.2.6 Intermediate Storage

This storage technology proposes that the wastes would be temporarily stored at an on-site or off-site facility for a period of approximately five to ten years, until an appropriate ultimate on-site or off-site disposal facility or treatment process is available. For this screening process, a designated storage facility is considered applicable and has been retained for further consideration.

4.4.2.7 On-Site Disposal

Disposal technologies include physical measures which will provide a permanent engineered environment to restrict contaminant migration and thus minimize potential impacts on a receptor. For this screening process, the on-site engineering disposal facility has been designed to meet established federal and state regulations. On-site disposal of contaminated soils and sediments is considered applicable and has been retained for further consideration.

4.4.2.8 On-Site Backfilling

Backfilling of on-site excavations with the treated residuals is an inexpensive disposal option for the treated residuals, provided the treatment(s) reduces contaminant levels to, or below, PRGs. On-site backfilling is considered potentially applicable and has been retained for further consideration.

4.4.2.9 Off-Site Disposal

Off-site disposal technologies are practiced at existing facilities which are approved by the appropriate federal and state regulatory agencies, such as the EPA. For this screening process, the off-site engineered disposal facility has been designed to meet the applicable regulations. Off-site disposal of contaminated soils and sediments will be retained for further consideration.

4.4.2.10 Summary of Technology Screening for Surface Soils and Sediments

Table 4-5 presents the technologies and related process options that have been retained for further evaluation and for subsequent development of remedial action alternatives for soils and sediments.

The no-action response has also been retained for both media and will be considered as a remedial action alternative in the next phase of the FS.

TABLE 4-5
FEMP FEASIBILITY STUDY
OPERABLE UNIT 5 - ENVIRONMENTAL MEDIA
TECHNOLOGIES AND PROCESS OPTIONS RETAINED
FOR FURTHER EVALUATION - SOIL/SEDIMENTS

General Response Action	Remedial Technology	Process Option	Soils	Sediments
No Action	None	Not applicable	X	X
Institutional actions	Access/use restrictions	Physical barriers,	X	X
		deed restrictions	X	X
Control/containment	Capping	Single layer cap,	X	X
		multilayer cap	X	X
Removal	Extraction	Mechanical excavation	X	X
Treatment	Biological	Soil aeration	X	
	Physical	Soil vapor extraction	X	
	Physicochemical	Soil (liquid-solid) washing	X	X
	Solidification/stabilization	Cement-based/pozzolanic-based	X	X
	Microencapsulation	Thermoplastic	X	X
	Vitrification	Batch vitrification	X	X
		In situ vitrification	X	X
	Thermal	Plasma centrifugal furnace	X	X
Intermediate storage	Engineered storage facility	Engineered storage facility	X	X
On-site disposal	Engineered disposal facility	Engineered disposal facility	X	X
	On-site backfilling	On-site backfilling	X	X
Off-site disposal	Engineered disposal facility	Engineered disposal facility	X	X

5.0 EVALUATION OF TECHNOLOGY PROCESS OPTIONS

The next step in developing and screening alternatives involves a detailed evaluation of the technologies and process options remaining from the initial technology screening. In particular, the initial list of screened technologies and process options is further evaluated against three criteria: effectiveness, implementability, and cost. The technology process options that have been identified are evaluated based on these criteria relative to other processes within the same technology types. The major focus of this evaluation is the effectiveness of each option, with less emphasis on implementability and cost.

Whenever attainable, one representative process will be selected for each technology type to facilitate the development and evaluation of alternatives upon completion of the process option evaluation. The representative process option provides a basis for developing performance specifications without limiting flexibility during preliminary design. However, more than one process option may be selected for a technology type if the process options are sufficiently different from each other.

5.1 SCREENING CRITERIA

5.1.1 Effectiveness

The effectiveness evaluation focuses on the following elements:

- The potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals identified in the remedial action objectives
- The potential impacts to human health and the environment during the construction and implementation phase
- The reliability and proven effectiveness of the process with respect to the contaminants and conditions at the site

5.1.2 Implementability

The implementability evaluation includes both the technical and institutional feasibility of implementing each process at the FEMP. The initial technology screening eliminated technology types or process options that were clearly ineffective or unworkable at the site; therefore, in addition to technical implementability, this detailed evaluation addresses the following institutional aspects of implementability:

- Ability to obtain necessary permits and rights-of-way for off-site actions

- The availability of necessary equipment and skilled workers to implement the technology

- The availability (including capacity) of treatment, storage, and disposal services

5.1.3 Cost

Cost plays a limited role in the screening of technologies. Relative capital and operation and maintenance (O&M) costs are considered rather than absolute costs. For this evaluation, the cost analysis is made on the basis of engineering judgment, with each technique evaluated as to whether costs are low, moderate, or high relative to other process options in the same technology type. The greatest cost consequences in site remediation are usually associated with the degree to which different technology types are used. Using different process options within a technology type usually has a less significant effect on cost than the use of different technology types. A technology process option can be eliminated on the basis of cost, only if other process options within the same technology type are comparably effective and implementable but have a much lower cost.

5.2 EVALUATION OF PROCESS OPTIONS FOR GROUNDWATER

The technologies and process options remaining after the initial screening for the groundwater medium were evaluated based on the aforementioned screening criteria; i.e., effectiveness, implementability, and cost, as indicated in the Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites (EPA 1988b).

The representative process option(s) that is selected for each technology type will be retained for incorporation into the remedial action alternatives. The results of this evaluation are summarized in Table 5-1 and are discussed below.

5.2.1 No Action

The no-action response provides no technology of remediation, monitoring, or restriction for groundwater at the site. The evaluation of no-action response is summarized below:

- Effectiveness (low): The no-action response will not achieve any of the remedial action objectives by itself within an acceptable time frame. Effectiveness of this response action depends on the groundwater's natural attenuation ability to lower contaminant concentrations through physical, chemical, and biological processes within the groundwater regime. This response action does not reduce risk to human health or the environment.

- Implementability (low): This response action does not involve the implementation of technologies and services. However, this response action is not administratively acceptable to local/government agencies.

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TABLE 5-1
OPERABLE UNIT 5 - ENVIRONMENTAL MEDIA
DETAILED EVALUATION OF PROCESS
OPTIONS FOR GROUNDWATER

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
No action[c]	None	Not applicable	Low; will not achieve remedial action objectives; depends on natural attenuation; does not reduce risk to human health and the environment	Low; does not involve technologies or services; not administratively acceptable to local/government agencies	None	None
Institutional actions	Monitoring	Groundwater monitoring[c]	Low; will not achieve remedial action objectives to itself; potential exposure by sampling and analytical personnel	High; wells can be installed easily; equipment and services are readily available; alone may not be administratively acceptable to local/government agencies	Low; additional wells and public notice only	Low; for maintenance, sampling, etc.
	Access/Use restrictions	Deed restrictions[c]	Moderate; achieves the human health objectives; does not reduce contaminants in the environment	Moderate; simple for areas that fall within FEMP; involves legal process for areas outside of FEMP	Low; legal fees only	None
		Land acquisition[d]	Moderate; effective in achieving human health objectives; ineffective in achieving environmental objectives	Low; landowner opposition expected; difficult to implement due to potential legal complications	High; property purchasing and legal fees are expected	Low; property maintenance only

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See footnotes at end of table.

TABLE 5-1
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
Control/Containment	Pumping wells	Extraction/Injection wells[c]	Moderate; effective in achieving public health objectives; ineffective in achieving environmental protection objectives; used for hydraulic isolation; may contaminate elsewhere	Moderate; may be technically difficult due to site hydrogeologic conditions; approval for extraction wells is readily obtainable	Moderate; large volume of groundwater expected; wells, pumps, and pipelines are expensive	Moderate; maintenance is extensive; electricity cost is a fixed fee
	Alter natural drainage system	Pave Paddys Run	Low; limited effectiveness in achieving remedial action objectives; does not address existing source; channel paving is a proven technology and has no effect on groundwater flow pattern; has impact on vegetation and aquatic habitats; long-term integrity is a concern	Moderate; paving is simple to implement; equipment and labor are readily available; agency acceptance for waterway modification is a significant task	Moderate; site preparation, material, and labor are expensive	Low; regular inspection and repair are needed
	Vertical barriers	Slurry wall[d]	Moderate; effective for reducing horizontal migration of contaminants; does not reduce volume or concentration of contaminants by itself; a proven and reliable technology; could be effective for the perched zone but not for the Great Miami Aquifer; long-term effectiveness depends on the contaminants	Moderate; materials and equipment readily available; hydrogeologic conditions limit the implementability to the Great Miami Aquifer; difficult to encompass the perched groundwater zone	Moderate; highly depends on depth and length of the wall	Low; some maintenance and periodic monitoring

See footnotes at end of table.

TABLE 5-1
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
Removal	Pumping wells	Extraction wells[c]	Moderate; potentially effective removal technique for achieving public health and environmental protection objectives with treatment; exposure to human health and the environment is minimal; careful design to minimize effect on nearby wells	High; installation, construction, and operation is common practice and flexibility exists; need land and easement access to other properties; skilled workers not needed	Moderate; standard practice; cost depends on depth and number of wells	Low; electricity and repair or replacement of pumps and pipes
		Wellpoint system[c]	High; effective extraction process in shallow groundwater (perched) conditions; minimal impacts; well points spacing is critical for effectiveness	Moderate; materials and equipment are readily available; no permit required	Moderate; costs for installation and removal	Moderate; electricity and regular maintenance
	Gravity drainage	French drains/ Interceptor trenches	Moderate; appropriate for groundwater extraction from low permeable material; effective for shallow (perched) groundwater	Moderate; difficult to construct trenches at depth; soil permeability determines width, depth, and spacing of trenches; work hazards exist for deep trench; skilled workers needed; no agreement or permit required	Moderate; less expensive than pumping wells	Moderate; periodic maintenance is required

See footnotes at end of table.

TABLE 5-1
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
Treatment	Physical	Air stripping[c]	High; effective for removal of VOCs from dilute aqueous waste stream, i.e, perched groundwater; requires secondary treatment of VOC in off-gas; proven technology and expected to meet PRGs	High; commercially available technology; skilled workers not required; air emission approval required	Moderate; standard equipment and practice	Moderate; standard practice; costs include energy and off-gas cleaning
		Reverse osmosis[c]	Moderate; found to be effective in experimental applications; full-scale study required; potential exposure to concentratred waste streams exists	Moderate; commonly utilized technology; additional handling and treatment for residuals and high concentration waste stream; skilled worker needed; multiple disposal approvals required	High; relatively expensive equipment, design and construction costs	High; membrane replacement, electricity, residual handling and disposal, etc., are costly
		Electrodialysis	Moderate; used on experimental basis; treatability study needed to confirm uranium removal; potential impacts during implementation are minimal	Moderate; used for domestic water treatment and industrial applications; pretreatment may be required; will generate concentrated waste streams; multiple approvals needed for disposal of residual and effluent	High; relatively expensive equipment, design and construction costs. Treatability studies would be required	High, membrane replacement, electricity, residual handling and disposal, etc., are costly
		Advanced membrane filtration/ultrafiltration	Low; not effective for removal of uranium in dissolved state	Moderate; widely utilized technology; not yet adapted to uranium removal; skilled workers required; residual disposal needed	High; need treatability investigation, design, and construction	High; membrane replacement; electricity, residual disposal, etc.

See footnotes at end of table.

TABLE 5-1
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
Treatment (Continued)	Physicochemical	Adsorption[c]	Moderate; limited effectiveness in treatment of uranium complexes; may need to be used with other treatment process; potential exposure risk exists; proven technology	High; commonly utilized technology; generation of residuals; skilled workers not required; residual disposal approval needed	Moderate; equipment and material are readily available	Moderate; cartridges, spent media, and residuals spent need to be managed
		Precipitation[c]	High; pH sensitive process; effective in treatment of uranium with proprietary reagents; treatability study should be performed	Moderate; commonly utilized technology; skilled workers not required; precipitated sludge requires treatment and disposal; residual disposal approval needed from agencies	Low; commercially available equipment	Moderate; standard practice; residual management
		Ion exchange[c]	High; proven and reliable technology; effective in reduction of uranium in aqueous waste streams; potential exposure risk exists	High; commonly utilized technology for uranium removal; skilled workers not required; discharge or disposal of spent resin and concentrated flow are needed	High; requires studies, design, equipment, etc.	High; resin replacement, regular maintenance; residuals and spent resin need treatment/disposal
		Biosorption	Moderate; has achieved some degree of separation of heavy metals in pilot-plant testing; same technology as ion exchange, different medium used; residuals are radioactively contaminated	Moderate; emerging technology; treatability studies required; skilled workers and equipment may not be available	Moderate; costs include design construction, equipment, and treatability study	High; residual disposal and replacement resin are high

See footnotes at end of table.

TABLE 5-1
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
Treatment (Continued)	Physicochemical (Continued)	UV radiation/oxidation	Low; effective as a destruction process for organics; also used as polishing and disinfection processes. Not effective in turbid conditions for the perched groundwater	High; materials and equipment available; skilled workers required; residual disposal approval needed	High; patented equipment is required	High; energy cost is high
	Chemical	Solvent extraction[d] (liquid-liquid)	Low; not effective for removal of radionuclides in dilute form; direct human exposure exists; treatability study needed; effective in extracting uranium from acid leach liquor	Moderate; equipment is available but custom design needed; skilled workers required; residual disposal approval needed	High; costs include equipment, solvent recovery, design, installation, etc.	Moderate; solvent recovery, electricity, residual management, etc.
Discharge	Discharge to surface water	Discharge groundwater to Great Miami River via pipeline under construction[c]	High; effective in achieving public health and environmental objectives; current NPDES permit does not regulate uranium content	Moderate; easy to implement; NPDES permit modifications required; administrative acceptance by local/government agencies is expected	Low; minor construction	Low; minor O&M activities
		Discharge to Paddys Run	Moderate; effectiveness may be hindered due to capacity; potential impacts to human health and the environment	Moderate; easy to implement, requires major modification of the existing NPDES permit; administrative acceptance by local/ government agencies is expected	Low; construction, material and labor	Low; maintenance, sampling and analysis

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TABLE 5-1
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
	Underground discharge	Injection wells[c]	High; public health and environmental risks are minimal; information to evaluate impact on regional groundwater is available; could enhance flushing of contaminants, and/or use for gradient control	High; common technology; equipment and materials are readily available; administrative acceptance by local/government agencies is expected	Moderate; aquifer studies and well construction	Moderate; pumping and regular maintenance

[a]Relative to other process options in the same technology type.

[b]Operation and maintenance cost.

[c]Process options retained for incorporation into alternative development based on ratings of effectiveness, implementability, and cost.

[d]Support technology.

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- Capital Cost (none): This response action does not utilize any technologies or process options. Therefore, there is no capital cost for this response action.

- O&MCost (none): This response action does not utilize any technologies or process options. Therefore, there is no O&M cost for this response action. The NCP, however, requires the no-action response to be carried through the detailed analysis of alternatives. The no-action response will be utilized as a baseline for comparison with other remedial action alternatives developed for the groundwater medium. Therefore, the no-action response is retained for further evaluation.

5.2.2 Institutional Actions

The remedial technologies retained for this response action include monitoring and use/access restrictions. The process options pertaining to these technology groups are groundwater monitoring, land acquisition, and deed restrictions.

5.2.2.1 Groundwater Monitoring

Groundwater monitoring, sampling, and analysis of selected wells are used to assess the concentration levels and movement of the contaminants of concern. The evaluation of groundwater monitoring is summarized below:

- Effectiveness (low): Groundwater monitoring will not meet any of the remedial action objectives by itself. The potential impact on human health and the environment during the construction and implementation phase of this option is negligible. The only additional potential exposure to the contaminated groundwater is to sampling and analytical personnel. Groundwater monitoring is a reliable and proven technology for monitoring purposes.

- Implementability (high): A large number of monitoring wells currently exist at and near the FEMP site. Also, additional wells can be installed quickly and equipment and services are readily available. This process option may not, however, be administratively acceptable to the local/government agencies without additional remedial response.

- Capital Cost (low): This item includes the cost for additional monitoring wells and preparation of a public notice.

- O&M Cost (low): Major cost items include well maintenance, sampling and analysis, and payments to some landowners for property access and use.

Groundwater monitoring will be appropriate as either compliance monitoring or response action monitoring. It is, therefore, retained for incorporation into the remedial action alternatives.

5.2.2.2 Deed Restrictions

This option involves restricting the use of water and/or land during and after remediation by recording in property deeds. Deed restrictions are particularly valuable for public health protection during the implementation period for engineering options. The effectiveness, implementability, and cost of this option are discussed below:

- Effectiveness (moderate): Use of this option should be effective in achieving human health objectives, but would not reduce contaminant concentrations in the environment.
- Implementability (moderate): Prohibiting use of groundwater and land outside of the FEMP may be hindered by legal issues, but is expected to be authorized by the court.
- Capital Cost (low): Costs include fees for legal counsel.
- O&M Cost (none): No O&M costs are associated with this action.

Although this action alone does not achieve the environmental objectives, it is applicable if used in conjunction with active engineering options and is retained as an institutional measure for every active alternative.

5.2.2.3 Land Acquisition

This process option involves the purchasing of land to prevent receptor access to groundwater containing elevated levels of contaminants. It would require the purchase of the off-site land above the contaminated aquifer. Eminent domain rights of the federal government could potentially be implemented if necessary. This process option evaluation follows:

- Effectiveness (moderate): Use of this process option should be effective in achieving the human health objectives but does not achieve the environmental objective of reducing the mobility, toxicity, and volume of contaminants.
- Implementability (low): Landowners opposition to the purchase of their properties are expected. Potential lawsuits may contribute to the difficulty of implementing this process option.
- Capital Cost (high): Cost items include purchase of homes, industries, and productive farmland. Also, the potential for legal action stemming from the implementation of eminent domain rights will contribute significantly to the final cost for this option.
- O&M Cost (low): Cost items will include maintenance of property, fencing, security, and warning signs.

This process option will meet human protection objectives, but not environmental protection objectives. Legal issues can be complex and difficult. This process option will be more effective if performed in conjunction with other process options that are effective in reducing the mobility,

toxicity, and volume of contaminants. Therefore, land acquisition is considered as a support action technology and may be used in conjunction with other process options.

5.2.3 Control/Containment

The technologies retained from the initial screening for this response action include pumping wells, alteration of the natural drainage system, and vertical barriers.

5.2.3.1 Extraction/Injection Wells

This option is the combination of two process options, extraction and injection of uncontaminated groundwater, or treated contaminated water. It includes extraction of uncontaminated groundwater by pumping and the injection of this groundwater into wells to impose artificial hydraulic gradients to divert the plume and alter the direction of groundwater movement. In the case of contaminated groundwater, it will be treated prior to reinjection into the aquifer. Using techniques of actively modifying and managing the groundwater system, the contaminated plume can be directed away from residential and industrial wells. In addition, this process option can modify the velocity of groundwater flow. The effectiveness, implementability, and cost of this option are discussed below:

- Effectiveness (moderate): The use of this process option is effective in achieving public health objectives by diverting the plume away from receptor wells, but is ineffective in achieving the environmental objectives, unless the extracted groundwater is treated prior to reinjection. The uranium concentration in the plume is not reduced. The process of controlling a groundwater gradient with pumping and injection is proven and has been effectively used for hydraulic isolation. Diverting the plume to other areas could, however, lead to problems elsewhere.

- Implementability (moderate): The high transmissivities of the Great Miami Aquifer, as discussed in Section 2.2, may complicate the implementation of this technology. Steep hydraulic gradients in the GMA south of the South Plume may also make reversal of hydraulic gradients or alteration of flow patterns by this technology difficult. Obtaining land access for well installation may cause delays and other impediments. Although permits will be required for those wells located off-property, the approval for extraction wells should be readily obtainable. Permits will also be necessary to install injection wells, since these are regulated through the Underground Injection Control (UIC) program by the U.S. EPA.

- Capital Cost (moderate): The high well yields from the Great Miami Aquifer require large volumes of uncontaminated water to be extracted and injected in order to impact the plume movement. The large number of wells required, high capacity pumps, and large diameter transfer piping add to the capital cost.

- O&M Cost (moderate): The primary O&M cost items include electricity for the pumps; maintenance of the wells, valves, and instrumentation; and monitoring of groundwater levels.

Technical considerations such as the steep groundwater gradients and high transmissivities make the implementation of this option difficult. However, it is considered a viable technology and is retained for incorporation into other remedial alternatives.

5.2.3.2 Alter Natural Drainage System

This remedial technology provides for paved channels as a process option which would reduce infiltration to the aquifer from the surface waterways. This action reduces the recharge to the aquifer and slows the movement of the plume. The lining may consist of traditional materials emplaced by standard construction methods, including:

- Concrete
- Gunite (sprayed-on cement mortar)
- Asphalt

Each of these materials, within specific design limitations, provides a durable, low permeability, and erosion-resistant surface. Concrete, either roller compacted concrete or reinforced concrete, can provide strength as well as durability. On the basis of its well-known characteristics of durability, permeability, and erosion resistance, concrete was chosen as the representative process option for paving Paddys Run, the major recharge channel within the aquifer, including the SSOD.

This technology is specifically useful for limiting the effects of recharge from periodic high-velocity water discharges and has been used to isolate contaminated bottom sediments in large stream channels. The evaluation of this process option is discussed below:

- Effectiveness (low): Due to the known effect of Paddys Run recharge on the uranium contribution into the aquifer, the ability of this technology to meet the remedial action objectives is limited. The lining will have no observable effect on regional groundwater flow patterns. Implementation of this process option will not remove or decrease the concentration in the existing off-site plume. The long-term integrity of a concrete liner is a concern. The application of a concrete channel may not be acceptable since it destroys all vegetation and aquatic habitats in the stream. In addition, removal of the actual source of contaminants flowing into Paddys Run would be more effective than paving the bottom of the stream and the existing and planned storm water runoff control projects will eliminate the need for channel lining. Channel paving, however, is a proven technology.

- Implementability (moderate): The construction techniques of this technology are simple and environmentally safe. Necessary equipment and skilled labor are readily available to implement the paving. Significant requirements for waterway modification required by the U.S. Army Corps of Engineers would have to be met for this option. Additionally, interactions with other agencies are required due to possible destruction of existing wetlands, habitat, and vegetation along Paddys Run.

- Capital Cost (moderate): Although concrete is moderately priced and relatively easy to install, several other associated labor-intensive procedures such as site clearing, grubbing, and preparation of the creek bottom for installation add significant expense to the capital costs.

- O&M Cost (low): Concrete channels crack, are subject to scouring damage from flood flows, and will need regular inspection and repair.

This process option may be viable as a pathway control method for selected channel reaches. However, due to its low and moderate rating on effectiveness and implementability respectively, alteration of natural drainage system is eliminated from further consideration.

5.2.3.3 Slurry Wall

Slurry walls are vertical, low permeability barriers that restrict horizontal movement of groundwater. A slurry cutoff trench/wall is constructed by excavating a narrow vertical trench, typically 2 to 4 feet wide, and backfilling with a low-hydraulic conductivity material to contain a waste source and to prevent contamination from migrating off site. The trench, as excavation proceeds, is filled with a bentonite-water slurry which stabilizes the walls of the trench, thereby preventing collapse. The slurry penetrates into the permeable soils, creating a filter cake on the trench walls that seals the soil formations, prevents slurry loss, and also contributes to the low permeability of the completed cutoff wall. This narrow trench is then backfilled with a slurry mixture. Slurry walls are differentiated by the materials used to backfill the slurry trench. If a mixture of soil and bentonite is used, then the wall is known as a soil-bentonite (SB) slurry cutoff wall. In some cases, the trench is excavated under a slurry of portland cement, bentonite, and water, and this mixture is left in the trench to harden into a cement-bentonite (CB) slurry wall.

Slurry walls can be installed in several configurations. Circumferential installations (totally surrounding the wastes) are the most common type of slurry wall (EPA 1985). Downgradient placement of a slurry wall can be used to prevent downgradient migration of contaminated groundwater. A slurry wall could also be installed upgradient of a contaminated area to divert clean groundwater around a site.

Vertical configurations of slurry cutoff walls may be "keyed-in" or "hanging." A keyed-in slurry cutoff wall is excavated into a continuous low-permeability horizontal confining layer, such as a clay deposit or competent bedrock. The confining layer forms the bottom of the contained site. A penetration into the confining layer of 2 to 3 feet is essential for adequate containment. The depth of the confining layer will also impact the type of excavation equipment used and the completed wall costs. Hanging slurry walls are not tied into a confining layer, but extend to a hydraulically calculated depth to act as a barrier to the movement of floating contaminants (such as oil or fuels) or migrating

gases, or for creating an inward hydraulic gradient used in conjunction with a groundwater treatment system. The hydraulic conductivity of a SB wall, with good construction quality control, is approximately 1 x 10^{-8} centimeters per second (cm/sec). The hydraulic conductivity of a good CB wall is typically 1 x 10^{-6} cm/sec or less (EPA 1985).

A number of factors may limit the application of slurry cutoff walls. Site topography can limit the use of a soil-bentonite wall because the excavation slurry and the backfill will flow under stress. Thus, the trench line must be within a few degrees of level. Cement-bentonite walls that harden quicker are better suited to irregular topography. If a keyed-in slurry wall is considered, the depth to and nature of the confining layer becomes a concern. The layer must have sufficiently low permeability to prevent leakage underneath the wall; it must have adequate thickness to allow an adequate key (2 to 3 feet). If the bottom of the slurry wall is beyond the conventional depth (50 to 70 feet), excavation of the trench will be less cost-effective.

A major limitation to the application of a slurry cutoff wall/trench as a physical barrier is the compatibility of the cutoff trench backfill mixture with site contaminants. SB backfills are susceptible to attack by strong acids or bases, strong salt solutions, and some organic chemicals. CB backfills are susceptible to attack by sulfates, strong acids and bases, and highly ionic substances. In order to minimize this problem, compatibility testing should be performed using soil and groundwater samples with the highest concentrations of contaminants from the site. The concentration of bentonite in the mix can be adjusted, or a chemically resistant bentonite or sulfate-resistant cement can be used to provide a satisfactory solution.

The evaluation of this process option is provided below:

- Effectiveness (moderate): A slurry wall may provide an effective means of reducing contaminant migration into or through an aquifer, with a groundwater extraction system. Slurry wall is a proven and reliable technology for localized containment. However, effectiveness of this process option for containment of the perched groundwater zone and the Great Miami Aquifer is impeded due to the location and depth of these aquifers. The perched groundwater zone is not a continuous aquifer. The slurry wall application would then require a number of small walls or one large wall which potentially encompasses some unnecessary areas. The slurry wall for the Great Miami Aquifer would have to be either a conventional wall that is keyed in to the bedrock at a depth of 200 feet or a "hanging" slurry wall that is primarily used for "floating" contaminants. Long-term effectiveness of the slurry wall is very dependent on the types and concentrations of contamination. The slurry wall process option is a containment technology and therefore, is considered ineffective in achieving other remedial action objectives, i.e., reduction of toxicity and volume of contaminants. The impact on human health and the environment during the construction and implementation phase of this process option is minimal.

- Implementability (moderate): Construction of the slurry walls is relatively simple, and materials/equipment are readily available. Excavation is massive and requires coordination with underground utilities. Although it is not favorable due to the scattering nature of the contaminated perched groundwater, slurry wall is considered implementable based on the depth of the perched groundwater zone. The slurry walls would be designed to key in the low permeability clay interbed (approximately 130 feet below ground surface) underlying the perched groundwater zone. Containment of the Great Miami Aquifer has technical implementability problems due to the depth of the bedrock (as much as 200 feet below ground surface). Hanging slurry wall will not serve its purposes due to the presence of contaminants that do not readily float. The magnitude of these difficulties related to applying this technology significantly impedes the implementability.

- Capital Cost (moderate): Requires construction of a trench and creating a low permeable wall. Cost is dependent on the depth and the linear footage required. Experience in slurry wall construction indicates that slurry trenches up to 75 feet deep are considered typical, and any depth beyond 75 feet to more than 200 feet is feasible, but costly. The depths of the slurry wall required for the Great Miami Aquifer (slurry materials and excavation, labor, etc.) significantly increase the cost of applying this technology to the FEMP.

- O&M Cost (low): Slurry walls require no operation and little maintenance. Periodic monitoring of slurry wall performance may be needed.

The slurry wall is retained as a support technology for further consideration on the basis that the hydrogeologic conditions for the perched zone may afford the installation of an efficient and cost-effective slurry wall for the containment of groundwater contamination.

5.2.4 Removal Technologies

The groundwater removal technologies selected for detailed evaluation are pumping wells and gravity drainage systems. Extraction wells are retained for plume removal in the deep aquifer (Great Miami Aquifer), while wellpoint systems and gravity drainage systems are selected for further evaluation for plume removal from the perched groundwater zones.

5.2.4.1 Extraction Wells

This process option involves the pumping of water from the aquifer to capture a plume and alter the direction of the plume toward the extraction wells. By using techniques to actively modify and manage the groundwater system, a contaminated plume can be contained and removed. Extraction wells are most effective where contaminants are miscible and move readily with water, hydraulic conductivity is high, and quick removal is not a requirement.

Extraction of contaminated groundwater is accomplished through the use of extraction wells which are completed at specified locations and depths to optimize contaminant recovery. Determination of the

location and depth of extraction wells or drains requires prior delineation of the contaminant plume and knowledge of the aquifer properties such as hydraulic conductivity (K), storage, stratigraphy, and depth to bedrock. In order for this technology to be effective, it must be possible for contaminants to readily flow to extraction wells, thus the subsurface must have sufficient hydraulic conductivity (i.e., K $>10^{-5}$ cm/s) and the chemicals must be transportable by the groundwater (i.e., not strongly sorbed to soils).

Variations in the operation of the extraction system can affect the recovery of the contaminants. The two basic modes of extraction are continuous and pulsed pumping. Continuous pumping refers to un-interrupted extraction of groundwater to create a capture zone around the plume of contamination, thereby controlling migration while the contaminants are flushed from the aquifer. The pumping rate is limited by the yield of the aquifer. Pulsed pumping involves regular or periodic cessation of pumping activities to enhance the extraction of groundwater contaminants. Pulsed pumping may be necessary or more cost-effective in cases where extraction wells cannot sustain even moderate yields (e.g., in bedrock and unconsolidated deposits of low permeability), where desorption and/or dissolution of contaminants in the subsurface is relatively slow, or where hydraulic conductivity heterogeneity is high. In the latter two cases, pulsed pumping would result in periodic low groundwater velocities, allowing contaminants to build up equilibrium concentrations locally and allow more efficient removal of contaminants. The instantaneous pumping rate may exceed the yield of the aquifer, but the long-term rate of withdrawal is limited by it.

The evaluation of this process option is discussed as follows:

- Effectiveness (moderate): This option can prevent further plume migration, in addition to removal/reduction of the plume. This process option will achieve complete remedial objectives when applied with treatment process options. Potential exposure to humans and the environment exists during implementation of this option, but only to a minimal degree. Care in the design of the system should minimize any effects on water levels and pumping efficiencies at nearby wells.

- Implementability (high): The installation, construction, and operation of a groundwater extraction system will use commonly practiced engineering techniques and pose no unusual technical difficulties. The necessary materials, equipment, and labor services are readily available. This process option can be designed to be versatile in operation and often can be modified or augmented during operation to enhance performance as additional data are available. Removal of contaminated groundwater by pumping is a widely accepted remedial technology. In the case of the FEMP, the transmissivities and steep gradients will require the use of multiple wells pumping at high rates. Access and easements across other properties may be required. Obtaining access and easement agreements may cause delays and other impediments.

- Capital Cost (moderate): Pumping wells and transfer piping are standard construction items. Capital costs are related to the depth and number of wells to be installed.

- O&M Cost (low): The major cost items are electrical usage and maintenance of the pumps and transfer pipes.

Due to high ratings in effectiveness and implementability, groundwater pumping using extraction wells is considered a viable technology and the process is retained for further consideration and incorporation into the various remedial alternatives.

5.2.4.2 Wellpoint System

A wellpoint system consists of a series of small-diameter riser pipes connected to a common header. The process is applicable when the hydraulic head required for pumping is small (i.e., less than approximately 20 feet). Therefore, shallow aquifers such as the perched groundwater at the FEMP are good candidates for this technology.

A suction (vacuum) pump is typically used in wellpoint systems to lift water. Suction pumps (either oil sealed or water sealed) accomplish lift by developing a negative pressure head at the pump intake rather than by applying force to the water source as in ejector pump systems. The maximum lift theoretically attainable by a suction pump is about 32 feet at sea level. Due to the elevation of the FEMP above sea level and the actual pump efficiencies achievable, the potential lift capacity would be approximately 22 feet.

Wellpoints are specially made well screens that are typically 1.5 to 3.5 inches in diameter and are capable of yields up to 35 gallons per minute. Large wellpoints (up to 8 inches in diameter) generally called suction wells, are also available. They have capacities greater than 35 gallons per minute. Wellpoint screens can be made of heavy wire mesh, continuous wire, slotted plastic, or perforated plates. As with deep wells, the materials selected should minimize the potential for corrosion and encrustation.

Because wellpoints are typically installed in oversized boreholes, filter sands are placed around the wellpoint to fill the annular space. The filter sands increase the effective diameter of the wellpoint, decrease the entrance velocities of water, prevent clogging of the screen with fines, and provide for vertical drainage from overlying layers.

Although drawdown is limited to approximately 22 feet below land surface, wellpoints can be set at almost any depth, depending on the situation. The only criterion for wellpoint depth is to avoid dewatering below the screen. If this occurs, air enters the system and reduces the vacuum and therefore the drawdown. During normal operation of the system, dewatering below the top of a well screen can sometimes occur. The problem can be minimized in the field by adjusting the valves that control individual wells.

The evaluation of this process option is presented below:

- Effectiveness (high): This is a proven and reliable technology for the extraction of the perched groundwater as long as the wells are maintained. The potential impacts to human health and the environmental during implementation phase is minimal. Spacing between the well-points is critical for maximum effectiveness.

- Implementability (moderate): Materials and equipment are readily available. Special engineering may be required to account for local hydrology and site conditions. No permits will be required for the wellpoints, except if they are outside of FEMP property.

- Capital Cost (moderate): Capital costs associated with the wellpoint system include mobilization, installation, and removal costs.

- O&M Cost (moderate): Maintenance of the pumping units is required.

This option is viable for the perched groundwater at the FEMP and, therefore, the process is retained for further evaluation.

5.2.4.3 French Drains/Interceptor Trenches

French drains/interceptor trenches are effective in collecting contaminated groundwater from shallow aquifers (in the FEMP, the perched groundwater is less than 20 feet below grade) through trenches or perforated pipes which feed a shaft. The glacial till layer where the perched groundwater exists is generally 20 to 30 feet thick. From the information presented in the Sitewide Characterization Report (DOE 1992a), it appears that the french drain will be 30 to 45 feet below grade. The collected perched groundwater can be pumped to the surface for treatment or discharge to an appropriate facility.

Drains or trenches are typically installed perpendicular to the direction groundwater flow, although other orientations may be applicable in certain cases. Drains are generally constructed by excavating a trench and installing perforated pipe on gravel bedding on the bottom of the trench. The trench is then backfilled with gravel or the envelope material, followed by backfilling the remainder of the trench with soil. The gravel may be enveloped in a geotextile fabric to prevent fine soil particles from entering the gravel and clogging the drain. If the surrounding soils have a moderately high to high hydraulic conductivity and there is some question as to whether the drain will be a complete barrier, an impermeable synthetic membrane may be installed on the downgradient side of the drain to prevent water from passing though it.

Trenches and drains can be either active (pumped) or passive (gravity flow). Passive systems are usually left open with an installed skimming pump or settlement tank for removal of the pollutant.

There are, however, a number of limitations to the use of subsurface drains as a remedial technique. Subsurface drains are not feasible at depths exceeding 40 feet, due to the difficulty of shoring during installation. Also, contamination at great depth or in bedrock aquifers may cause construction costs to be prohibitive, particularly if a substantial amount of rock must be excavated. The excavation required for trench or drain installation is complicated in areas where subsurface utilities are ubiquitous, or where tanks, buildings, and roadways exist.

The evaluation of this process option is presented below:

- Effectiveness (moderate): Appropriate for groundwater removal from low permeable formations. This process option is effective for collecting groundwater from the perched zone. The method is proven and reliable, except for deep aquifers.

- Implementability (moderate): Materials and equipments are readily available. Generally, width, spacing, and depths of drains will vary depending on soil permeability. Underground utilities must be incorporated in the design phase. Dangers in excavating thick, saturated zones may be caused by instability of sidewalls during construction of deeper trenches. Skilled labor is needed for deep trenching. No access agreement or permit is required for on-site work.

- Capital Cost (moderate): Although subsurface drains perform many of the same functions as pumping well systems, drains may be more cost-effective in certain circumstances. For example, drains may be particularly well suited to sites with relatively low hydraulic conductivities, where the cost of wells may be high due to the need to locate wells very close together. Costs for this process option include construction of drains/trenches and installation of pumping units.

- O&M Cost (moderate): Maintenance of drains/trenches and pumps is needed.

Due to uncertainties in site hydrogeologic conditions and lack of flexibility of this process option, this process is retained only as a support technology in alternatives for extraction of shallow water zones.

5.2.5 Treatment

The treatment technologies retained from the initial screening (Section 4.0) for this response action include physical, physicochemical and chemical treatments. Specific process options retained from the physical treatment technology group includes air stripping, RO, electrodialysis and advanced membrane filtration/ultrafiltration. Additionally, physicochemical and chemical processes, including adsorption, ion exchange, (biosorption), precipitation, UV radiation/oxidation, and (liquid-liquid) solvent extraction were retained for further evaluation. Each technology or process option is evaluated for its application to the perched groundwater zones and the Great Miami Aquifer.

5.2.5.1 Air Stripping - Physical

Air stripping uses packed column cross-flow tower, coke tray aeration, and diffused air basins to treat volatile organics in aqueous or soil phase (EPA 1987a). Air stripping is a mass transfer process in which volatile contaminants in water or soil are transferred to gas. Air stripping is frequently accomplished in a packed tower equipped with an air blower. The packed tower works on the principle of countercurrent flow. The water stream flows down through the packing while the air flows upward, and is exhausted through the top. Volatile, soluble components have an affinity for the gas phase and tend to leave the aqueous stream for the gas phase. In the cross-flow tower, water flows down through the packing as in the countercurrent packed column; however, the air is pulled across the water flow path by a fan. The coke tray aerator is a simple, low-maintenance process requiring no blower. The water being treated is allowed to trickle through several layers of trays. This produces a large surface area for gas transfer. Diffused aeration stripping and induced draft stripping use aeration basins similar to standard wastewater treatment aeration basins. Water flows through the basin from top to bottom or from one side to another with the air dispersed through diffusers at the bottom of the basin. The air-to-water ratio ranges from 10:1 to 300:1 by volume.

Generally, chemical compounds with Henry's Law constants of greater than 0.003 can be effectively removed by air stripping. This includes such components as 1,1,1-trichloroethane, trichloroethylene, chlorobenzene, vinyl chloride, and dichloroethylene. The feed stream must be low in suspended solids and may require pH adjustment of hydrogen sulfide, phenol, ammonia, and other organic acids or bases to reduce solubility and improve transfer to the gas phase. Stripping is often only partially effective and must be followed by another process such as biological treatment or carbon adsorption. Combined use of air stripping and activated carbon can be an effective way of removing contaminants from groundwater. The air stripper removes the more volatile compounds not removed by activated carbon and reduces the organic load on the carbon, thus reducing the frequency (and expense) of carbon regeneration.

This process option is evaluated below:

- Effectiveness (high): The process is considered only applicable to dilute aqueous waste streams containing volatile organics; i.e., the perched groundwater. This process may require the use of activated carbon, catalytic oxidizer, or fume incinerator to eliminate or reduce the volatilized organic compounds in off-gas prior to its discharge. This technology has been proven effective and would be expected to meet PRGs for volatile organics.

- Implementability (high): Application of an air-stripping system with appropriate packing medium and off-gas collection is commercially available. Skilled workers are not required. Approval for air emission is required.

- Capital Cost (moderate): The capital cost of air stripping is moderate because the process requires no sophisticated equipment and uses well-established principles.

- O&M Cost (moderate): Maintenance of aeration towers and pumps is standard practice. Energy costs are a major component of the O&M cost. Air phase pollution control units need to be replaced periodically.

Effectiveness and implementability of this process option are high since volatile organics are present in groundwater in diluted concentrations. The process is retained for detailed analysis.

5.2.5.2 RO - Physical

RO (RO) involves diffusion of water through a semipermeable membrane with applied pressure (EPA 1985). RO is the application of sufficient pressure to the concentrated solution to overcome the osmotic pressure and force the net flow of water through the membrane toward the dilute phase. This allows the concentration of solute (impurities) to be built up in a circulating system on one side of the membrane while relatively pure water is transported through the membrane. Ions and small molecules in true solution can be separated from water by this technique.

The basic components of a RO unit are the membrane, a membrane support structure, a containing vessel, and a high-pressure pump. The membrane and membrane support structure are the most critical elements. Membranes are usually fabricated in flat sheets or tubular forms and are assembled into modules. The most common materials used are cellulose acetate and other polymers such as polyamides and polyether-polysulphone. There are three basic module designs: tubular, hollow fiber, and spiral wound.

RO is used to reduce the concentrations of dissolved solids, both organic and inorganic. In treatment of hazardous waste contaminated streams, use of RO would be primarily limited to polishing low flow streams containing highly toxic contaminants. In general, good removal can be expected for high molecular weight organics and charged anions and cations. Multivalent ions are treated more effectively than are univalent ions. Advances in membrane technology have made it possible to remove such low molecular weight organics as alcohols, ketones, amines, and aldehydes.

RO units are subject to chemical attack, fouling, and plugging. Pretreatment requirements can be extensive. Wastewater must be pretreated to remove oxidizing materials such as iron and manganese salts; to filter our particulates; adjust pH to a range of 4.0 to 7.5; and to remove oil, grease, and other film forms. The growth of slimy biomass on the membrane surface or the presence of organic macro-molecules may also foul the membrane. This organic fouling can be minimized by prechlorination, addition of biocides, and/or pretreatment with activated carbon.

An evaluation of the effectiveness, implementability, and cost for this process option is discussed in the following paragraphs:

- Effectiveness (moderate): RO has been used only on an experimental basis for uranium removal. Full-scale studies will be required to confirm the effectiveness of this technology for uranium removal. There is a potential exposure risk to plant employees, the environment, and the public from handling the concentrated radioactivity-contaminated groundwater and residuals.

- Implementability (moderate): RO is a commercial process that can be reliably implemented once full-scale studies confirm the effectiveness for uranium removal. Pretreatment may be required to prevent system fouling. RO generates a sizeable concentrated residual waste stream that requires additional handling and treatment. Multiple approvals for disposition of residual and effluent will be required for operation.

- Capital Cost (high): RO membrane is a costly item in addition to the other treatment equipment that is similar to other process options.

- O&M Cost (high): Membrane replacement, chemical additions, residual handling and disposal, electric usage, and operator costs are the primary O&M cost items.

With pretreatment, RO is considered a viable technology for removing uranium from the groundwater. The process is retained for detailed analysis in alternatives.

5.2.5.3 Electrodialysis - Physical

Electrodialysis concentrates or separates ionic species dissolved in an aqueous solution. In electrodialysis the contaminated groundwater would be passed through a cell containing alternately placed cation-permeable and anion-permeable membranes. An electrical potential is applied across the membranes to provide the motive force for ion migration. The ion-selective membranes are thin sheets of ion exchange resin reinforced with a synthetic fiber backing.

The process is well established for purifying brackish water and has been demonstrated to be effective in the recovery of metal salts from plating rinse. Units are being marketed to reclaim metals of value from rinse streams. Such units can be skid mounted and require only piping and electrical connections.

Electrodialysis units are subject to chemical attack, fouling, and plugging. Pretreatment requirements can be extensive, particularly to reduce fouling by organic matter.

An evaluation of the effectiveness, implementability and cost for this process option is discussed in the following paragraphs:

- Effectiveness (moderate): Electrodialysis has been used only on an experimental basis for uranium removal. Treatability studies would be required to confirm the effectiveness of this technology for uranium removal. Potential impacts to human health and the environment during implementation phase are minimal.

- Implementability (moderate): Electrodialysis units have been installed for domestic water treatment and industrial applications with capacities ranging from 1,000 gpd to 6 million gpd. Electrodialysis can be implemented if treatability studies confirm its effectiveness for uranium removal. Pretreatment may be required to prevent membrane fouling. Electrodialysis would generate a concentrated residual waste stream that would require additional handling and treatment. Multiple approvals would be required for operation as well as for residual and effluent disposal.

- Capital Cost (high): Bench and pilot treatability studies, treatment system design and construction, and expensive equipment contribute to the high capital costs of this process option.

  The comparative economics of electrodialysis for desalting brackish waters is discussed by Belfort (1984): for lower salinities, electrodialysis and RO are competitive, but for higher salinities electrodialysis is inferior. IT has assumed that this is also true if these two process options were to be applied to the treatment of uranium-contaminated groundwater.

- O&M Cost (high): Membrane replacement, chemical additions, residual handling and disposal, electric usage, and operator costs are the primary O&M cost items.

Electrodialysis is potentially applicable, however, for the purposes of the ISA, RO has been chosen as the representative process option for the advanced membrane separation technology. This decision takes into consideration the treatability studies already completed (Duratek 1990; IT 1989b) for the FEMP and published results of other treatability studies that have focused on RO to treat uranium-contaminated groundwaters.

5.2.5.4 Advanced Membrane Filtration/Ultrafiltration - Physical

Advanced membrane filtration uses a specific pore-sized membrane usually in a special configuration. Ultrafiltration is a low-pressure (25 to 50 pounds per square inch [psi]) membrane mediated separation process, which may be enhanced chemically or structurally to attract particles to the surface of the media for more effective filtering. The technology can be applied in combination with chemical treatment to selectively remove suspended particles from dilute aqueous solutions. The membrane system collects contaminant particles with sizes as small as 0.001 to 0.02 micron. Advanced membrane filtration has been used in the treatment of plating wastewater, printed circuit board wastewater, laundry recycling, and contaminated groundwater.

The evaluation of this process option is discussed below:

- Effectiveness (low): The use of this technology is not applicable to the removal of contaminants in dissolved state. Since the uranium present in the groundwater is primarily in the dissolved form, advanced membrane filtration would not be effective unless suitable pretreatment was provided to alter the state of contaminants.

- Implementability (moderate): This technology is undergoing rapid improvement and adaptation to numerous industrial wastewater problems but has not yet been accepted as a uranium removal process. Skilled labor and specialized equipment are needed. Residual production and disposal presents additional technical difficulties.

- Capital Cost (high): Complex design, construction, and bench- and pilot-plant studies of multiple membrane types would be required to develop the application of this technology for uranium removal.

- O&M Cost (high): Membrane replacement, chemical additions, electric usage, residual disposal, and operators are major cost factors.

Due to its inability to treat dissolved contaminants, advanced membrane filtration/ultrafiltration is not a preferred technology for removal of uranium from the site groundwater. It is not retained for consideration in the subsequent development and screening of alternatives.

5.2.5.5 Adsorption - Physicochemical

Adsorption is a physicochemical process that involves the removal of mixed organics from liquid waste by adsorption onto a treatment medium (e.g., activated carbon or activated alumina). As described in literature (EPA 1985), the medium selectively adsorbs hazardous constituents by a surface attraction phenomenon in which organic molecules are attracted to the internal pores of the carbon/ alumina granules.

Adsorption depends on the strength of the molecular attraction between adsorbent and adsorbate, molecular weight, type and characteristic of adsorbent, electrokinetic charge, pH, and surface area.

Once the micropore surfaces are saturated with organics, the medium is "spent" and must either be replaced with virgin medium or removed, thermally regenerated, and replaced. The time to reach "breakthrough" or exhaustion is the single most critical operating parameter. Medium longevity balanced against influent concentration governs operating economics.

Most hazardous waste treatment applications involve the use of adsorption units which contain granular activated carbon (GAC) and operate in a downflow series mode. The downflow fixed bed series mode has been found to be generally most cost-effective and produces the lowest effluent

concentrations relative to other adsorber configurations (e.g., downflow in parallel, moving bed, upflow-expanded). The units may be connected in parallel to provide increased hydraulic capacity.

An evaluation of the effectiveness, implementability, and cost for this process option is presented below:

- Effectiveness (moderate): Adsorption has been used effectively for the removal of organics, fluorides, arsenics, chromium, and some radionuclides. It has been shown to effectively remove uranium from water, but efficiencies are not as great as other treatment processes. The efficiency of contaminant capture during the adsorption process is dependent on water chemistry and type of adsorption material. Other treatment processes may be used in conjunction with adsorption in order to improve the quality of final effluent. There is potential risk to human health from spent adsorption material, handling, and disposal. Adsorption is a conventionally proven and well established process.

- Implementability (high): Materials and equipment are readily available. The process requires removing packaging and disposing spent adsorption material at regular intervals. Workers using this water treatment process do not need to be skilled in water treatment, but must be familiar with handling and disposal of radioactive waste and hazardous waste. An approval for disposal of residuals is needed if disposed off site.

- Capital Cost (moderate): Capital costs for this process are moderate. Major cost items include cartridges and equipment.

- O&M Cost (moderate): Operating costs include spent adsorbent material removal and disposal.

The adsorption process option is a viable technology, especially for the removal of organic contaminants and is retained for further consideration.

5.2.5.6 Precipitation - Physicochemical

Precipitation is a physicochemical process whereby dissolved inorganic contaminants are transformed into an insoluble solid phase, thereby promoting separation. It is based on the alteration of chemical equilibrium relationships affecting the solubility of inorganic species.

Removal of metals as hydroxides or sulfides is the most common precipitation application in wastewater treatment and is accomplished by adding lime or sodium sulfide to the influent in a rapid mixing tank. Many precipitation reactions such as the precipitation of metals from solutions by the addition of sulfide ions do not readily form large, settable particles, but rather precipitate as very fine and relatively stable colloidal particles. In such cases, flocculating or coagulating agents such as alum or polyelectrolytes must be added to enhance the settling of the precipitates.

Once suspended particles have been flocculated into larger particles, they usually can be removed from the liquid by sedimentation/clarification, provided sufficient density differences exist between the suspended matter and the liquid. These residuals would require further treatment to achieve reductions in contaminant toxicity, mobility and/or volume.

The evaluation of this process option is presented below:

- Effectiveness (high): The results of past treatability studies conducted for the FEMP (Duratek 1990; IT 1989b) and the published results of other treatability studies conducted on uranium-contaminated groundwaters have indicated that chemical precipitation may not be so effective as other available technologies for treatment of uranium-contaminated groundwater. The precipitation can be utilized in pretreatment or posttreatment stages in a treatment train. The concerns include:

  - The valence state of uranium is very pH sensitive and therefore, precipitation of uranium is strongly pH dependent. Slight variations in the pH of the groundwater influent can reduce the efficiency of uranium precipitation.

  - A large quantity of mixed-waste sludge is generated which may potentially create problems in handling and disposal.

  However, recent research results showed that chemical precipitation can be used effectively for uranium precipitation with the use of proprietary reagents, i.e., potassium ferrate (ADC 1991). Ferrate (Iron VI) technology has been demonstrated at the bench level and the full plant operations level to remove radionuclides (e.g., uranium, plutonium, and americium), suspended solids, and priority pollutants from wastewaters. For contaminated water similar to OU5 groundwater, the proprietary reagent is reported to precipitate uranium at the pH range of 10.6 to 11.2, and generate five to ten times less sludge than the ferric sulfate and lime as conventionally used for precipitation. The effectiveness of this process option is considered high (98 percent or greater of uranium removal) based on the results of proprietary reagents used on similar water treatment. A treatability study should be performed on the OU5 groundwater with the proprietary reagent.

- Implementability (moderate): The chemicals and equipment required to implement this technology are readily available. This process does not require skilled labor. Contingent upon the proprietary reagents and processes, the precipitation process may generate more sludge than other process options. The sludge requires additional treatment and disposal due to the characteristics of mixed waste. Residual management requires additional efforts, including agency approvals.

- Capital Cost (low): Technique and equipment of this process option are commercially available. Capital costs including equipment and design are relatively low.

- O&M Cost (moderate): Major O&M costs include the required chemicals, electric power usage, sludge treatment, and effluent disposal.

Chemical precipitation is considered a viable technology for uranium removal by itself or in conjunction with other treatment technologies. This process option is retained in alternatives for detailed evaluation.

5.2.5.7 Ion Exchange - Physicochemical

Ion exchange is a process in which certain dissolved ions are removed from water by exchanging them with other (counter) ions held by electrostatic forces to charged groups on the surface of an insoluble solid (resin) with which the solution is contacted. Ion exchange resins are typically polymer beads that have been modified by the addition of chemical groups which attract various ionic species. The resins can be regenerated for reuse with a strong solution of the exchangeable counter ion. Resin types range from general purpose demineralization resins that remove nearly all salts to selective chelating resins that have high affinities for specific ions. The effectiveness, implementability, and cost of this treatment option are discussed below:

- Effectiveness (high): Ion exchange is a reliable and commercially proven technology. Treatability studies conducted for the FEMP (Duratek 1990; IT 1989b) and the published results of a number of other treatability studies have all indicated that ion exchange is a suitable technology for treating uranium-contaminated groundwater. The results indicated that ion exchange can achieve reductions in uranium concentrations in groundwater to more than 99 percent. There are a number of ion exchange systems currently employed for treating uranium-contaminated waste streams including a 900 gpm unit at the Schwartzwalder Mine in Golden, Colorado and a 7,000 gpm unit used to extract uranium from a copper leach liquor. There is a potential exposure risk to humans and the environment during the implementation of this process.

- Implementability (high): Ion exchange is a commonly utilized process for uranium removal. Skilled workers are not required, but must be familiar with radioactive substances management. The resins may be used once and disposed of or they may be regenerated. If the resin is regenerated, it will yield a concentrated stream requiring additional handling and disposal. Alternately, if the resin is used to exhaustion, the exhausted resin will need handling and disposal.

- Capital Cost (high): Full-scale installation requires extensive studies, design, complex equipment, and instrumentation. The capital cost will be high due to the need to treat a high-flow, low-concentration waste stream.

- O&M Cost (high): O&M cost includes replacement resin which can be significantly different for a resin regeneration system as compared to resin use until exhaustion. Additional cost elements are regeneration chemicals and treatment and disposal of exhausted resin or the concentrated stream resulting from resin regeneration. Treatment cost is dependent on the type of resin employed, the quantity of the various ionic species removed from the wastewater, and the amount of waste generated.

These data indicate that ion exchange is a viable technology for removing uranium from an aqueous waste stream. This treatment process is retained for incorporation into the remedial action alternatives.

5.2.5.8 Biosorption - Physicochemical

This sorption process for removing toxic metal ions from water is based upon the natural strong affinity of biological materials, such as the cell walls of plants and microorganisms, for heavy metal/radionuclide ions. Biological materials, primarily algae, are immobilized in a polymer to produce a "biological" ion exchange resin. The bound metals can be stripped and recovered from the algal material in a manner similar to conventional ion exchange resins (EPA 1991c).

The evaluation of this process option is discussed below:

- Effectiveness (moderate): The biological exchange resin has achieved some degree of separation of heavy metals/radionuclides in pilot plant testing; it is a relatively new commercial process that may be considered a modification of the conventional ion exchange method. This process may be effective in meeting long-term public health and environmental objectives. Residuals from this process option need to be managed as radioactively contaminated materials.

- Implementability (moderate): This process uses a proprietary sorption technique and is being newly marketed; therefore, the availability of equipment or workers may be limited.

- Capital Cost (moderate): Components of capital cost include plant construction, design, equipment, instrumentation, and treatability studies.

- O&M Cost (high): Major O&M costs include residual disposal, electric usage, operator/maintenance costs, and costs associated with monitoring.

Information presented by the developer of the process (Bio-Recovery Systems, Inc.) in an EPA publication (EPA 1991c) indicates that this process is viable for the removal of uranium from groundwater. However, the process is a form of ion exchange using algae as the "resin", and therefore, is not retained as a representative process option for incorporation into remedial action alternatives.

5.2.5.9 Ultraviolet Radiation/Oxidation - Physicochemical

The ultraviolet (UV) radiation/oxidation process uses UV irradiation, sometimes enhanced by ozone (O_3) and hydrogen peroxide (H_2O_2), to destroy or detoxify hazardous compounds in aqueous solution (EPA 1987a). The process oxidizes organic compounds that are toxic or refractory (resistant to biological oxidation) in concentrations of parts per million (ppm) or parts per billion (ppb). Adsorption of energy in the UV spectrum results in a molecule's elevation to a higher energy state, thus increasing the ease of bond cleavage and subsequent oxidation of the molecule. The inability of UV

light to penetrate and destroy pollutants in soil or in turbid or opaque solutions is a limitation of this approach.

This process is evaluated below:

- Effectiveness (low): The UV radiation/oxidation process destroys toxic organic compounds, especially chlorinated hydrocarbons, such as PCBs and dioxins, in water. It also serves as a disinfection process capable of destroying disease germs and other harmful microorganisms. However, due to the highly turbid condition of the perched groundwater, this technology's effectiveness is greatly diminished.

- Implementability (high): Materials and equipment are readily available for the process; however, specific design and construction for this application may be needed. Skilled workers are required. Residuals are expected and an approval for disposal is needed.

- Capital Cost (high): This process requires high capital cost, partly because the patented equipment is needed.

- O&M Cost (high): Due to high energy operation costs, O&M costs are expected to be high.

Due to UV radiation/oxidation's low effectiveness rating for perched groundwater, it is not retained for incorporation into the remedial alternatives.

5.2.5.10 Solvent Extraction (Liquid-Liquid) - Chemical

This process involves the separation of constituents of a liquid solution by transfer to a second liquid that is immiscible in the first liquid. This technology involves the use of various reagents including extractants, diluents, and modifiers. The reagents are usually recovered for reuse in the process.

The liquid-liquid solvent extraction consists of a two-step process. In the first step, termed "extraction," the dissolved contaminants are transferred from the aqueous phase into the organic or solvent phase. The second step, called "stripping," recovers the concentrated contaminants into a second aqueous phase after which the barren organic is recycled back to the extraction step. The aqueous and organic solutions flow continuously and countercurrently to each other through the required number of contacting stages in the extraction and stripping portions of the circuit. The contaminants are recovered from the second aqueous solution by precipitation or other recovering technologies.

The extraction of contaminants from the aqueous solution and eventual transfer to another aqueous solution requires a suitable vessel to bring about intimate contact between the different liquids. The extractants are the reagents in the solvent that extract the contaminants. Extractants that are used in

recovery of uranium from acid leach solutions are alkylphosphoric acid, amines, tri-n-butyl phosphate and trictyl phosphine oxide.

The diluents comprise the bulk of solvent and are inert ingredients whose principal function is to act as carrier for the relatively small amount of extractant. Kerosene is the most commonly used diluent, although other organics such as fuel oil, toluene, and paraffins are also used. The most commonly used modifiers for increasing the solubility of the extracted species are long-chain alcohols, such as isodecanol.

The process is evaluated below:

- Effectiveness (low): Liquid-liquid solvent extraction is not a proven treatment option for radionuclides in dilute aqueous form. This option may cause possible primary pathways for direct human exposure. Bench-scale and pilot-scale studies are needed to evaluate the effectiveness of this option. In conjunction with other treatment technologies, solvent extraction is reported as the preferred technology for extracting uranium from acid leach liquor circuits by uranium extraction plants (EPA 1988c).

- Implementability (moderate): The equipment utilized is mostly standard processing equipment. A custom-designed extraction unit would most likely be required after field feasibility testing is completed. Skilled labor is needed to operate the equipment. Residuals need to be managed as radioactively contaminated substances.

- Capital Cost (high): The capital costs include materials and installation costs. The overall capital cost would be high if solvent recovery is required.

- O&M Cost (moderate): The O&M cost would be minimized if the solvent is recovered for reuse. Other costs include operators, electrical usage, and analytical costs.

This process may be used as a support technology, but will not be retained for further evaluation.

5.2.6 Discharge

The technologies retained from the initial screening for this response action include discharge to surface water or pumping wells. The specific process options relating to these remedial technologies are discharge of treated or untreated groundwater to the Great Miami River via the pipeline currently under construction , discharge to Paddys Run, and reinjection through wells.

5.2.6.1 Discharge Groundwater to Great Miami River via FEMP Pipeline Currently Under Construction

This process option consists of discharging site groundwater via the pipeline currently under construction at the FEMP for discharge to the Great Miami River. It was indicated by FERMCO that

the pipeline was near completion and has sufficient capacity to accommodate additional flow from Operable Unit 5. The effectiveness, implementability, and cost of this option are discussed below:

- Effectiveness (high): Discharge of treated effluent to the Great Miami River meets the remedial action objectives. The FEMP currently holds a permit to discharge treated water to the Great Miami River. The uranium content of the existing discharge is not regulated by the current NPDES permit but by internal DOE Derived Concentration Guides (DCG).

- Implementability (moderate): This discharge option is easy to implement. Associated construction (piping connection), materials, and equipment are well-established. This option will require modification of the existing NPDES permit for the added flow. Discharge of treated effluent is likely to be administratively acceptable to local/government agencies.

- Capital Cost (low): Construction costs to connect the proposed discharge line to the pipeline currently under construction, which includes materials and labor.

- O&M Cost (low): Maintenance, sampling, and analysis are currently performed by the FEMP or other DOE contractors.

Discharge of effluent to the Great Miami River via the pipeline currently under construction is a viable process option. It is retained in the alternatives for further evaluation.

5.2.6.2 Discharge Groundwater to Paddys Run

This process option consists of discharging site groundwater to via a newly constructed pipeline from the groundwater treatment facility to Paddys Run. Paddys Run discharges to the Great Miami River near New Baltimore, Ohio. The effectiveness, implementability, and cost of this option are discussed below:

- Effectiveness (moderate): Discharge of treated effluent to Paddys Run meets the remedial action objectives. The effectiveness of this process option may be hindered due to the capacity of Paddys Run. Potential impacts to human health and the environment are slightly higher than those by discharging to the Great Miami River because Paddys Run travels through agricultural and residential areas. The FEMP currently holds a permit to discharge treated water to the Great Miami River. The uranium content of the existing discharge is not regulated by the current NPDES permit but by internal DOE Derived Concentration Guides (DCG).

- Implementability (moderate): This discharge option is easy to implement. Associated construction (piping connection), materials, and equipment are well-established. This option will require major modification of the existing NPDES permit for the FEMP. New discharge permits may be required. Discharge of treated effluent is likely to be administratively acceptable to local/government agencies.

- Capital Cost (low): Construction costs to connect the proposed discharge line from the treatment facility to Paddys Run includes materials and labor.

- O&M Cost (low): Maintenance, sampling, and analysis will be required.

Discharge of effluent to Paddys Run via a newly constructed pipeline is a viable process option. It is retained in the alternatives for further evaluation.

5.2.6.3 Injection Wells

Injection wells can be used to reinject treated groundwater into the aquifer, with or without the intention of gradient control. Installation and construction of the injection well are approximately the same as for the extraction well. Many well-points may be needed to achieve 100 percent injection. The pumping force of the injection well may cause silting and hydraulic mounding around the well. Any area or zone with low hydraulic conductivity will hinder the capacity of the injection wells and should be avoided.

The evaluation of this process option is presented below:

- Effectiveness (high): The public health and environmental risks associated with reinjecting treated groundwater to the deep aquifer are minimal. The current understanding of the regional hydrogeology is considered adequate to evaluate the impact of injection well stresses on the groundwater flow regime. Reinjection will also enhance the flushing of contaminants in the aquifer. If used for groundwater gradient control, this process option can be effective.

- Implementability (high): Deep well injection is a common and proven technology. The materials necessary for this option are readily available. Approval for deep well injection is required. Administrative acceptance by local/government agencies is expected.

- Capital Cost (moderate): Costs include aquifer studies, material and labor needed for installation of an injection well system. An injection well system is more expensive compared to discharge via the existing pipeline.

- O&M Cost (moderate): Injection wells require regular borehole and pump maintenance. Electric usage, sampling, and analytical costs are also a factor.

Reinjection of treated effluent into the aquifer would be easy to implement. It is retained for incorporation into the remedial action alternatives.

5.3 EVALUATION OF TECHNOLOGY PROCESS OPTIONS FOR SOILS AND SEDIMENTS

The technologies and process options remaining after the initial screening for the soils and sediments were evaluated based on the three criteria defined in Section 5.1. The process options within each

technology were compared and the preferred or representative options were retained for incorporation into the remedial action alternatives. The results of this evaluation are summarized in Table 5-2 for soil and sediment and are discussed below.

5.3.1 No Action

The no-action response is applicable to the soils and sediments as required by the NCP. The no-action response will be further evaluated as a baseline for comparison with other remedial action alternatives developed for the soils and sediments.

The no-action alternative is evaluated below:

- Effectiveness (low): The effectiveness of this alternative for protecting human health and the environment is defined as ineffective and unacceptable. The mobility, toxicity or volume of the contaminated soils and sediments will not be reduced under this alternative. Since the contaminated soils are a source of contamination to the groundwater, no-action is not effective in reducing leachate generation and, therefore, would not meet remedial action objectives.

- Implementability (low): This response action does not involve the implementation of technologies or services. It is not administratively acceptable to local/ government agencies.

- Capital Cost (none): There is no cost associated with this alternative since no action is taken.

- O&M Cost (none): This response action does not utilize a technology or process option, therefore, there is no O&M cost.

The no-action response is retained for further evaluation as a baseline for comparison with other remedial alternatives.

5.3.2 Institutional Actions

The remedial technology retained under this general response action is access/use restrictions. Under this technology type, two process options considered applicable for soils are the use of physical barriers for contaminated areas of the site and deed restrictions. The only access restriction process option considered potentially viable for sediments is the use of physical barriers.

5.3.2.1 Physical Barriers

This option includes fencing localized areas of soil contamination to prevent access. As applied to sediments, fencing may be used as a temporary measure to restrict access during implementation of the selected remedial action. In addition, security systems and posted warning signs are potentially applicable for long-term remedial activities.

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TABLE 5-2

OPERABLE UNIT 5 - ENVIRONMENTAL MEDIA
DETAILED EVALUATION OF PROCESS
OPTIONS FOR SOILS AND SEDIMENTS

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
No Action[c]	None	Not applicable	Low; will not achieve remedial action objectives for areas exceeding the clean-up levels	Low; not administratively acceptable to local/ government agencies	None	None
Institutional Actions	Access/Use restrictions	Physical Barriers[c]	Low; indirectly achieves public health objectives by preventing access; dependent on maintenance; does not achieve environmental objectives since contaminants are left in place	High; readily available technology; no permits required; contaminants are not widespread, therefore, this technology is easily implemented	Low; includes materials and labor, and is dependent on extent of area enclosed	Low; once installed requirements are minimal
		Deed restrictions[c]	Moderate; achieving the public health objectives is dependent upon adherence and implementation into the future; does not achieve remedial action objectives	Moderate; relatively easy to implement; non-FEMP properties may pose legal/permitting problems	Low; include fees for legal counsel	None
Control/Containment	Capping	Single layer cap[d]	Moderate; effective in achieving human health but does not achieve environmental objectives since contaminants are left in place; subject to maintenance	Moderate; material, equipment and workers are readily available; non-mixed waste areas only	Moderate; include cost for materials and installation, dependent on type of cover material	Moderate; limited to inspections and repair

See footnotes at end of table.

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TABLE 5-2
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
Control/Containment (Continued)	Capping (Continued)	Multilayer cap[c]	Moderate; effective in achieving human health; does not reduce toxicity or volume of contaminants, dependent on types of materials used and maintenance	Moderate; material, equipment and workers are readily available	Moderate; include material and installation, dependent on types of material used	Moderate; limited to inspections and repairs, including vegetation control
Removal	Extraction of source	Mechanical excavation[c]	High; very effective in achieving remedial action objectives; potential for exposure to workers	Moderate; equipment is readily available; reliable technology; may require construction permit	Moderate; include equipment rental and labor	None; limited to fuel and maintenance of equipment
Treatment	Biological	Soil aeration	Moderate; effective in removing VOCs from soil, a treatability study would be required	High; requires readily available equipment	Low; include equipment	Low; utilities, labor, and chemicals
	Physical	Soil vacuum extraction[d]	Moderate; effective in removing VOCs from soil; potential exposure to human health and the environment; a treatability study would be required	Moderate; requires readily available equipment; air permit required	Moderate; include equipment	Moderate; electrical usage, labor, and residual handling
	Physicochemical	Soil washing[c]	Moderate; has achieved some degree of separation with clayey soil in pilot-plant testing, emerging technology; treatability studies required	High; mobile commercial units available; no permits required	Moderate; equipment rental and material	None

See footnotes at end of table.

TABLE 5-2
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
Treatment (Continued)	Stabilization/Fixation	Pozzolanic-based/Cement-based[c]	Moderate; effective at immobilizing radioactive wastes, thus eliminating exposure pathways; subject to leaching; requires treatability study	High; uses commonly available technology; no permits required	Moderate; equipment, reagents, labor and electrical usage	Low; long-term monitoring and maintenance
		Microencapsulation	Low; limited applicability to radioactive wastes; less potential for leaching; long-term stability is uncertain	Moderate; requires special equipment and highly trained operators; no permits required	High; equipment rental, reagents, and operators	Low; long-term monitoring and maintenance
		Batch vitrification/Glassification[c]	High; has been used to solidify low-level radioactive waste	Moderate; requires special equipment and highly trained operators; air permit required for off-gases	High; equipment rental, utility costs, and operators	None
		In situ vitrification	High; effective in immobilizing contaminants in a vitrified mass or slag; difficulties in treating soils around and under structures	Low; requires special equipment and highly trained operators; air permit is required for off-gases; technology currently being refined	High; equipment, utility costs, and operators	Low; long-term monitoring and maintenance
		Plasma centrifugal furnace (PCF)	Moderate; the PCF is effective for treating soils contaminated with both organics and radionuclides/metals; however, problems with the emissions system and volatile metals have been reported	Low; technology is still in the R&D stage; problems have been encountered with the emissions system, short electrode life and volatilization of metals	High; equipment, utility costs and installation	None

See footnotes at end of table.

TABLE 5-2
(Continued)

General Response Actions	Remedial Technology	Process Option	Effectiveness	Implementability	Cost[a]	
					Capital	O&M[b]
Storage	Intermediate storage	Storage facility[c]	Moderate; effective in isolating contaminated soils and sediments; not a permanent measure; dependent on continued maintenance	Moderate; design and construction are well-established practices; equipment and skilled workers are readily available	High; construction is costly	Moderate; facility requires monitoring, maintenance, and security
Disposal	Engineered Disposal Facility	On-site disposal[c]	High; effective and reliable; dependent on continued maintenance	Moderate; uses conventional technology; must meet intent of permit requirements	High; building a facility	Moderate; monitoring, maintenance, and security
	On-site backfilling	On-site backfilling[c]	Moderate/low; effective in reducing contaminant mobility; does not reduce contaminant toxicity or volume; possible exposure risk during backfilling operations. Would require additional (institutional) actions	High; uses conventional earth moving equipment; permits and/or approvals would be required	Low; equipment rental and labor, minor materials costs	Low; long-term monitoring and maintenance
	Engineered Disposal Facility	Off-site disposal[c]	High; effective and reliable; dependent on continued maintenance; possible exposure during transportation	Moderate; uses conventional technology; must meet permit requirements; transportation required; dependent on available capacity of disposal facility	High; transport and disposal	None

[a] Relative to other process options in the same technology type.
[b] O&M - operation and maintenance cost.
[c] Selected as representative process option for incorporation into alternative development based on its ratings in effectiveness, implementability, and cost.
[d] Support technology.

The following paragraphs summarize the evaluation of this process option:

- Effectiveness (low): This option indirectly achieves human health objectives by preventing human access to these areas. Restrictions to these areas, however, require maintenance of the fence. Physical barriers do not meet environmental objectives since the contaminated material is left in place. The potential exists for migration of contaminants through the soils to the groundwater. Physical barriers also do not restrict the resuspension of materials to the air or in runoff to surface waters. Also, the potential for uptake of contaminants via roots/plants still exists.

- Implementability (high): Physical barriers are a readily available technical solution. The extent of soils and sediments contaminated at levels of total uranium exceeding the PRG of 35 pCi/g is not widespread and, therefore, fencing of these areas can be easily implemented. No permits are required.

- Capital Cost (low): The capital costs necessary for physical barriers include materials and labor and are dependent on the extent of the areas to be enclosed.

- O&M Cost (low): Once installed, maintenance requirements are minimal. A requirement to prevent breaching of the fence by unauthorized individuals would necessitate the attention of FEMP's existing security force.

Physical barriers do not achieve the remedial objectives by itself; however, it may be considered as an ancillary option in conjunction with other remedial solutions and is retained as an institutional action.

5.3.2.2 Deed Restrictions

Deed restrictions may be potentially viable for areas of contaminated soil. This would include possible restrictions on the use of land for agricultural purposes. Deed restrictions may also be used to ensure the integrity of containment structures such as caps or slurry walls.

A summary of the effectiveness, implementability, and cost of this process option is discussed in the following paragraphs:

- Effectiveness (moderate): Indirectly achieves the human health objectives. It is dependent upon adherence to the restrictions by landowners. The remedial action objectives are not met by this option since the contamination is not reduced or eliminated. As with the physical barrier options, the contaminated soil areas remain as a potential pathway to other environmental media.

- Implementability (moderate): Elevated soil contamination of total uranium concentrations exceeding the PRG of 35 pCi/g located within the vicinity of the FEMP would require land use restrictions. Land not owned by the FEMP may pose legal/permitting problems.

- Capital Cost (low): The capital costs associated with this option include fees for legal counsel.

- O&M Cost (none): No O&M costs are associated with this option.

Although this action alone does not achieve the environmental objectives, it is applicable if used in conjunction with engineering options and is retained as an institutional measure for soil only.

5.3.3 Control/Containment

The remedial technology retained under this general response action is capping. The specific process options retained within this technology group includes single-layer and multilayer capping.

5.3.3.1 Single-Layer Capping

Single-layer capping involves the installation of a barrier over the surface of the contaminated area and can alleviate possible direct and/or indirect exposures, as well as minimize the amount of precipitation that infiltrates the contaminated soil, thereby reducing leachate generation. Single-layer capping may be applicable to both soils and sediments, although not all capping materials such as soil or clay would be applicable to sediments in subaqueous conditions. The cap is constructed of any low permeability materials such as high density polyethylene (HDPE), concrete, asphalt, or clay.

The discussion of the effectiveness, implementability, and cost of this option is presented in the following paragraphs:

- Effectiveness (moderate): This option provides protection of human health by minimizing the potential for direct contact with or ingestion of contaminated soils or sediments but, does not reduce toxicity or volume of contaminants. It reduces the potential of the surface soils and sediments to act as a pathway of contaminants to air, groundwater, surface water, and plant and/or aquatic uptake. The overall effectiveness is dependent upon the type of material used and how well it is maintained and the nature of the contamination.

- Implementability (moderate): Materials, equipment, and skilled personnel necessary for the installation of a cap are readily available. The equipment utilized is mostly standard construction equipment. No significant technical difficulties are expected during implementation. Single-layer capping does not comply with regulatory requirements for RCRA or mixed waste contamination, but is a proven technology for non-mixed waste contaminated areas.

- Capital Cost (moderate): The capital costs include materials and installation costs. These costs are dependent on the type of material selected and the extent of the area to be covered.

- O&M Cost (moderate): O&M costs are limited to inspections on a regular basis and any subsequent minor repairs, including vegetation control.

Single-layer capping is considered effective as a support option for control of soil and sediment contamination. This technology will be retained as a support option for non-RCRA (non-mixed) waste contaminated areas.

5.3.3.2 Multilayer Capping

Multilayer capping involves the installation of a multilayer barrier over the surface of the contaminated area and can alleviate possible direct and/or indirect exposures and minimize infiltration of precipitation. Capping may be applicable to both soils and sediments, although not all capping materials, such as soil or clay, would be applicable to sediments in subaqueous conditions. The cap is constructed of a combination of low permeability materials such as HDPE, concrete, asphalt, or clay.

The current design standards for mixed low-level radioactive and hazardous waste landfill cap that would be acceptable to both the EPA and NRC would include: (1) an outer rock or vegetative layer to minimize erosion and provide for long-term stability, (2) a filter and drainage layer that transmits infiltrated water away from the underlying low permeability layers to prevent ponding, (3) an impervious flexible membrane liner overlying a compacted low permeability clay layer, and (4) a filter and drainage layer beneath the compacted clay layer. If the solidified waste zone does not consist of an engineered vault structure with a top roof, an additional compacted clay layer should be placed immediately above the emplaced waste to direct any water infiltration away from the waste zone.

The discussion of the effectiveness, implementability, and cost of this option is presented in the following paragraphs:

- Effectiveness (moderate): This option provides protection of human health by minimizing the potential for direct contact with or ingestion of contaminated soils or sediments. Additionally, it reduces the potential of the surface soils and sediments to act as a pathway of contaminants to air, groundwater, surface water, and plant and/or aquatic uptake. The overall effectiveness is dependent upon the type of materials used and how well it is maintained. A multilayer cap would ensure the long-term isolation of contaminants in the event one layer fails its function. It does not, however, reduce toxicity or volume of contaminants.

- Implementability (moderate): Materials, equipment, and skilled personnel necessary for the installation of a cap are readily available. The equipment utilized is mostly standard construction equipment. No significant technical difficulties are expected during implementation.

- Capital Cost (moderate): The capital costs include materials and installation costs. These costs are dependent on the type of materials selected and the extent of the area to be covered.

- O&M Cost (moderate): O&M costs are limited to inspections on a regular basis and any subsequent repairs, including vegetation control.

The multilayer cap is considered a viable process option for soils and sediments control/containment. It is retained for incorporation into the remedial action alternatives.

5.3.4 Removal

The removal response is applicable for both soils and sediment. The only remedial technology for removal remaining from the initial screening for the surface soils and sediments is extraction of the source. The removal process option considered for surface soils and sediments is mechanical excavation. Excavation costs will depend greatly on whether the existing FEMP facilities are demolished or remain on site.

5.3.4.1 Mechanical Excavation

Removal by excavation can be accomplished with conventional heavy construction equipment and is applicable to almost all site conditions. Backhoes, gradalls, and loaders are most appropriate for the removal of soils and dry stream sediments. Sections of Paddys Run and the SSOD are dry during the summer and autumn months; therefore, standard excavation techniques can be accommodated. Large volumes of potentially contaminated soils are beneath the site facilities. Excavation of these soils, if necessary, will be performed in a fashion similar to mining operations or else excavation will occur through the floor of the facility if the facility is not to be removed. Otherwise, the facility will be demolished and removed prior to excavation of soils beneath it.

An evaluation of this process option is presented in the following paragraphs:

- Effectiveness (high): Mechanical excavation effectively removes contaminated soils and sediments and achieves the objectives for protecting public health and the environment. There is a potential for exposure to workers during the removal process.

- Implementability (moderate): The equipment necessary for the removal of site soils and sediments is conventional and readily available. The site conditions are also conducive for easy implementation. The removal of soils or sediments from off-site properties will require access approval and adherence to requirements of the U.S. Army Corps of Engineers for dredging Paddys Run. Before excavation underneath a building would commence, a thorough study of the existing building/structure would have to be made to ascertain the current situation. This structural analysis would yield information relative to locating grade beams and columns or other vertical supports such as soldier beams for shoring the aboveground structure to permit the removal of subgrade contaminated soils. This would be necessary to ensure that no extensive load displacements occur during the excavation.

- Capital Cost (moderate): The capital costs for soil and sediment excavation would include equipment rental and labor. The cost per unit basis is moderate. However, the cost will vary depending on whether the site buildings are demolished.

- O&M Cost (none): There are no O&M costs associated with excavation.

Excavation of soils and sediments is deemed highly effective and implementable, and is retained for incorporation into the site remedial alternatives.

5.3.5 Treatment

The technologies remaining from the initial screening for the response action of treatment include biological, physical, physicochemical, and solidification/stabilization techniques.

5.3.5.1 Soil Aeration - Biological

Soil aeration is an application of the common agricultural practices of tilling and draining the soil in order to stimulate the decomposition of organic matter in an aerobic environment. Under aerobic conditions organic contaminants are mineralized and made available for assimilation by plant life. Aerobic metabolism is more energy-efficient and microbial decomposition processes are generally more rapid under aerobic conditions. Although the decomposition of some xenobiotic organic compounds appear to require anaerobic metabolism, most soil organisms are shown to be active in the decomposition of organic contaminants are aerobic. Therefore, enhancing the aeration and drainage of the soil will often enhance the rate of biological decomposition. Aeration can be accomplished by the additions of air, oxygen, or other oxidants or oxygen sources such as hydrogen peroxide, ozone, and/or nitrates to the soil by means of a gas injection well system or by an infiltration system using water containing these alternate oxygen sources. Both ozone and hydrogen peroxide have been demonstrated to enhance dissolved oxygen levels in soil/groundwater systems which stimulate microbial activity and also chemically degrade organic contaminants by partial or complete oxidation.

- Effectiveness (moderate): It has been demonstrated that biodegradation of organic contaminants is favored by creating a soil environment similar to those obtained by the practice of tilling the soil. Achievable reduction levels range from low to high depending upon the biodegradability of the organic contaminants and the suitability of the site and soils for the enhancement of aerobic conditions. If the site is too wet, a condition that restricts aeration, a drainage system would have to be installed. This can be achieved with common agricultural methods.

  The use of oxidizing agents requires a detailed evaluation because they can oxidize nontarget organic compounds, reducing the soil's sorptive capacity; they are toxic to soil organisms above a certain concentration which would need to be established by treatability studies and because they can generate gas bubbles which reduce the soil's permeability. Hydrogen peroxide can also mobilize heavy metal and other inorganic contaminants.

- Implementability (high): A variety of equipment, all grouped under the category of tillers, is available for aerating surface soils. Aeration of soils deeper than about 2 feet can be accomplished by a well-point injection system; however aeration through well points has been used and shown to be effective primarily for saturated soils. The well points are also subject to blowouts. Hydrogen peroxide and other oxidants can be infiltrated through surface irrigation systems, shallow infiltration galleries or ponds or

they can be injected into subsurface soils through drains or injection wells, depending upon the depth of the contaminated soil layers.

- Capital Cost (low): Capital costs would cover the purchase of tillers for aeration of surface soils and/or wellpoint system, surface irrigation system, infiltration gallery system, pumps, blowers, and chemical feed systems as required in the final design of the soil aeration system.

- O&M Costs (low): O&M costs would cover utilities (primarily electric), labor, and the purchase of chemicals.

This process is applicable to areas contaminated with volatile organics (e.g., UST areas) and, therefore, is retained as a support option for limited soil areas for all alternatives developed.

5.3.5.2 Soil Vacuum Extraction - Physical

In situ soil vacuum extraction is a process of removing and venting volatile organic compounds from the vadose or unsaturated zone of soils. In this technology, wells and/or other extraction apparatus are used to extract subsurface organic contaminants in a gaseous form. The vacuum may be applied through vertical extraction wells (for low water tables) or horizontal extraction systems (for high water tables). The extracted contaminant stream passes through a vapor/liquid separator, and the resulting off-gases undergo adsorption (activated carbon treatment), incineration (fume incineration), or separation (scrubbing) before being released into the atmosphere.

The technology uses readily available equipment such as extraction and monitoring wells, manifold piping; a vapor/liquid separator; a vacuum pump; and an emission control device, such as an activated carbon canister or burner. Once a contaminated area is completely defined, an extraction system can be installed and connected by piping to a vapor/liquid separator device. A typical extraction system consists of a vacuum pump drawing the subsurface contaminants through the well, to the separator device, and through an activated carbon canister before the air stream is discharged to the atmosphere. Subsurface vacuum and soil vapor concentrations are monitored using vadose zone monitoring wells.

An evaluation of the process is given below:

- Effectiveness (moderate): The process is effective in removing volatile organics. It serves as an effective "source control" measure for containing the spread of contamination in the soil and prevents further release of contaminants to the groundwater. It is particularly effective in remediating VOC contaminated soil which has limited access. Potential risk exists to human health and the environment due to inhalation, if the extracted air collection system fails. Progress and completeness achieved with the vapor extraction process are difficult to monitor. A treatability study would have to be performed to determine site-specific effectiveness.

- Implementability (moderate): This process is easily implemented at sites with low groundwater tables and loose sandy formations. The technology does not require highly trained operators for vacuum extraction and is not limited by depth. The hydrogeology and geology of the site and underground utilities must be considered before locating the extraction wells. Air permits are required.

- Capital Cost (moderate): Capital costs include vacuum pumps, air collection systems, and off-gas treatment systems.

- O&M Cost (moderate): This process is not labor intensive, and the operating cost includes handling of secondary residuals and energy costs.

This process is applicable to areas contaminated with volatile organics (e.g., UST areas) and, therefore, is retained as a support option for limited soil areas for all alternatives developed.

5.3.5.3 Soil Washing - Physicochemical

Soil washing is a physicochemical treatment process which involves the extraction of radioactive, organic, and inorganic compounds from soils or sediments by leaching. This is accomplished by passing a leaching solution (e.g., ammonium carbonate) through the soils using an injection/recirculation process. This process is used on excavated soils or sediments that are fed into a washing unit. This process is based on the principle that the contaminants are associated primarily with soil components finer than 200 mesh, including fine silts, clays, and soil organic matter. The system uses attrition scrubbing to disintegrate or break up soil aggregates, resulting in the liberation of the highly contaminated fine particles from the coarser sand and gravel. Furthermore, the surfaces of the coarser particles are scoured by abrasive action. Volume reduction is achieved by separating the "washed" coarse material from the highly contaminated fine particles, soils, and wash water. The contaminated residual products can then be treated by other methods, including incineration and stabilization. The evaluation of this process option is discussed in the following paragraphs:

- Effectiveness (moderate): The process is based on commonly available mineral treatment processes and has been proven effective during batch treatability pilot study testing. In this process, waste is minimized and both environmental and health objectives can be met. It is an emerging technology. A treatability study is required to determine its effectiveness for site-specific conditions.

- Implementability (high): Mobile units are commercially available. Soil washing has been shown effective on soils contaminated with radionuclides (Marcus, et al., 1989), inorganics and organics. No permits are required.

- Capital Cost (moderate): Costs include operators, electricity, equipment rental, material and residual handling. The costs are usually competitive or lower than other treatment technologies.

- O&M Cost (none): No O&M costs associated with soil washing.

Soil washing is a potentially viable option and is retained for incorporation into remedial action alternatives. Treatability studies are currently being performed as part of the RI/FS to further evaluate the effectiveness of this technology.

5.3.5.4 Pozzolanic-based/Cement-based - Stabilization/Fixation

This process technology reduces the mobility of contaminants by binding them into a solid mass that resists leaching. This particular process combines the contaminated soils and sediments with a stabilizing mixture. The evaluation of this process option is presented in the following paragraphs:

- Effectiveness (moderate): On a commercial basis, cement-based or pozzolanic-based (e.g., lime or fly ash) methods have been effective in immobilizing radioactive wastes. This solidification process would be effective in eliminating direct exposures to receptors and also in eliminating the soil/sediments as a pathway to other environmental media. However, long-term stability and leachability are a potential concern. It creates a solidified mass of larger volume. Bench-scale treatability testing may be necessary to determine the selection and proportion of proper additives.

- Implementability (high): The equipment necessary for this process is similar to that used for cement mixing and handling. It includes a feed system, mixing vessels, and a curing area. No permits are required.

- Capital Cost (moderate): Capital costs include equipment, reagents, labor expenses and electrical usage.

- O&M Cost (low): O&M costs include long-term monitoring and maintenance of stabilized areas.

Pozzolanic-based/cement-based stabilization/fixation is a potentially viable option and is retained for incorporation into remedial action alternatives. Treatability studies are currently being performed as part of the RI/FS to further evaluate the effectiveness of this technology. Both ex-situ and in-situ processes will be evaluated in greater detail.

5.3.5.5 Microencapsulation (Thermoplastic, Organic Polymer and Related Technologies) - Stabilization

This in situ process option involves mixing the contaminated soils/sediments with a plastic monomer and a catalyst (such as heat or chemical catalyst) to encapsulate the contaminants in a stable, solid plastic matrix.

- Effectiveness (low): This method is most applicable and effective for heavy metals. Relative to cement solidification, the increase in volume and rate of leaching is significantly less. However, this technique has not been applied to radioactive materials and long-term stability and leachability are uncertain.

- Implementability (moderate): Specialized equipment, reagents, and trained operators are available for this process. No permits are required.

- Capital Cost (high): Costs include equipment rental, specialized reagents and trained operators.

- O&M Cost (low): Long-term monitoring and maintenance of stabilized materials.

Based on the overall evaluation and the availability of more proven methods, this option is not retained for incorporation into the remedial alternatives.

5.3.5.6 Batch Vitrification/Glassification - Stabilization

Batch vitrification is used to chemically and physically transform wastes such that the treated residues contain contaminated material immobilized in a vitreous glassified mass. The soils or sediments are excavated prior to being placed within a reaction chamber, where high temperatures reduce organics to elemental gas and carbon while inorganic contaminants become entrained in the glass and silicaceous melts. An electrical network is used to melt soils or sediments at temperatures of 1600 to 2000°C, thus destroying organic pollutants by pyrolysis. Inorganic pollutants are immobilized within the vitrified mass, which has properties of glass. Both the organic and inorganic airborne pyrolysis by-products are captured in a hood, which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants of concern.

The batch vitrification also could be performed on excavated materials on site or off site in an electric furnace or in a rotary kiln. In the first, the materials would be melted and poured into molds. In the second, the contaminated materials are sintered in a rotary kiln. While sintering may not necessarily produce a solid monolithic mass, it may reduce availability of the radioactive constituent for leaching and therefore may be appropriate for containing the radioactivity.

Electric furnace vitrification on excavated material would produce a glassy mass, which can be poured into molds of some convenient size. The glassy blocks might supplant waste containers or solidification blocks. The rotary kiln is significantly more energy-efficient than the electric furnace. The products in either case are likely to require an engineered final disposal method.

The evaluation of this process option is presented below:

- Effectiveness (high): The effectiveness of this process varies depending on the types of radionuclides and chemicals contained in the contaminated material. It has been developed specifically for application to radioactive waste sites, particularly to be used by the DOE in its remediation programs. The volume of soil is usually reduced after vitrification. The collection and treatment of off-gases is an important technical consideration.

- Implementability (moderate): Most techniques for this process are not commercially available but can be made available for DOE sites, since much of the supporting research and development were conducted in support of DOE programs. Air permits required for off-gases.

- Capital Cost (high): High equipment rental and utility costs are expected. Highly trained operators are required.

- O&M Cost (none): There are no O&M costs associated with this process.

This process is potentially viable for treatment of soils and sediments and will be retained for incorporation into the remedial alternatives.

5.3.5.7 In Situ Vitrification - Stabilization

In situ vitrification was evaluated as a technology for solidification of soils and sediments. This process is similar to batch vitrification, except that the contaminants are transformed to glass form in situ or in place instead of being excavated prior to treatment. The vitrification process begins by inserting large electrodes into the soil to support the formation of a melt. An array (usually square) of four electrodes is placed to the desired treatment depth in the volume to be treated. Because soil typically has low conductivity, flaked graphite and glass frit are placed on the soil surface between electrodes to provide a starter path for electric current. The electric current passes through the electrodes and begins to melt soil at the surface. As power is applied, the melt continues to grow downward. The heat generated will drive off any volatile organic compounds and solidify the soils into a glassy, solid matrix resistant to deterioration from weathering or leaching. The resulting obsidian is inert and stable in an anhydrous setting.

This technology is evaluated below:

- Effectiveness (high): This process is a fully demonstrated technology for hazardous wastes and radionuclides. The volume of soil is usually reduced after vitrification and it is converted to an obsidian-type of material that is inert and stable. The collection and treatment of off-gases is an important technical consideration.

- Implementability (low): Much of the supporting research and development of this technology were conducted in support of DOE programs. This process requires special equipment and highly trained operators. Difficulties exist in treating soils around and under structures. This technology is currently licensed for commercial application, but the licensee has recently taken the technology off the market for refinement of its equipment. Air permits are required.

- Capital Cost (high): High equipment and utility costs are expected. Highly trained operators required.

- O&M Cost (low): Long-term monitoring and maintenance of stabilized areas are required.

For reasons discussed above concerning implementability, this process is not retained for further consideration.

5.3.5.8 Plasma Centrifugal Furnace - Thermal

Plasma centrifugal furnace (PCF) is a thermal treatment technology that uses the heat from a plasma torch to create a molten bath to decontaminate soil. Organic contaminants are vaporized and react at very high temperatures to form innocuous products. Solids melt and are incorporated into the molten bath. Metals are retained in this phase, and when cooled, the material is a nonleachable matrix. This process is most appropriate for soils contaminated with metals and hard-to-destroy organic compounds and for highly concentrated wastes. It is effective with almost any toxic material, but because electric energy is expensive, it is most beneficial for wastes with high solids content containing heavy metals and/or organics. Mixed radioactive wastes can also be processed.

The evaluation of this process option is presented below:

- Effectiveness (moderate): This process is most appropriate for soils contaminated with heavy metals and organic compounds. Mixed radioactive wastes can also be processed. This process degrades or destroys the hazardous contaminants and immobilizes the radioactive waste and other residuals in the resulting matrix due to the high temperature in the reactor. Potential risk to human health and the environment exists due to off-gas emissions and residual waste.

- Implementability (low): The PCF technology is still in the R&D stage. Specialized equipment and skilled workers are required. Problems have been encountered with the emissions system's short electrode life and volatilization of metals.

- Capital Cost (high): Equipment and utility costs are high.

- O&M Cost (none): No O&M costs are associated with this process.

Due to its similarity to the batch vitrification process, and its low implementability rating, plasma arc incineration is not retained for further evaluation during the alternative development and screening phase.

5.3.6 Intermediate Storage

This response action proposes that the waste would be temporarily stored on- or off-site for a period of approximately 5 to 10 years. The storage facility must be sited in accordance with requirements of the EPA and NRC. In 1982, the NRC promulgated regulations which contain minimum site suitability requirements for low-level radioactive waste (LLW) land disposal facilities in 10CFR61. The EPA has

also promulgated minimum location standards for hazardous waste treatment, storage, and disposal facilities in 40CFR264 and 40CFR270. By combining the technical requirements, standards, and guidance of both agencies, the NRC and EPA have formulated 11 siting guidelines for mixed LLW disposal facilities.

In addition, the storage facility must be designed in accordance with the Joint NRC-EPA Guidance on a Conceptual Design Approach for Commercial Mixed Low-Level Radioactive and Hazardous Waste Disposal Facilities. This guidance is intended to present basic design concepts that are acceptable in addressing the regulations of both the NRC and EPA with respect to requirements for liners, leachate collection systems, and efforts to minimize the contact of liquid with the waste. It should be recognized that the guidance is being provided at the conceptual level and that the design and details that are complementary to specific site conditions need to be engineered by potential waste facility owners and operators.

The effectiveness, implementability, and cost of this option are discussed below:

- Effectiveness (moderate): This option is effective in isolating contaminated soils and sediments, thereby meeting the public health and environmental objectives if the materials are treated. A storage facility would only be a temporary measure, not a permanent solution for disposal of radioactively contaminated materials. The effectiveness is dependent on the continued maintenance of the facility.

- Implementability (moderate): The design and construction of these facilities are widely practiced technologies. Equipment and skilled workers are readily available. However, the EPA retains approval authority through the ROD process of the siting of a storage facility.

- Capital Cost (high): The cost of constructing this facility will be high.

- O&M Cost (moderate): The storage facility will require monitoring, maintenance, and security measures.

Due to its ratings for effectiveness and implementability, intermediate storage is retained for incorporation into the remedial action alternatives as a "fall-back" option if the preferred disposal options are not implementable at the time of action.

5.3.7 Disposal

5.3.7.1 On-Site Disposal

On-site disposal of soils, sediments, and solid residuals from treatment systems would be disposed of in an on-site engineered disposal facility. This facility may be a tumulus or other concrete aboveground structure or a RCRA landfill-type of facility.

The effectiveness, implementability, and cost of this process option are discussed below:

- Effectiveness (high): This process is effective in isolating contaminated soils and sediments, thereby meeting the public health and environmental objectives. An on-site engineered disposal facility would be a permanent solution for disposal of radioactively contaminated materials. The effectiveness is dependent on the continued maintenance and permanence of the facility.

- Implementability (moderate): The design and construction of engineered disposal facilities are widely practiced technologies. Equipment and skilled workers are readily available. However, the EPA retains approval authority through the ROD process of the siting and permitting of a disposal facility within the property boundaries. On-property siting conditions and land limitations may pose problems.

- Capital Cost (high): The cost of building this facility will be high.

- O&M Cost (moderate): On-site disposal will require monitoring, maintenance, and security measures for the life of the facility.

Based on its high effectiveness rating, on-site disposal is retained for incorporation into the remedial action alternatives.

5.3.7.2 On-Site Backfilling

Disposal of treated residuals by backfilling on-site excavations with these materials has potential implementability, provided that the contaminant levels have been reduced to, or below, established PRGs.

- Effectiveness (moderate/low) - The effectiveness of on-site backfilling is contingent upon the effectiveness of a particular remedial option to reduce the contaminant toxicity, mobility and/or volume of the residual. In the case of vitrification, organic contaminants would be incinerated and the inorganics/radionuclides would be locked within the vitrified matrix. Backfilling this material, which possesses a low level of radioactivity, could potentially result in short-term exposure during placement. Additional institutional actions would be required.

- Implementability (high): Equipment, labor and on-site disposal sites are readily available; permits and/or approvals would be required.

- Capital Cost (low): Equipment rental, labor and minor materials costs.

- O&M Costs (low): Long-term monitoring and minor maintenance costs.

Based on its high implementability and low costs, on-site backfilling is retained for disposal of treated material.

5.3.7.3 Off-Site Disposal

Off-site disposal in an approved engineered disposal facility was retained as the applicable process option for both soils and sediments for this general response action. Low-level contaminated soils and sediments can be transported for permanent disposal to an arid western site (e.g., the DOE owned Nevada Test Site [NTS]), to a commercial mixed waste disposal site (e.g., Envirocare in Utah), to a federally owned regional disposal site, within a 300-mile radius of FEMP (e.g., Portsmouth), or a site which would require the purchase of nearby property better suited for the siting of the facility. Waste acceptance criteria for this facility shall be assumed to be consistent with the requirements for the FEMP on-site disposal cell. As a condition of NTS disposal, no untreated wet, raw waste, or free liquids will be accepted. An additional NTS requirement is that the waste can be characterized as either mixed or low-level radioactive waste. If identified as mixed waste, it will only be accepted in a solidified form. Waste transport may be provided by truck or railroad. Radioactive waste from the FEMP is currently shipped to NTS; however, depending on the level of uranium in the material and whether any organics are present, the soil could qualify for disposal at other low-level disposal facilities closer to the FEMP.

The evaluation of this process option follows:

- Effectiveness (high): Effective at meeting public health and long-term environmental objectives at the FEMP. Exposure scenarios possible during removal and transport.
- Implementability (moderate): Removal is straightforward; however, packaging and transport in a form acceptable to the disposal site may need further study; mixed waste issues are complex; safety issues are important. This option is vulnerable to dictates from host states. Dependent on available capacities of disposal facilities.
- Capital Cost (high): Transport (via truck or rail) to the disposal site is expensive and disposal costs are high.
- O&M Cost (none): No O&M costs are associated with this option.

Due to its ratings for effectiveness and implementability, off-site disposal is retained for incorporation into the remedial action alternatives.

5.4 SUMMARY OF SELECTION OF PROCESS OPTIONS

Based on the evaluations presented in Sections 5.2 and 5.3, representative process options were selected to simplify the subsequent development and evaluation of alternatives without limiting flexibility during design. This summary indicates which actions are viable and selected for inclusion into the development of alternatives in Section 6.0 of this report. The representative process options selected provide a basis for preliminary design; however, the specific process actually used to implement the design may not be selected until the remedial design phase. Some of the process

options that are not being carried to the next phase at this time could still be reconsidered during the design phase as long as the satisfaction of evaluation criteria is maintained at an equivalent level.

5.4.1 Selection of Process Options for Groundwater

The selection of representative process options for groundwater remediation is summarized as follows:

- The no-action response action has been retained for incorporation into remedial action alternatives as required by the NCP.

- Groundwater monitoring and deed restrictions are both viable as institutional actions for groundwater. Monitoring may be appropriate as either compliance monitoring or response action monitoring. Since monitoring is normally required under every alternative, it is included in the alternative development at this stage. Deed restrictions are included as appropriate in the detailed description of alternatives. Land acquisition is considered as a support action and may be used as needed in conjunction with other process options.

- Extraction/injection wells were retained as representative of control/containment actions. The extraction and injection of uncontaminated or treated water for purposes of plume control will be incorporated into remedial alternatives. The process option of paving Paddys Run is eliminated due to its low effectiveness in achieving remedial action objectives. The slurry wall option is retained as a support action for its potential application to isolate the perched groundwater.

- The removal of groundwater via extraction wells for the regional aquifer and wellpoints for perched groundwater areas are retained for incorporation into the development of alternatives. French drains or interceptor trenches will be utilized as support option for extraction of groundwater from shallow water zones.

- Five groundwater treatment options were found to be potentially applicable for contaminant removal as a result of the process option evaluations. These treatment options include air stripping, RO, adsorption, precipitation, and ion exchange. The treatment options selected as representative processes for contaminant removal from groundwater are treatment of radioactive compounds using ion exchange, precipitation, and RO. The process options selected for treatment of organic contaminants are air stripping and adsorption. In addition, liquid-liquid solvent extraction is selected as a support action for the primary treatment process options. Precipitation can also be incorporated as a support technology with other viable process options for groundwater treatment.

- The two representative discharge actions selected for incorporation into remedial alternatives are surface water discharge, either to the Great Miami River or Paddys Run and reinjection of treated groundwater into wells with or without the intention of gradient control. The use of the FEMP facilities provides a greater level of administrative control and security.

The representative process options that have been retained for incorporation into alternatives are presented in Table 5-3.

5.4.2 Selection of Process Options for Soil/Sediment

The selection of representative process options for remediation of contaminated soil and sediment is summarized as follow:

- The no-action response has been retained for the soils and sediments as required by the NCP.

- Physical barriers is considered viable as an institutional action in remediation of contaminated soils and sediments. Deed restriction is also a viable institutional action for soil remediation if used in conjunction with engineering controls.

- Based on its effectiveness and implementability, multilayer capping is the selected control/containment action for incorporation into the remedial alternatives. Single-layer capping has been retained as a support option for non-mixed waste areas and will be retained for consideration for each alternative.

- Mechanical excavation is selected as the representative removal option for the soils. Since Paddys Run and the SSOD are dry during most of the year, standard excavation techniques are preferred for the removal of sediments also.

- Three soil/sediment treatment options remain viable as a result of the process evaluation. They are soil washing, pozzolonic-based/cement-based stabilization/fixation and batch vitrification. These process options will be incorporated and considered in the development and initial screening of alternatives. As appropriate, these process options will be further evaluated during the detailed screening of alternatives. Soil vacuum extraction and soil aeration have been retained as support options for areas of volatile organic contamination (e.g., UST areas) and will be considered for each alternative.

- Intermediate storage facility has been retained for incorporation into remedial alternatives.

- On-site and off-site engineered disposal facilities, with or without intermediate storage, has been retained for incorporation into remedial alternatives.

- On-site backfilling of treated residuals has been retained for incorporation into remedial alternatives.

The representative process options that have been retained for incorporation into alternatives are presented in Table 5-4.

Each of the selected options for the groundwater, surface soils, and sediment media are used in the development and initial screening of potential remedial action alternatives for Operable Unit 5 as presented in Sections 6.0 and 7.0, respectively.

TABLE 5-3

FEMP FEASIBILITY STUDY
OPERABLE UNIT 5 - ENVIRONMENTAL MEDIA
TECHNOLOGIES AND PROCESS OPTIONS - GROUNDWATER
RETAINED FOR INCORPORATION INTO ALTERNATIVES

General Response Action	Remedial Technology	Process Options	Primary[a]	Support[b]
No action	None	Not applicable	X	
Institutional actions	Monitoring	Groundwater monitoring	X	
	Use/Access Restrictions	Land acquisition		X
		Deed restrictions	X	
Control/ Containment	Pumping wells	Extraction wells	X	
		Injection wells	X	
	Vertical barriers	Slurry wall		X
Removal	Pumping wells	Extraction wells	X	
		Wellpoint system	X	
	Gravity drainage	French drains and/or Interceptor trenches		X
Treatment	Physical	Air stripping	X	
		Reverse osmosis	X	
	Physicochemical	Adsorption	X	
		Precipitation	X	X
		Ion exchange	X	
		Liquid-liquid Solvent extraction		X
Discharge	Discharge to surface water	Pipeline currently under construction to the Great Miami River (Option 1) or discharge to Paddys Run (Option 2)	X	
	Underground discharge	Injection wells	X	

[a]Primary - Primary technology/process option retained for incorporation into alternatives.

[b]Support - Support technology/process option retained for potential use in alternative(s).

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TABLE 5-4

FEMP FEASIBILITY STUDY
OPERABLE UNIT 5 - ENVIRONMENTAL MEDIA
TECHNOLOGIES AND PROCESS OPTIONS - SOIL/SEDIMENTS
RETAINED FOR INCORPORATION INTO ALTERNATIVES

General Response Action	Remedial Technology	Process Option	Primary[a]	Support[b]
No Action	None	Not applicable	X	
Institutional actions	Access/Use restrictions	Physical barriers	X	
		Deed restrictions	X	
Control/Containment	Capping	Single layer cap		X
		Multilayer cap	X	
Removal				
	Extraction	Mechanical excavation	X	
Treatment	Biological	Soil Aeration		X
	Physical	Soil vapor extraction		X
	Physicochemical	Soil washing	X	
	Solidification/ Stabilization	Cement-based/Pozzolanic-based	X	
		Batch vitrification	X	
Intermediate Storage	Storage facility	Storage pile/Surface impoundment	X	
On-site disposal	Engineered disposal facility	Engineered disposal facility	X	
	On-site backfilling	Backfilling of treated residuals	X	
Off-site disposal	Engineered disposal facility	Engineered disposal facility	X	

[a]Primary - Primary technology/process option retained for incorporation into alternatives.

[b]Support - Support technology/process option retained for potential use in alternative(s).

6.0 DEVELOPMENT AND DESCRIPTION OF REMEDIAL ACTION ALTERNATIVES

Remedial action alternatives have been developed by assembling the selected medium-specific representative process options into alternatives representing possible cleanup remedies for Operable Unit 5. The alternatives were developed to address identified problems in Operable Unit 5 with respect to the specified remedial objectives. Guidance for the development of these alternatives was obtained from the following sources:

- CFR, Title 40, Part 300 (NCP)
- Section 121 of SARA
- EPA, October 1988, Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA

As recommended by the EPA Guidance Document and the NCP, acceptable engineering practices, as related to site-specific conditions, were considered during remedial action alternative development.

As previously indicated, certain baseline condition assumptions and strategic planning considerations for cleanup of the FEMP have been incorporated into the remedial alternative development process for Operable Unit 5. The acceptance and implementation of the removal action for the uranium-contaminated groundwater south of the FEMP "South Groundwater Contaminated Plume Removal Action" represents a major baseline condition assumption and is an ongoing project separate from the No Action alternative. The preferred alternative, as detailed in the EE/CA - South Plume (DOE 1990a) and the subsequent addendum entitled "Explanation of Significant Differences Document," includes the following components:

- Installation and operation of extraction wells near the center of the plume, with subsequent discharge to the Great Miami River
- Expanded treatment of existing FEMP discharge through an interim advanced wastewater treatment system so that total mass of uranium currently discharged is not exceeded
- Provision of an alternate water supply for the two industrial receptors known to be using groundwater with concentrations exceeding 20 µg/L
- Groundwater monitoring
- Institutional controls in the form of tracking and controlling any new groundwater extraction points (wells) in the area
- Further investigations south of the extraction wells

The remedial action alternatives were formulated by developing the most feasible groundwater actions and the most feasible soil/sediments actions as discussed in the evaluation of process options in Section 5.0. Other alternatives were formulated to incorporate additional potential actions. This method was used in an effort to limit the number of alternatives requiring evaluation. The process remains flexible for any necessary additions or refinements to these alternatives.

The selected process options carried through from Section 5.0 have been assembled into seven remedial alternatives (Alternatives GW-1 through GW- 7) for the groundwater medium and eleven remedial alternatives (Alternatives SS-1 through SS- 11) for the soil/sediment medium. The groundwater alternatives as discussed in Section 6.1 address the remediation of the perched groundwater and the Great Miami Aquifer. The remedial actions for sediments and surface soils (Section 6.2) are combined, since the technologies and process options used to formulate the alternatives are applicable to each of these submedia.

6.1 GROUNDWATER ALTERNATIVES

The remedial alternatives developed for the groundwater at Operable Unit 5 are:

- Alternative GW-1: No Action
- Alternative GW-2: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, RO, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)
- Alternative GW-3: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)
- Alternative GW-4: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, RO, Reinjection Discharge
- Alternative GW-5: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Reinjection Discharge
- Alternative GW-6: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)
- Alternative GW-7: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Reinjection Discharge

Except for the no-action response (Alternative GW-1), all alternatives use groundwater monitoring and deed restrictions as institutional actions. Deed restrictions involve restricting the use of groundwater before and during remediation by recording such in the property deeds. Also, land acquisition is

provided as a support technology and, if deemed appropriate, may be used in conjunction with other technologies and process options. Land acquisition will prevent receptor access to the contaminated groundwater. It involves the purchase of the off-site properties above the areas of the aquifer which are in excess of preliminary RAO concentrations.

The monitoring process option consists of the continued or additional monitoring of selected on- and off-property wells in the affected area. The monitoring may be either compliance monitoring or remedial action monitoring. At present, no residential wells containing concentrations of uranium in excess of the proposed groundwater remedial action objective of 20 µg/L for uranium or in excess of acceptable limits for other contaminants in drinking water are being used as a potable water source. The monitoring program associated with these alternatives is intended to detect changes in contaminant content which may indicate movement of the plume into or toward industrial, commercial, or residential wells. Quarterly monitoring for uranium will take place in selected wells until a modified monitoring program is implemented as part of the final remedial action. If increasing contaminant concentrations are detected in any wells during the monitoring program, the potential for exceeding the proposed MCL for uranium in drinking water will be evaluated and, if necessary, an appropriate additional response action will be taken.

Extraction/injection wells are groundwater control/containment measures. This option is considered to be applicable to each groundwater alternative and is not discussed specifically in the description of each groundwater alternative. The specifications for these measures (e.g., number and placement of wells for removal of uncontaminated groundwater) have been used as the baseline condition in Alternative GW-2 and have not been duplicated for other alternatives for groundwater remediation.

6.1.1 Alternative GW-1: No Action

Under the no-action alternative, no additional remediation, monitoring, or security activities are provided to reduce risk to public health or the environment. Routine monitoring and security activities will continue at the FEMP in accordance with DOE operational requirements. The no-action alternative provides no remediation for the groundwater medium. However, the alternate water supply and institutional actions planned for the South Plume removal action are assumed to represent baseline permanent changes. The permanent continuation of pumping from the four extraction wells placed at the middle of the plume under the removal action is not assumed.

6.1.2 Alternative GW-2: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, RO, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)

This alternative includes extraction and treatment of groundwater from the regional aquifer and the perched groundwater zone contaminated with uranium, organic, and inorganic compounds at levels

above remedial action objective levels. Treatment processes consist of air stripping and adsorption for organic compounds and RO for radionuclides. The treated water will be conveyed to the existing NPDES-permitted outfall at FEMP via the pipeline currently under construction. Subsequently, the treated water is discharged to the Great Miami River (Option 1) or Paddys Run (Option 2). This alternative and the other alternatives with treatment and discharge processes will be augmented by an extraction/injection of groundwater as a groundwater control/containment measure for groundwater contamination migration. During and after implementation, this alternative will be supplemented by groundwater monitoring. Components of this alternative are described below.

Extraction and Injection Wells

The groundwater control/containment activities (e.g., number and placement of wells for removal of uncontaminated groundwater) have been applied in this alternative and will be implemented to other alternatives as baseline conditions. Specifications of the control/containment measures are provided as follows:

- A series of uncontaminated groundwater extraction and injection wells is used to create cones of depression and mounds in the groundwater table of the Great Miami Aquifer. The intention is to manipulate the hydraulic gradient to control the direction and rate of migration of contaminated portions of the aquifer. This could potentially be used to direct the contaminated plume away from potential human receptors. As with the other alternatives, groundwater monitoring is required.

- Pumping wells will be used to remove groundwater in specific locations to change the hydraulic gradient and consequently alter groundwater velocity and direction. In particular, an inward hydraulic gradient is created within the zone of influence of the well, creating a hydraulic barrier and trapping contaminants from outward migration. Injection wells would inject uncontaminated groundwater obtained from pumping wells located in areas or screened at depths not affected by contamination. This injection will create an artificial groundwater mound to change the hydraulic gradient and consequently alter and control groundwater velocity and direction. Based on preliminary model results, a total of 18 wells (i.e., 9 extraction and 9 injection) would be needed to effect the necessary gradient changes.

For purposes of scoping and costing this component of the alternative, system requirements are assumed to include the following:

- Public notice
- Construction and injection permits
- Eighteen wells to extract and inject groundwater
- Pumps
- PVC piping
- Electric power/instrumentation
- Construction of caps

Extraction Wells and Wellpoint System

This remedial action includes the extraction of groundwater from the regional aquifer and the perched groundwater containing uranium and organic and/or inorganic contaminants at levels above acceptable limits. The untreated groundwater will be conveyed to the treatment unit composed of an air stripper and carbon adsorption canister for organic removal. Subsequently, the groundwater will be treated by RO prior to being discharged to the Great Miami River via pipeline that is currently under construction (Option 1) or Paddys Run (Option 2).

The extraction wells installed within the regional aquifer as part of the removal action will become an integral part of this alternative. Depending on the time frame for cleanup, as determined in the detailed analysis, additional wells may be added in other portions of the plume to accelerate removal. For example, two to four wells may be placed near the leading edge of the South Plume within the area of the aquifer containing uranium, inorganics, and organics; i.e., in the area of the plume requiring action by both the FEMP and the Paddys Run Road site. The Paddys Run Road site is an OEPA lead RI/FS project, conducted in close proximity to the FEMP, that deals with organic and inorganic contamination of the groundwater. If there is concern for future southward migration of uranium from the production facility, an additional two to four wells may be placed further north along the southern boundary of the FEMP. Within the FEMP, localized areas with elevated contamination levels may be candidates for additional well locations. There are three to six potential locations within the FEMP for groundwater extraction. Therefore, the additional well coverage for the site is qualitatively estimated to range from 7 to 14 wells to achieve the remedial action objectives. The actual number of wells will be dependent on the results of the RI modeling.

For purposes of scoping and costing this alternative and others requiring groundwater extraction, a total of ten wells, in addition to the four wells proposed for the South Groundwater Contaminated Plume Removal Action, will be used. Each well is estimated to be able to produce 500 gpm. This production rate is consistent with the existing analysis of plume capture modeling performed as part of the South Plume EE/CA. This is considered a maximum flow rate for the restoration of the Great Miami Aquifer. A reduction of these rates may be realized depending on localized aquifer conditions. Further refinements of these rates will be accomplished during the detailed analyses of alternatives using the regional groundwater flow and solute transport model.

System requirements are assumed to include the following:

- Public notice
- Associated substantive permitting requirements for construction and surface water discharge
- Ten pumping wells to handle up to 500 gpm each

- Centralized water collection and flow equalization facility with booster pumps
- Piping system from each well (assumed 12-inch polyvinyl chloride [PVC]) to water collection facility and to existing FEMP effluent discharge line (assumed 30-inch PVC)
- Electric power/instrumentation

Discharge into the pipeline/outfall to the Great Miami River (Option 1) or discharge to Paddys Run (Option 2) would require confirmation of available capacity as well as modifications to the existing NPDES permit.

The perched groundwater, which contains uranium, organic and/or inorganic constituents, will be extracted using a wellpoint system supported by French drains/interceptor trenches, and extraction wells. A preliminary study of the perched groundwater system shows that there are 19 localized lenses of water in the perched zone that will require extraction. Due to the low flow rates in 12 of these localized areas, French drains ranging in depth from approximately 30 to 45 feet will be used for extraction. The total length of these French drains is estimated to be approximately 2500 feet. Five areas will be extracted by wellpoint systems, and two by extraction wells. The total flow rate from the perched groundwater zone will be approximately 30 gpm.

In addition, slurry wall is considered as a support option for control and containment of the perched groundwater zones. Slurry wall may be used, where appropriate, to isolate the perched groundwater zones. In conjunction with the extraction systems, the remedial actions for the perched groundwater may be accelerated. However, the design and cost of the slurry wall may not be determined at this stage.

<u>RO (Radionuclides), Air Stripping and Adsorption (Organics)</u>

Conceptually, the treatment facility will consist of the equipment and facilities necessary to treat the perched groundwater organic contaminants via air stripping, followed by liquid and vapor phase carbon adsorption for removal of organics and RO for uranium and inorganics removal. The system will be able to process up to an estimated 5500 gpm (which includes an approximate 10 percent safety factor) from the aquifer extraction system and will be designed to remove uranium to an effluent concentration of less than 20 µg/L and other contaminants to below MCL levels or other established remediation goals.

The reject flow from the RO process can be treated in a posttreatment step with ammonium chloride and polymer to promote precipitation and flocculation of ammonium uranate. A highly concentrated uranium (yellow cake) sludge will be generated as a result of post-treatment steps. The sludge is then concentrated in a sedimentation tank and dewatered with a filter press. The disposal of this dewatered

sludge will be accomplished in accordance with all regulatory requirements as part of FEMP's ongoing waste management activities and could be incorporated into the disposal strategy for higher concentration wastes being removed from other operable units.

Surface Water Discharge

This action consists of discharging the treated groundwater either via the pipeline currently under construction at the FEMP and release to the Great Miami River through the NPDES-permitted outfall, or to Paddys Run by new pipelines that are to be constructed between the treatment facility and the outfall(s) on Paddys Run. Discharge into the pipeline/outfall and subsequently to the surface water bodies will require confirmation of available capacity of the surface water bodies as well as modifications to the existing NPDES permit or application for a new NPDES premit. The projected maximum capacity of the pipeline currently under construction is estimated to be 8000 gpm.

6.1.3 Alternative GW-3: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)

This alternative includes extraction and treatment of groundwater from the regional aquifer and the perched groundwater zone contaminated with uranium, organic, and inorganic compounds at levels above PRGs. Treatment processes consist of air stripping and adsorption for removal of organic compounds and ion exchange for removal of radionuclides. The treated water will be conveyed to the existing NPDES-permitted outfall at the FEMP via the pipeline currently under construction (Option 1) or discharged to Paddys Run (Option 2). Subsequently, the treated water is discharged to the Great Miami River. This alternative and the other alternatives with treatment and discharge processes will be augmented by an extraction/injection well system as groundwater control/containment measures. During implementation, this alternative will be supplemented by groundwater monitoring. Components of this alternative have been described in Alternative GW-2, except the ion exchange process as presented below.

Ion Exchange (Radionuclides)

The treatment for radionuclides will be accomplished using the ion exchange process as described in Section 5.0. Similar to Alternative GW-2, the system will be able to handle an estimated maximum flow of 5500 gpm from the aquifer extraction system and will be designed to remove uranium to an effluent concentration of less than 20 µg/L and other contaminants to below MCL levels or other established remediation goals.

In addition to a highly concentrated uranium sludge generated from the post-treatment of the spent regenerant solution, ion exchange resin will be replaced periodically. Disposal of the spent resin will add an additional burden to the disposal requirements for the regenerant sludge. The disposal will be

conducted in accordance with all regulatory requirements as part of FEMP's ongoing waste management activities and could be incorporated into the disposal strategy for higher concentration wastes being removed from other operable units.

6.1.4 Alternative GW-4: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, RO, Reinjection Discharge

Similar to Alternative GW-2, this alternative includes extraction and treatment of groundwater from the Great Miami Aquifer and the perched groundwater zone. Treatment processes consist of air stripping and adsorption for removal of organic compounds and RO for removal of radionuclides. The treated water will be reinjected to the Great Miami Aquifer via injection wells or a wellpoint system with or without the intention of groundwater gradient control. During implementation, this alternative will be supplemented by groundwater monitoring. Components of this alternative have been described in Alternative GW-2, except for the discharge process as presented below.

Reinjection Discharge

In this alternative, the treated groundwater is discharged through the injection wells and/or wellpoint system. The injection process may be accomplished by using either an open-end or slotted pipe. For aquifer application, slotted pipes will be more appropriate. The slotted pipe may be plastic (PVC) pipe, 12 inches in diameter placed in a 18- to 24-inch borehole. The lower portion of the pipe is slotted over an interval corresponding to the zone to be reinjected, and surrounded by gravel or coarse sand. Above the slotted portion, a cement grout is placed around the pipe up to the ground surface. The maximum injection pressure should be kept below 1 psi per foot of overburden above the injection level. Depending on the characteristics of the aquifer and the discharge rate that is required, spacing between injection holes will be determined later. For purposes of scoping and costing, the reinjection needs are similar to those of groundwater extraction. Therefore, a total of 10 wells will be used. Each well is estimated to be able to inject a maximum of 500 gpm. Pumps, piping, and other ancillary equipment are also needed. Discharge into the aquifer will require a discharge permit for reinjection to the Great Miami Aquifer under the Underground Injection Control (UIC) program in Ohio. The actual number of reinjection wells required for this alternative will be reviewed and evaluated during the detailed feasibility study.

6.1.5 Alternative GW-5: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Reinjection Discharge

Similar to Alternative GW-4, this alternative includes extraction and treatment of groundwater from the Great Miami Aquifer and the perched groundwater zone. The treated water will be reinjected to the Great Miami Aquifer via injection well or wellpoint system with or without the intention of groundwater gradient control. Treatment processes consist of air stripping and adsorption for removal

of organic compounds and ion exchange for removal of radionuclides. During implementation, this alternative will be supplemented by groundwater monitoring. Components of this alternative have been described in Alternatives GW-2 through GW-4.

6.1.6 Alternative GW-6: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)

Similar to the previous alternatives, this alternative includes extraction and treatment of groundwater from the regional aquifer and the perched groundwater zone contaminated with uranium, organic, and inorganic compounds at levels above PRGs. Treatment processes consist of air stripping and adsorption for removal of organic contaminants and precipitation for removal of radionuclides. The treated water will be conveyed through the pipeline currently under construction to the existing NPDES-permitted outfall at FEMP, and subsequently discharged to the Great Miami River (Option 1) or discharged to Paddys Run (Option 2). This alternative and the other alternatives with treatment and discharge processes will be augmented by an extraction/injection well system as groundwater control/containment measures. During implementation, this alternative will be supplemented by groundwater monitoring. Components of this alternative have been described in Alternative GW-2, except the precipitation process as presented below:

Precipitation (Radionuclides)

The treatment for radionuclides, as well as inorganic contaminants, will be accomplished by the precipitation process as described in Section 5.0 of this document. With the use of proprietary reagent in one or two-stage treatment process, this precipitation treatment process can effectively remove uranium in the influent at pH range of 10.6 to 11.2 (ADC 1991). Jar tests performed with the proprietary reagent on similar wastewaters indicated that the proprietary chemical precipitation system removed 68 to 86 percent of the uranium in the waste stream using a single-step treatment and a total of 98 percent or greater of the uranium being removed from the waste stream after second application of the proprietary reagent. Therefore, it is assumed that a two-stage chemical precipitation process will be utilized for the treatment of the contaminated groundwater at FEMP. Similar to other alternatives with groundwater treatment, the treatment system will be designed to handle an estimated maximum flow of 5500 gpm from the aquifer extraction system and will be able to remove uranium to an effluent concentration of less than 20 µg/L and other contaminants to below MCL levels or other established remediation goals.

As with the use of any other precipitation chemical, sludge will be generated by the proprietary chemical precipitation process during the coagulation, flocculation, and sedimentation steps in the treatment system. However, the proprietary chemical precipitation process generates less sludge as compared to other chemical precipitation processes. It has been estimated that five to ten times less

sludge will be generated using the proprietary reagent instead of ferric sulfate and lime, as conventionally used in chemical precipitation processes. The added benefit of generating lower volumes of sludge will be the reduction in the total amount of sludge material requiring disposal. The disposal will be conducted in accordance with all regulatory requirements as part of FEMP's ongoing waste management activities and could be incorporated into the disposal strategy for higher concentration wastes being removed from other operable units.

6.1.7 Alternative GW-7: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Reinjection Discharge

Similar to Alternative GW-6, this alternative includes extraction and treatment of groundwater from the Great Miami Aquifer and the perched groundwater zone. Instead of discharging to a surface water body, the treated water will be reinjected to the Great Miami Aquifer via injection well or wellpoint system with or without the intention of groundwater gradient control. Treatment process consist of air stripping and adsorption for removal of organic compounds and precipitation for removal of radionuclides. During implementation, this alternative will be supplemented by groundwater monitoring. Components of this alternative have been described in Alternatives GW-2 through GW-6.

The alternatives, including process options and technologies, as discussed above for the groundwater media are presented in a matrix form in Table 6-1.

As shown in Table 6-1, all alternatives provide for groundwater monitoring. The monitoring process option consists of the continued or additional monitoring of selected on- and off-property wells in the affected area.

6.2 SOIL AND SEDIMENT ALTERNATIVES

The eleven remedial alternatives developed for the initial screening process for the Operable Unit 5 remedial action for soils and sediments are as follows:

- Alternative SS-1: No Action
- Alternative SS-2: Institutional Actions, Excavation, Intermediate Storage
- Alternative SS-3: Institutional Actions, Excavation, Disposal (Option 1: On Site, Option 2: Off Site)
- Alternative SS-4: Institutional Actions, Excavation of Sediments, Multilayer Capping for Soil/Sediments
- Alternative SS-5: Institutional Actions, Excavation, Soil Washing, Intermediate Storage of Residuals

PROCESS OPTION	APPLICATION	ALTERNATIVES: NO ACTION	1: INSTITUTIONAL ACTIONS, CONTROL/CONTAINMENT, REMOVAL, ORG. TREATMENT, R.O., SW DISCHARGE OPTION 1: GREAT MIAMI RIVER, OPTION 2: PADDY'S RUN	2: INSTITUTIONAL ACTIONS, CONTROL/CONTAINMENT, REMOVAL, ORG. TREATMENT, I.E., SW DISCHARGE OPTION 1: GREAT MIAMI RIVER, OPTION 2: PADDY'S RUN	3: INSTITUTIONAL ACTIONS, CONTROL/CONTAINMENT, REMOVAL, ORG. TREATMENT, R.O., REINJECTION	4: INSTITUTIONAL ACTIONS, CONTROL/CONTAINMENT, REMOVAL, ORG. TREATMENT, I.E., REINJECTION	5: INSTITUTIONAL ACTIONS, CONTROL/CONTAINMENT, REMOVAL, ORG. TREATMENT, PRECIPITATION, SW DISCHARGE OPTION 1: GREAT MIAMI RIVER, OPTION 2: PADDY'S RUN	6: INSTITUTIONAL ACTIONS, CONTROL/CONTAINMENT, REMOVAL, ORG. TREATMENT, PRECIPITATION, REINJECTION
NONE (NO ACTION)	NCP REQUIREMENT	●						
DEED RESTRICTIONS	INSTITUTIONAL CONTROLS – ACCESS AND/OR LAND USE RESTRICTIONS		●	●	●	●	●	●
GROUNDWATER MONITORING	MONITORING PLUME MOVEMENT AND PROGRESS OF REMEDIATION		●	●	●	●	●	●
EXTRACTION/INJECTION WELL SYSTEM	EXTRACT AND INJECT UNCONTAMINATED WATER TO CONTROL PLUME MOVEMENT		●	●	●	●	●	●
WELLPOINTS AND EXTRACTION WELLS	REMOVE CONTAMINATED GROUNDWATER		●	●	●	●	●	●
AIR STRIPPING	REMOVE ORGANICS		●	●	●	●	●	●
ADSORPTION	REMOVE ORGANICS, INORGANICS, AND RADIONUCLIDES		●	●	●	●	●	●
REVERSE OSMOSIS	REMOVE METALS AND RADIONUCLIDES		●		●			
ION EXCHANGE	REMOVE METALS AND RADIONUCLIDES			●		●		
PRECIPITATION	REMOVE METALS AND RADIONUCLIDES						●	●
DISCHARGE TO SURFACE WATER	DISPOSE OF TREATED GROUNDWATER		●	●			●	
REINJECTION WELLS	DISPOSE OF TREATED GROUNDWATER WITH OR WITHOUT GRADIENT CONTROL				●	●		●

TABLE 6–1

GROUNDWATER
REMEDIAL ACTION ALTERNATIVES
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

- Alternative SS-6: Institutional Actions, Excavation, Soil Washing, Disposal of Residuals (Option 1: On Site, Option 2: Off Site)
- Alternative SS-7: Institutional Actions, Excavation, Batch Vitrification, Backfilling of Vitrified Residuals
- Alternative SS-8: Institutional Actions, Excavation, Batch Vitrification, Disposal (Option 1: On Site, Option 2: Off Site)
- Alternative SS-9: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Backfilling of Vitrified Residuals
- Alternative SS-10: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Disposal (Option 1: On Site, Option 2: Off Site)
- Alternative SS- 11: Institutional Actions, Pozzolanic-Based/Cement-Based Stabilization/Solidification

Except for the no-action response (Alternative SS-1), all alternatives incorporate institutional controls, physical barriers, and/or deed restrictions, to aid in the implementation of other remedial processes.

In addition, three process options, single layer capping, soil vacuum extraction, and soil aeration are carried through as support options that will be considered applicable for all soil/sediment alternatives. Single-layer capping will be considered for limited soil areas of non-mixed waste contamination and soil vacuum and soil aeration extraction will be considered for limited areas of organic contaminated soils (i.e., UST contaminated soils). These three process options will not be evaluated thoroughly until the detailed analysis of alternative stage of the FS.

6.2.1 Alternative SS-1: No Action

Under the no-action alternative, no additional remediation, monitoring, or security activities are provided to reduce risk to public health or the environment. Routine monitoring and security activities will continue at the FEMP in accordance with DOE operational requirements. The no-action alternative provides no remediation for soils and sediments and will result in no changes to the existing site environment.

6.2.2 Alternative SS-2: Institutional Actions, Excavation, Intermediate Storage

This alternative utilizes the excavation of sediments from contaminated portions of the FEMP SSOD and Paddys Run, the excavation of soil from the former production area and "hot spots" (i.e., locations of elevated contaminant concentrations above PRGs), and intermediate storage prior to disposal at an approved disposal facility or treatment.

Institutional Actions

The institutional actions implemented for this alternative are fencing and deed restrictions. Fencing will be used to restrict access to contaminated areas of soil and sediment during excavation. Deed restrictions will be used to restrict land use during implementation of the alternative.

Excavation

A total volume of approximately 366,000 cubic yards of soils and sediments is estimated to be removed for this alternative. This volume includes the overburden clean soils (approximately 45,000 cubic yards) that will have to be removed in order to reach contaminated areas. The excavation depth ranges between zero and 20 feet below the surface. The estimated excavation volume may change in the field since excavation would continue until acceptable target levels are reached. The locations of soil and sediment samples exceeding the preliminary remediation goals are provided in Figures 3-11 through 3-17 and Figure 3-19. The estimated volume of contaminated soils and sediments requiring storage/treatment is approximately 320,500 cubic yards.

For the sediment portion, the extent of contamination in the FEMP SSOD and Paddys Run is assumed to extend upstream and downstream from each sampling location that exceeded the target level to the next sample location. The sampling grid provided three sample locations across the width of the stream. Since, in each case, only one of the sample locations is above the criteria for uranium or radium, the effective width of the stream subject to removal is assumed to be 1/3 of the total width. A total volume of approximately 140 yd^3 of sediments is estimated to be removed as part of this alternative as described in Section 3.7.

Since these water courses are dry much of the year, standard construction equipment (backhoe, bulldozer, or front-end loader) can be used to remove the material if the work is timed to coincide with the dry season. As excavation progresses, the contaminated material will be loaded into covered dump trucks, transported, and stored on site. The material is expected to be dry (i.e., passes a paint filter test), and thus it can be loaded directly onto trucks for transport to the designated on-site storage facility. If necessary, a stabilizing agent such as concrete or kiln dust can be added to solidify the material sufficiently for transport and storage.

The excavation of soil is designed for two situations: (1) removal of soils from accessible areas (approximately 274,000 cubic yards); and (2) removal of soils from least accessible areas which include areas mainly covered with concrete and/or piping, or soils underneath a facility (approximately 92,000 cubic yards). Contaminated soils in accessible areas will be removed by heavy construction equipment that has been modified or altered for work in contaminated areas (i.e., appropriate equipment components such as shields, enclosures, etc., will be used).

For soils underneath a facility that is not to be removed, excavation will be performed in a fashion similar to mining operations or else excavation will occur through the floor of the facility. Before such an activity would commence, a thorough study of the existing building/structure would have to be made to ascertain the current situation. This structural analysis would yield information relative to locating grade beams and columns or other vertical supports such as soldier beams or shoring the above-grade structure to permit the removal of subgrade contaminated soils. This would be necessary to ensure that no extensive load displacements occur during the excavation. Whenever possible, buildings and other on-site facilities will be demolished and removed prior to excavation activities.

Soils in the contaminated zone will be excavated to the bottom of the contamination. Any zones of soil with contamination below remediation goals (based upon analysis) will be separated and used as backfill.

Intermediate Storage

After excavation, the soils may go through solids processing to facilitate packaging. Solids processing would consist of sorting, shredding, and/or compaction of the soils. The contaminated soils will then be loaded onto trucks for transportation to the designated on-site or off-site intermediate storage facility for temporary storage (10 years) prior to on-site disposal or off-site disposal at such regulated facilities as the Nevada Test Site (NTS), Envirocare, or Portsmouth or treatment. A period of 10 years was assumed to be sufficient time to evaluate additional permanent disposal or treatment options. Additional costs for treatment and/or permanent disposal in excess of this time frame can not be defined at the present time. The on-site disposal may be accomplished by either closing the storage pile or surface impoundment as a landfill in accordance with EPA and NRC requirements, or excavating the content in the intermediate storage facility and disposing at a newly constructed on-site disposal facility. The intermediate storage facility will be considered a long-term storage facility under RCRA and will have to comply with substantive RCRA permitting requirements.

Intermediate on-site storage assumes that the cost for constructing the intermediate facility will be borne by an operable unit other than OU 5. Operable Unit 5 would be required to pay a surcharge on a volume proportional basis for storing the contaminated material in the intermediate facility in order to help defray the cost of the intermediate facility.

6.2.3 Alternative SS-3: Institutional Actions, Excavation, Disposal (Option 1: On-Site, Option 2: Off-Site)

This alternative utilizes similar institutional actions and excavation and removal processes of the surface soils and sediments as those described in Alternative SS-2. The only difference between this alternative and Alternative SS-2 is that the excavated material will be transported and disposed of at an

on-site or approved off-site engineered disposal facility as described below. This alternative may also require intermediate storage prior to on-site or off-site disposal.

On-Site Disposal

The on-site disposal process option will utilize an engineered disposal facility that, depending on the characteristics of the materials to be disposed of, meets regulatory requirements in RCRA, NRC, or combination of these two sets of regulations. Conceptually, the disposal facility includes the following design features:

- Multilayered cap system - including vegetative soil layer, geotextile, high permeability drainage layer, intruder barrier (roller compacted concrete), low permeability clay layer, and common fill;
- Solidified waste forms;
- Multilayered liner system - including reinforced concrete mat (beneath the waste forms), high permeability drainage layers (2 layers in the liner system), low permeability clay layers (2 layers in the liner system), and geotextile; and
- Leachate collection and detection systems

The disposal facility is intended for permanent waste disposal purposes with a design life of 1,000 years. The structure is designed to withstand high-intensity earthquakes and severe weather conditions; e.g., tornado, snow, and rainwater intrusion. It can accept unsorted low-level radioactive or mixed waste in bulk and/or containerized forms. It is likely to be constructed in areas to the north and east of the production area.

Off-Site Disposal

The contaminated soils and sediments may be transported to a regulated disposal facility such as NTS, Envirocare, or Portsmouth for permanent disposal. As a condition of NTS disposal, no untreated wet, raw waste, or free liquids will be accepted. An additional NTS requirement is that the waste can be characterized as either mixed or low-level radioactive waste. If identified as mixed waste, it will only be accepted in a solidified form. Radioactive waste from the FEMP is currently shipped to NTS; however, depending on the level of uranium in the material and whether any organics are present, the soil could qualify for disposal at other low-level disposal facilities in closer proximity to the FEMP. Waste transport may be provided by truck or railroad and packaged in low specific activity (LSA) boxes. For the purpose of scoping and costing, railroad transportation was used due to its considerably lower cost than trucking. It is assumed, since NTS is DOE owned, the disposal surcharge would be minimal, therefore, NTS is the proposed off-site disposal location for costing purposes. If a commercial disposal facility, such as Envirocare is to be used, the disposal cost will be significantly higher.

This alternative assumes that no solidification of the contaminated soils is required. Since any solidification option would result in a volume and/or weight increase (and a concurrent increase in the transportation cost) it is presumed that solidification, if required, would occur at the off-site disposal facility and this cost would be added into the off-site disposal cost.

6.2.4 Alternative SS-4: Institutional Actions, Excavation of Sediments, Multilayer Capping for Soil/Sediments

This alternative proposes similar institutional actions as discussed in Alternative SS-2. A multilayer cap for control/containment of contaminated soils is utilized in this alternative to cover the contaminated areas. The multilayered cap consists of a combination of different types of low permeability covers, such as HDPE, concrete, asphalt, or clay. Additionally, sediments within the SSOD and Paddys Run would be excavated and placed underneath the capped areas.

Institutional Action

Fencing will be used to restrict access to contaminated areas of soil and sediments during and after implementation of the technology. Deed restrictions will be used to ensure the integrity of the cap by placing land restrictions on the areas capped.

Multilayer Cap

The areas of the streambeds to be excavated are the same as presented in Alternative SS-2. This work will be undertaken during the summer dry season in order to avoid diverting or dewatering the site. Excavating portions of surface water pathways will prevent contaminant migration into the underlying aquifer and transport of contaminated sediment by surface waters. This alternative will require ongoing maintenance and monitoring into the future.

The total soil areas requiring capping is derived from the dimensions established in Section 3.5. The total soil area requiring multilayer capping is estimated at approximately 275,100 square yards. Areas capped with multilayer caps will be covered with 6 inches of topsoil and revegetated. Where access is limited, capping may be performed in small sections or with some access modification. If buildings exist in areas that are to be capped, the cap will be made contiguous with the buildings or the buildings will be demolished.

6.2.5 Alternative SS-5: Institutional Actions, Excavation, Soil Washing, Intermediate Storage of Residuals

This alternative proposes similar institutional actions as those described in Alternative SS-2. This alternative proposes the excavation and removal of the soils and sediments as described in Alternative SS-2. For this alternative, however, the material will be temporarily stockpiled in a suitable area prior to being treated. The treatment option for this alternative is soil washing. The

nature of the site soils and stream sediments (i.e., sandy till) should make them amenable to the soil washing procedure. A treatability study is currently being conducted to determine its effectiveness. The treatment residuals will be temporarily stored. The soil washing process is presented below:

Soil Washing

The soil washing process will extract uranium, organic, and/or inorganic contaminants from the soil/sediment matrix using a liquid medium as the washing solution. Initially, the excavated soil is processed to remove large rocks and debris. This process is accomplished through a combination of particle separation by size and/or density. This process utilizes conventional equipment (e.g., hydrocyclones, hydrogravimetric separators, scalping screens, trommels, mineral jigs, and centrifuges) for scrubbing, size reduction, washing, and dewatering of soils. The soil is then processed in a rotating drum or vibrating screen device to sort and prewash the material. Large probably uncontaminated pieces of soil are washed with a leaching solution, rinsed with water, and returned to the site.

The remaining soil/sediment is placed in a countercurrent chemical extractor, where additional washing fluid is passed concurrent to the soil/sediment flow, removing the contaminants. The treated solids are then dewatered. Once the soil and sediments have been treated by soil washing, they can be safely backfilled on site. The remainder of the process is a multistep treatment for removal of contaminants from the washing fluid prior to its recycling.

Intermediate Storage of Residuals

The residual treatment sludges will have concentrated contaminants and will be temporarily stored at a designated on- or off-site storage facility for 10 years prior to final disposition of the residuals at an on-site or off-site disposal or treatment facility.

6.2.6 Alternative SS-6: Institutional Actions, Excavation, Soil Washing, Disposal of Residuals (Option 1: On-Site, Option 2: Off-Site)

This alternative proposes the same institutional actions, excavation processes, and soil washing treatment technology as discussed in Alternative SS-5. The only difference is that the residuals will be transported to a regulated on-site or off-site disposal facility for permanent disposal, with or without prior intermediate storage, as previously discussed in Alternative SS-3.

6.2.7 Alternative SS-7: Institutional Actions, Excavation, Batch Vitrification, Backfilling of Vitrified Residuals

This alternative proposes the same institutional actions and excavation and removal process of soils and sediments as described in Alternative SS-5. For this alternative, however, the treatment option is batch vitrification. The batch vitrification process is presented below.

Batch Vitrification

The destruction of the hazardous waste is achieved in a reaction chamber in which high temperature is used to reduce toxic organic compounds to elemental gas and carbon. Inorganic contaminants should remain entrained in the glass and siliceous melts. The advantage of vitrification over other thermal processes are the lack of oxidation products and large air emissions and the reduced leachability of inorganic materials, such as heavy metals.

The reaction chamber is divided into upper and lower sections, both of which are refractory lined and have separate electric (480 volt, 3 phase) heating systems. The upper section accepts the waste feed via gravity and contains gases and other products of pyrolysis: the lower section contains the two-layer molten zone for the melts of the metal and siliceous components of the waste.

For solid waste treatment, the feed, limited to 4 inches is gravity fed on a conveyor into the reactor. The wastes are destroyed at a nominal temperature of 3002 °F or 1650 °C (±104 °F or 40 °C). The off-gas and particulates are drawn off by an induction fan and treated through a cyclone, a baghouse, and an acid gas scrubber. Solid waste is withdrawn from the lower section of the chamber via separate molten glass and metal taps. Both particulate and gas streams can be recycled to the reactor.

After organic contaminants are destroyed by the process, the residual solids are fluxed into the molten glass. The residual solids (such as ash and heavy-metal oxides) and nontoxic solid components such as silica, alumina, and lime) are incorporated into the glass and become part of its matrix. The final product is generally reduced in volume by factors of from 2 to 100, depending on the soil characteristics and product-quality requirements. When cooled, the inorganic/metals and radionuclides remain fixed and immobilized in a glass matrix that does not dissolve in water, has high leach resistance, and exhibits strength properties better than those of concrete. The glass possesses hydration properties similar to those of obsidian, which hydrates at rates of less than 1 mm/10,000 yr. At these rates the life of the glass matrix can be expected to exceed 1 million years.

The degree to which the residual contaminants are retained in the molten glass during processing is dependent upon the type of molten-glass process, the processing conditions, and the chemical elements comprising the glass.

The residue streams from the vitrification unit are molten glass, molten metal, scrubber water, and off-gas. The concentrations of hazardous constituents in the residuals are such that further treatment is not required.

The resulting vitrified mass will be returned to the excavated area and backfilled with clean material. The area will then be regraded and revegetated. Long-term monitoring of the backfilled areas would be required.

6.2.8 Alternative SS-8: Institutional Actions, Excavation, Batch Vitrification, Disposal (Option 1: On-Site, Option 2: Off-Site)

This alternative proposes the same institutional actions, excavation and removal processes, and batch vitrification treatment technology, as discussed in Alternative SS-7. The only difference is that the vitrified mass will be directly transported to an on-site or off-site disposal facility as discussed in Alternative SS-3.

6.2.9 Alternative SS-9: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Backfilling of Vitrified Residuals

This alternative proposes the same institutional actions, excavation processes, and soil washing treatment technologies as discussed in Alternatives SS-5 and SS-6. It also incorporates the same batch vitrification and backfilling technologies discussed in Alternative SS-7. However, in this alternative the treatment residuals of the soil washing process are to be vitrified and backfilled, rather than the contaminated soil as described in Alternative SS-7.

6.2.10 Alternative SS-10: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Disposal (Option 1: On-Site, Option 2: Off-Site)

This alternative is similar to Alternative SS-9, with the exception that the vitrified soil washing residuals are to be disposed of in an on-site or off-site engineered disposal facility.

6.2.11 Alternative SS- 11: Institutional Actions, Pozzolanic-Based/Cement-Based Stabilization/Solidification

This alternative utilizes the same institutional actions as Alternative SS-2.

The cement/pozzolan-based solidification would involve the in-situ mixing of granular ion exchange resin (zeolites) and cement/pozzolan admixture (the binding agent) into the soil using specialized heavy equipment. The objective is to create a solidified block with relatively low permeability and reduced surface area across which the transfer of contaminants is significantly reduced. Long-term monitoring of the stabilized areas would be required.

The alternatives, including technologies and process options, as discussed above for the soil and sediment medium are presented in matrix form in Table 6-2.

PROCESS OPTION	APPLICATION	1. NO ACTION	2. INSTITUTIONAL ACTIONS, EXCAVATION, INTERMEDIATE STORAGE	3. INSTITUTIONAL ACTIONS, EXCAVATION, DISPOSAL (OPTIONS: 1. ON SITE, 2. OFF SITE)	4. INSTITUTIONAL ACTIONS, EXCAVATE SEDIMENTS, MULTILAYER CAPPING SOIL/SEDIMENTS	5. INSTITUTIONAL ACTIONS, EXCAVATION, SOIL WASHING, INTERMEDIATE STORAGE OF RESIDUALS	6. INSTITUTIONAL ACTIONS, EXCAVATION, DISPOSAL OF RESIDUALS (OPTIONS: 1. ON SITE, 2. OFF SITE)	7. INSTITUTIONAL ACTIONS, EXCAVATION, SOIL WASHING, VITRIFICATION, BACKFILLING TREATED RESIDUALS	8. INSTITUTIONAL ACTIONS, EXCAVATION, BATCH VITRIFICATION, DISPOSAL (OPTIONS: 1. ON SITE, 2. OFF SITE)	9. INSTITUTIONAL ACTIONS, EXCAVATION, SOIL WASHING, BATCH VITRIFICATION OF RESIDUALS, BACKFILLING OF VITRIFIED RESIDUALS	10. INSTITUTIONAL ACTIONS, EXCAVATION, BATCH VITRIFICATION, 2. OFF SITE)	11. INSTITUTIONAL ACTIONS, EXCAVATION, SOIL WASHING, BATCH VITRIFICATION OF RESIDUALS, DISPOSAL (OPTIONS: 1. ON SITE, 2. OFF SITE)	12. INSTITUTIONAL ACTIONS, POZZOLANIC-BASED/ CEMENT-BASED STABILIZATION
NONE (NO ACTION)	NCP REQUIREMENT	●										
INSTITUTIONAL ACTION	FENCING AND/OR DEED RESTRICTIONS		●	●	●	●	●	●	●	●	●	●
EXCAVATION	REMOVE CONTAMINATED SOIL/SEDIMENTS		●	●	●	●	●	●	●	●	●	
MULTILAYER CAP	CAP SOIL HOT SPOTS				●							
SOIL WASHING	"WASH" SOIL/SEDIMENTS TO REMOVE CONTAMINANTS					●	●			●	●	
BATCH VITRIFICATION	DESTRUCT ORGANICS AND GLASSIFY REMAINING CONTAMINATED MATERIAL							●	●	●	●	
POZZOLANIC-BASE/ CEMENT BASED STABILIZATION	STABILIZE AND SOLIDIFY CONTAMINANTS IN A STABLE MATRIX											●
INTERMEDIATE STORAGE	DESIGNATED STORAGE FACILITY		●			●						
DISPOSAL (ON SITE/OFF SITE)	ENGINEERED DISPOSAL FACILITY			●			●		●		●	
BACKFILLING	PLACEMENT OF TREATED RESIDUALS INTO EXCAVATED AREAS							●		●		

TABLE 6-2
SOIL/SEDIMENT
REMEDIAL ACTION ALTERNATIVES
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

7.0 INITIAL SCREENING OF ALTERNATIVES

This section presents an initial screening of the remedial action alternatives developed in Section 6.0. The assembled alternatives need to be refined and screened to reduce the number of alternatives that will be further analyzed in detail, while preserving a range. This screening aids in streamlining the feasibility process while ensuring that the most promising alternatives are being considered.

Information available at the time of this screening is used to identify and distinguish any differences among the various alternatives and to evaluate each alternative with respect to its effectiveness, implementability, and cost. Only the alternatives judged the best or most promising on the basis of these evaluation factors are retained for further consideration and analysis. Typically, those alternatives that are screened out will receive no further consideration unless additional information becomes available that indicates further evaluation is warranted.

The assembled remedial action alternatives are evaluated against the short- and long-term aspects of the criteria described in Section 7.1. The discussion of initial screening of groundwater and soil/sediment alternatives are presented in Sections 7.2 and 7.3, respectively.

7.1 ALTERNATIVE SCREENING METHODOLOGY

This section describes the process employed for screening the groundwater and soil/sediment remedial action alternatives. It also briefly describes each of the screening criteria and the various factors that were considered within each criterion.

7.1.1 Evaluation Process

The groundwater and soil/sediment remedial action alternatives are evaluated against three broad criteria: effectiveness, implementability, and cost. This evaluation should reduce the number of alternatives that will undergo a more thorough and extensive analysis; alternatives are evaluated more generally in this phase than they will be during the subsequent detailed analysis task. The detailed analysis will evaluate the retained alternatives against nine specific criteria and their corresponding factors. Per the methodology of OSWER Directive 9355.3-01 (EPA 1988a), "no-action," "containment," and "remove/treatment" alternative will be carried forward, to the extent practicable, for detailed analysis. The no-action alternative is retained as a baseline against which all other alternatives are compared.

7.1.2 Effectiveness

A key aspect of the screening evaluation is the effectiveness of an alternative in protecting human health and the environment. In addition to determining the effectiveness of the alternatives in meeting the remedial action objectives, each alternative will be evaluated for its effectiveness in achieving reductions in toxicity, mobility, and volume. The short- and long-term effectiveness are also

evaluated, with the short-term effectiveness referring to the active remediation (construction) period and the long-term effectiveness referring to the postremediation period.

The following factors were considered in evaluating the short-term protection of human health and the environment:

- Amount of contaminated soil disturbance/excavation
- Amount of contaminated material transported on site and off site
- Amount of time required to achieve target cleanup levels

The following factors were considered in evaluating the long-term protection of human health and the environment:

- Amount of risk remaining after remedial action implementation
- Likelihood of technologies meeting cleanup criteria
- Long-term management and maintenance requirements
- Long-term monitoring requirements
- Uncertainties associated with land disposal of untreated waste

ARARs provide the necessary criteria that must be satisfied in order for a remedial alternative to be eligible for selection. In turn, the selected remedial action must comply with all ARARs, unless use of a waiver is justified. ARARs will be discussed in detail for each alternative during the detailed feasibility study.

7.1.3 Implementability

Implementability is a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative. It provides a means of evaluating the ability of an alternative to be adapted to site-specific conditions.

The technical feasibility evaluation considered the following:

- Constructibility - The complexity and difficulty in construction of the remedial action alternative

- Reliability - The likelihood of technical or construction problems which could produce schedule delays

- Monitoring/Replacement - The amount of additional remedial action, monitoring, replacement, or maintenance required

The administrative feasibility evaluation considered the following:

- Permits and licensing approval for on- or off-site activities
- Availability of on-property/off-site treatment/storage/disposal (TSD) services
- Availability and development of technology and equipment required to implement the technology.
- Availability of or requirement of special equipment or expertise in the design, operation, or construction.

7.1.4 Cost

Cost evaluations were prepared for each alternative to allow a relative comparison between similar alternatives. For instance, treatment and nontreatment alternatives (containment and no action) are not compared with respect to costs, as they inherently do not provide similar degrees of remediation.

The costing was performed according to the guidelines set forth in the Remedial Action Costing Procedures Manual (EPA 1987b).

The cost evaluation was based on a variety of cost-estimating data such as vendor quotations, cost curves, generic unit costs, conventional cost-estimating guides, commercial remedial costs, and previous similar remediation costs as modified by site-specific information. The costs for groundwater and soil/sediment remediation are conceptual and order-of-magnitude estimates, and have been prepared based on preliminary conceptual engineering design for major construction components.

7.1.4.1 Capital Costs

Capital costs include direct capital costs for the equipment, labor, and materials necessary to install remediation measures. Indirect capital costs include engineering, predesign, laboratory, construction administration, and treatability studies. Engineering cost is assumed to be 10 percent of the direct capital costs and indirect capital costs, excluding construction administration. Construction administration is assumed to be 5 percent of the direct and indirect capital costs excluding nonconstruction costs, such as treatability studies. Twenty percent contingencies are also included.

7.1.4.2 Annual Operation and Maintenance (O&M) Cost

Annual costs are divided into two categories. Base operating costs include the costs of monitoring, reevaluation, and maintenance. By-product treatment and residual disposal are included in the annual (O&M) cost. Annual O&M costs for ongoing remedial operations are evaluated over a period of 30 years as per the EPA Remedial Action Costing Procedures Manual, although remediation may proceed beyond 30 years. Costs to reevaluate the remedial alternative are assigned every five years in the base operating cost. The 5-year cost is, however, apportioned equally over a 5-year period. The

costs of active treatment (e.g., ion exchange, soil washing, disposal, etc.) are shown as progressive annual operating costs. They are allocated to the year in which they occur. The base and progressive annual O&M costs, where applicable, are combined as annual O&M costs.

7.1.4.3 Present Worth

A present worth analysis was calculated using a 5 percent inflation factor and 10 percent present worth factor as per the guidelines set forth in the Remedial Action Costing EPA Procedures Manual. All present worth calculations are based on the year in which capital expenditures would be realized, recognizing that some alternatives may in fact require additional lead time.

7.2 GROUNDWATER ALTERNATIVES

7.2.1 Alternative GW-1: No Action

The no-action alternative provides the baseline against which other alternatives can be compared. It will result in leaving the contaminated groundwater in its current condition.

Screening Evaluation

Effectiveness

This alternative would not attain chemical-specific PRGs. It would not achieve any reduction in volume, toxicity, or mobility of the contaminants. Therefore, it is not protective to human health and the environment. Since this alternative does not involve contaminant, treatment, or removal, the site would have to be reviewed and the best demonstrated available technologies (BDAT) will be evaluated every five years per SARA requirements. It does not constitute a final remedy.

Implementability

The no-action alternative involves no technical implementation or requirements for equipment or services. Administrative feasibility; i.e., the ability to obtain approval from agencies, is low.

Cost

Costs associated with the no-action alternative are minimal and are incurred by maintaining the status quo (i.e., supporting ongoing monitoring activities, security, etc.). For the purposes of the ISA, the no-action alternative is used as the baseline and its costs will be assumed to be zero.

Summary

The no-action alternative will be retained for detailed analysis per NCP requirement. It serves primarily as the baseline against which the other alternatives can be compared.

7.2.2 Alternative GW-2: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, RO, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)

This alternative proposes institutional actions to reduce contact with the site contaminants. Pumping and reinjection of groundwater outside the contaminated plume would be performed to control the direction and rate of migration of contaminated groundwater.

Alternative GW-2 also provides for pump/treat/discharge of the contaminated perched and Great Miami Aquifer groundwater. Thirty gallons per minute (gpm) of groundwater will be extracted from the perched zones and 5500 gpm from the Great Miami Aquifer. Air stripping and adsorption would be used to treat the perched groundwater to remove organic contaminants. RO would be used to remove radionuclides and other inorganics in groundwater extracted from both the perched zones and the Great Miami Aquifer. Discharge of treated water would be via a pipeline currently under construction to the Great Miami River (Option 1) or via new pipeline to Paddys Run (Option 2).

Screening Evaluation

Effectiveness

Extraction/injection wells will be used for hydraulic containment, controlling the migration and redirecting the flow of the contaminated groundwater plume. The contaminated groundwater will be pumped and treated to meet PRG standards. There is no soil excavation or disturbance involved in this alternative. Treatment of the contaminated groundwater will be performed on site. If treatment or removal of the contaminated sources in the soil or sediment will be provided, the amount of time needed to cleanup the site groundwater will be reduced significantly. Therefore, in conjunction with treatment or removal of the contaminated soil or sediment, this alternative is considered able to offer short-term protection of human health and the environment.

The removal and treatment (air stripping, adsorption, RO) of contaminated groundwater will result in long-term protection of human health and the environment. Treatment technologies and process options will meet cleanup criteria for site groundwater. On-site treatment of the contaminated groundwater reduces the primary threat to groundwater users and achieves reduction of mobility, toxicity, and volume of contaminants. Actions taken under this alternative will not result in impacts to human health or the environment during implementation. No long-term management, maintenance, or monitoring is required in postremediation period, except for regular NPDES discharge monitoring.

Implementability

Treatment for organics by stripping and carbon adsorption and removal of metals and radionuclides using RO are proven technologies. RO systems have been successfully applied full scale for uranium removal. However, experience has demonstrated that a long start-up time may be required to bring the

system on line and meet its performance specifications. Regular monitoring and maintenance would also be required to prevent membrane fouling and ensure the maximum potential life expectancy is attained. In addition, a reject stream (typically 10 percent of the influent) will require subsequent treatment (i.e., chemical precipitation) and disposal of radionuclide waste sludge. Overall, this alternative is implementable, but concerns of technical feasibility exist.

The treated water from the treatment facility will be disposed of through a pipeline to the Great Miami River (Option 1) or via new pipeline to Paddys Run (Option 2). Agency acceptance to modify the existing NPDES permit or to apply a new NPDES permit for discharge of treated water is expected. Technologies and equipment are available to implement this alternative. However, specialized equipment and expertise are needed for design, operation, and maintenance of RO system.

Cost

Option 1: The capital cost estimate for this alternative is $50,645,000. The estimated annual O&M cost is $10,497,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although remediation may continue beyond 30 years. The present worth of the annual O&M costs, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $165,838,000. Total present worth of this alternative is estimated to be $216,483,000. These costs are presented in Tables C-1 and C-1B in Appendix C.

Option 2: The capital cost estimate for this alternative is $50,624,000. The estimated annual O&M cost is $10,497,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although remediation may continue beyond 30 years. The present worth of the annual O&M costs, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $165,838,000. Total present worth of this alternative is estimated to be $216,462,000. These costs are presented in Tables C-1a and C-1aB in Appendix C.

Summary

This alternative will result in reduction of radionuclide, metal, and organic contaminants in groundwater. Health risks would be greatly reduced and environmental impacts would be minimal. However, RO technology may be technically difficult to implement. It would also be more costly to construct and to operate and maintain than ion exchange. Since the ion exchange technology can provide an equivalent level of treatment, this alternative has been eliminated and will not be evaluated in the detailed analysis.

7.2.3 Alternative GW-3: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)

This alternative is similar to Alternative GW-2, except that ion exchange has been substituted for RO as the preferred technology to remove radionuclides and other inorganics from both the perched zone and the Great Miami Aquifer groundwater.

Screening Evaluation

Effectiveness

The effectiveness of ion exchange should be similar to that of RO (Alternative GW-2). This alternative's effectiveness evaluation is similar to Alternative GW-2.

Implementability

Pretreatment of the perched groundwater for organics contamination utilized in this alternative is similar to Alternative GW-2. However, ion exchange is substituted for RO to treat for uranium and metals. Ion exchange systems have been successfully used at other sites where uranium is a contaminant of concern. Start-up time is typically brief. Similar to GW-2, treatment facility will require specialized personnel and constant maintenance during implementation. A minimal reject stream (the spent regenerant solution contaminated with uranium and metals, typically one percent of the influent) will require subsequent treatment (by chemical precipitation) and disposal of a radioactive waste sludge.

Administrative implementability of this alternative is similar to that of Alternative GW-2. However, ion exchange will require less specialized equipment and expertise than RO.

Cost

Option 1: The capital cost estimate for this alternative is $28,096,000. The estimated annual O&M cost is $8,457,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although remediation may continue beyond 30 years. The present worth of the annual O&M costs, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $133,609,000. The total present worth of this alternative is estimated to be $161,704,000. These costs are presented in Tables C-2 and C-2B in Appendix C.

Option 2: The capital cost estimate for this alternative is $28,075,000. The estimated annual O&M cost is $8,457,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although remediation may continue beyond 30 years. The present worth of the annual O&M costs, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is

$133,609,018. The total present worth of this alternative is estimated to be $161,684,000. These costs are presented in Tables C-2a and C-2b in Appendix C.

Summary

This alternative will result in reduction of radionuclide, metal, and organics contaminants in groundwater. Health risks would be greatly reduced and environmental impacts would be minimal. The ion exchange technology may be somewhat easier to implement than RO. Also, it would be less costly to construct, operate, and maintain than the RO technology. Thus, this alternative has been retained for detailed analysis of alternatives.

7.2.4 Alternative GW-4: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, RO, Reinjection Discharge

This alternative is the same as Alternative GW-2, except that the treated water discharged from the treatment facility will be reinjected into the subsurface through reinjection wells, with or without the intention of groundwater gradient control.

Screening Evaluation

Effectiveness

This alternative will have the same effectiveness as Alternatives GW-2 and GW-3.

By placing the treated water into the subsurface rather than a surface water, there will be minimal effects on stream biota or other surface water uses. The reinjected treated water could also be used to control/contain the existing plume in conjunction with the proposed extraction/injection well system.

Implementability

Implementing this alternative will be very similar to Alternative GW-2. Concerns in technical and administrative implementability for RO exist. Regulatory requirements for reinjection wells will be more intense than those for surface water discharge.

Cost

The capital cost estimate for this alternative is $50,824,000. The estimated annual O&M cost is $10,537,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although remediation may continue beyond 30 years. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $166,470,000. Total present worth of this alternative is estimated to be $217,294,000. These costs are presented in Tables C-3 and C-3B in Appendix C.

Summary

This alternative will result in reduction of radionuclide, metals, and organic contaminants in groundwater. Health risks would be greatly reduced and environmental impacts would be minimal. However, the RO technology may be more difficult to implement. It also would be more costly to construct and would incur higher O&M costs than ion exchange. In addition, the discharge of treated water to reinjection wells will be slightly more costly and more difficult to implement than discharge to surface water bodies. For these reasons, this alternative has been eliminated from those to be evaluated in detail.

7.2.5 Alternative GW-5: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Reinjection Discharge

This alternative is the same as Alternative GW-3, except that treated water discharged from the treatment facility will be reinjected into the subsurface through reinjection wells, with or without the intention of groundwater gradient control.

Effectiveness

This alternative will have the same effectiveness as Alternatives GW-4. By placing the treated water into the subsurface rather than a surface stream, there will be minimal effects on stream biota or other surface water uses.

Implementability

Implementing this alternative will be very similar to Alternative GW-3. Regulatory requirements for reinjection wells will be more intense than those for surface water discharge.

Cost

The capital cost estimate for this alternative is $28,275,000. The estimated annual O&M cost is $8,497,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although remediation may continue beyond 30 years. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $165,996,000. The total present worth of this alternative is estimated to be $194,271,000. These costs are presented in Tables C-4 and C-4B in Appendix C.

Summary

This alternative will result in reduction of radionuclide, metal, and organic contaminants in groundwater. Health risks would be greatly reduced and environmental impacts would be minimal. Ion exchange technology will be less difficult to implement than RO, will be less costly to construct than the RO treatment system, and will be less costly to operate and maintain than the RO system. Discharge of treated water into injection wells will be slightly more costly and more difficult to implement than discharging the water to surface water bodies. This alternative has been retained due

to its overall lower cost compared to RO treatment and to preserve the reinjection option for detailed analysis.

7.2.6 Alternative GW-6: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)

This alternative is similar to Alternatives GW-2 or GW-3, except that precipitation has been substituted for ion exchange or RO as the preferred technology to remove radionuclides and other inorganics in the contaminated groundwater from both the perched groundwater zone and the Great Miami Aquifer.

Screening Evaluation

Effectiveness

The effectiveness of chemical precipitation with proprietary reagent in a two-stage treatment process for removal of radionuclides and other inorganics in similar groundwaters has been demonstrated by jar tests. The treatment technologies and process options in this alternative are expected to meet PRG for site groundwater. Treatability study of chemical precipitation with proprietary reagent(s) for the site groundwater should be performed to confirm its effectiveness and to obtain design information. The effectiveness of the treatment actions, technologies, and process options in this alternative are similar to other alternatives involving groundwater treatment.

Implementability

Pretreatment of the perched groundwater for organics contamination utilized in this alternative is same as that for Alternative GW-2. However, precipitation is substituted for RO as a primary technology to remove uranium and other inorganics in the contaminated groundwater. Chemical precipitation processes have been successfully used for similar wastewaters where uranium is a contaminant of concern. Sludge will be generated from the chemical precipitation process at an estimated rate of 2 tons per day. The sludge will be dewatered prior to final disposal as a radioactive waste. Start-up time for the treatment system, including chemical precipitation and sludge settlement, is typically brief. Treatment system does not require specialized personnel or constant maintenance during implementation.

The treated water from the treatment facility will be disposed of through pipelines to the Great Miami River or Paddys Run. Agency acceptance to modify the existing NPDES permit or apply a new NPDES permit for discharge of treated water is expected. Technologies and equipment are available to implement the discharge. Overall, this alternative is highly implementable.

Cost

Option 1: The capital cost estimate for this alternative is $20,955,500. The estimated annual O&M cost is $113,889,500, which includes the proprietary reagent cost (ADC 1991). Annual O&M costs are evaluated for a period of 30 years as per the EPA Remedial Action Costing Procedures Manual, although remediation may continue beyond 30 years. The present worth of the annual O&M costs, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $1,799,298,000. The total present worth of this alternative is estimated to be $1,820,253,000. These costs are presented in Tables C-5 and C-5B in Appendix C.

Option 2: The capital cost estimate for this alternative is $20,934,000. The estimated annual O&M cost is $113,889,500, which includes the proprietary reagent cost (ADC 1991). Annual O&M costs are evaluated for a period of 30 years as per the EPA Remedial Action Costing Procedures Manual, although remediation may continue beyond 30 years. The present worth of the annual O&M costs, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $1,799,298,121. The total present worth of this alternative is estimated to be $1,820,232,000. These costs are presented in Tables C-5a and C-5aB in Appendix C.

Summary

This alternative is expected to result in reduction of radionuclide, metal, and organics contaminants in groundwater to levels below PRG. Treatability study of chemical precipitation with proprietary reagent(s) for the site groundwater will need to be performed to confirm its effectiveness and to obtain design information. Health risks would be greatly reduced and environmental impacts would be minimal. Technical and administrative feasibility of this alternative is high. The precipitation technology is easier to implement than ion exchange and RO. Although the precipitation facility would be less costly to construct, O&M costs for the precipitation process would be more expensive than ion exchange and RO technologies. Nevertheless, due to its effectiveness and implementability, this alternative is retained for detailed analysis.

7.2.7 Alternative GW-7: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Reinjection Discharge

This alternative is similar to Alternative GW-6, except that the treated groundwater will be discharged to the subsurface through reinjection wells, with or without the intention of groundwater gradient control.

Screening Evaluation

Effectiveness

This alternative will have similar effectiveness as Alternative GW-6. Minor soil disturbance/ excavation will be needed for installation of reinjection wells.

By placing the treated water into the subsurface rather than a surface water, there will be minimal effects on stream biota or other surface water uses. The reinjected treated water could also be used to control/contain the existing plume in conjunction with the proposed extraction/injection well system. More long-term maintenance and monitoring for reinjection are required by this alternative than Alternative GW-6.

Implementability

Implementation of this alternative will be very similar to Alternative GW-6. Reinjection of treated groundwater will be slightly more complex and difficult than surface water discharge. Regulatory requirements for subsurface reinjection will be more intense than those for surface water discharge.

Cost

The capital cost estimate for this alternative is $21,134,000. The estimated annual O&M cost is $113,929,500, which includes the proprietary reagent cost (ADC 1991). Annual O&M costs are evaluated for a period of 30 years as per the EPA Remedial Action Costing Procedures Manual, although remediation may continue beyond 30 years. The present worth of the annual O&M costs, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $1,799,930,000. The total present worth of this alternative is estimated to be $1,821,064,000. These costs are presented in Tables C-6 and C-6B in Appendix C.

Summary

Similar to Alternative GW-6, this alternative is expected to result in reduction of radionuclide, metal, and organics contaminants in groundwater to levels below PRG. Treatability study of chemical precipitation with proprietary reagent(s) for the site groundwater will need to be performed to confirm its effectiveness and to obtain design information. Health risks would be greatly reduced and environmental impacts would be minimal. Technical and administrative feasibility of this alternative is high. The precipitation technology is easier to implement than ion exchange and RO. Although the precipitation facility would be less costly to construct, O&M costs for the precipitation would be more expensive than those for ion exchange and RO technologies. In addition, the discharge of treated groundwater by reinjection wells will be slightly more costly and more difficult to implement than discharge to surface water bodies. Nevertheless, due to its effectiveness and implementability, this alternative is retained for detailed analysis.

The initial screening of groundwater alternatives is summarized in Table 7-1.

TABLE 7-1

SUMMARY OF ALTERNATIVES SCREENING FOR GROUNDWATER

Alternative	Effectiveness	Implementability	Cost ($ Millions) Capital	Annual O&M[a]	Total Cost[b]	Detailed Evaluation
GW-1: No Action	1. Not protective to human health or the environment. 2. No reduction in volume, toxicity or mobility of contaminants. 3. Does not constitute a final remedy.	1. No implementation required. 2. Agency administrative approval is not expected.	0	0	0	Retained
GW-2: Institutional Actions, Extraction/ Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Reverse Osmosis, and Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)	1. Provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment. 3. Achieves reduction of toxicity, mobility, and volume.	1. Technically feasible, but concerns in constructability, reliability and maintenance exist. 2. Administratively feasible; specialized equipment and expertise needed for RO.	Option 1: 50.6 Option 2: 50.6	10.5 10.5	216.5 216.5	Eliminated
GW-3: Institutional Actions, Extraction/ Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, and Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)	1. Provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment. 3. Achieves reduction of toxicity, mobility, and volume.	1. Technically feasible; less concerns than RO system. 2. Administratively feasible; need less specialized equipment and personnel than RO.	Option 1: 28.1 Option 2: 28.1	8.5 8.5	161.7 161.7	Retained

See footnotes at end of table.

TABLE 7-1
(Continued)

Alternative	Effectiveness	Implementability	Cost ($ Millions) Capital	Annual O&M[a]	Total Cost[b]	Detailed Evaluation
GW-4: Institutional Actions, Extraction/ Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Reverse Osmosis, and Reinjection Discharge	1. Provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment. 3. Achieves reduction of toxicity, mobility, and volume. 4. Minimal impact on stream biota or water use.	1. Technically feasible, but concerns in constructability, reliability and maintenance exist. 2. Administratively feasible; specialized equipment and expertise needed for RO. 3. More regulatory requirements for subsurface discharge than surface discharge.	50.8	10.5	217.3	Eliminated
GW-5: Institutional Actions, Extraction/ Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, and Reinjection Discharge	1. Provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment. 3. Achieves reduction of toxicity, mobility, and volume. 4. Minimal impact on stream biota or water use.	1. Technically feasible; less concerns than RO system. 2. Administratively feasible; less specialized equipment and personnel needed than RO. 3. More regulatory requirements for subsurface discharge than surface discharge.	28.3	8.5	194.3	Retained

See footnotes at end of table.

TABLE 7-1
(Continued)

Alternative	Effectiveness	Implementability	Cost ($ Millions) Capital	Annual O&M[a]	Total Cost[b]	Detailed Evaluation
GW-6: Institutional Actions, Extraction/ Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, and Surface Water Discharge (Option 1: Great Miami River, Option 2: Paddys Run)	1. Provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment. 3. Achieves reduction of toxicity, mobility, and volume. 4. Treatability study needed to confirm effectiveness.	1. Technically feasible; highly constructible and reliable, no complex monitoring or maintenance. 2. Administratively feasible; conventional equipment needed, system start-up easily, do not require specialized personnel.	Option 1: 21.0 Option 2: 20.9	113.9 113.9	1820.0 1820.0	Retained
GW-7: Institutional Actions, Extraction/ Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, and Reinjection Discharge	1. Provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment. 3. Achieves reduction of toxicity, mobility, and volume. 4. Minimal impact on stream biota or water use.	1. Technically feasible; highly constructible and reliable, no complex monitoring or maintenance. 2. Administratively feasible; conventional equipment needed, system start-up easily, do not require specialized personnel. 3. More regulatory requirements for subsurface discharge than surface discharge.	21.1	113.9	1821.1	Retained

[a]O&M - operation and maintenance cost.

[b]Present worth.

7.3 SOIL AND SEDIMENT ALTERNATIVES

7.3.1 Alternative SS-1: No Action

The no-action alternative provides the baseline against which other alternatives can be compared. It will result in leaving the contaminated soil and sediment in place.

Screening Evaluation

Effectiveness

This alternative would not attain chemical-specific ARARs because contaminant concentrations in both soils and sediments presently exceed PRGs. This alternative would also not achieve any reduction in volume, toxicity, or mobility of the contaminants. Since this response does not address the threat of off-site contaminant migration, contaminants would continue to leach into the groundwater and migrate off site. This alternative is not effective in protecting short- or long-term human health and the environment. Also, because this alternative does not entail contaminant removal, the site will have to be reviewed and the BDAT will be evaluated every five years per SARA requirements. It does not constitute a final remedy.

Implementability

The no-action alternative involves no technical implementation or requirements for services or equipment. The no-action alternative is unlikely to receive agency approvals.

Cost

There are no costs associated with this alternative.

Summary

The no-action alternative will be retained for detailed analysis per NCP requirements. It serves primarily as the baseline against which the other alternatives can be compared.

7.3.2 Alternative SS-2: Institutional Actions, Excavation, Intermediate Storage

This alternative proposes the use of institutional actions to restrict access and land use during implementation; the excavation of approximately 365,600 cubic yards, over a period of 3 years, of contaminated soils and sediments for intermediate storage for 10 years after excavation operations are completed; and before permanent on-site or off-site disposal or treatment is decided upon.

Screening Evaluation

Effectiveness

Short-term effectiveness is achieved by ensuring proper safety procedures and protective gear will be used in excavating materials to limit exposure to workers. Precautions will be taken to minimize the potential exposure for the community and release to the environment during excavation and handling of the contaminated soil. Upon completion of the excavation activities, residual soil and sediment concentration levels will be below the remediation goals. Confirmatory sampling and analysis of the soil and sediment will be required to ensure that the volume of contaminated material has satisfactorily been removed. Monitoring and management of the storage facility is required. Since this alternative is interim in nature, long-term protection of human health and the environment is not applicable. Mobility, toxicity, and volume of contaminants in the environmental media are confined in the storage facility.

Implementability

This alternative would require excavation of the contaminated sediments and soils. Access to some of these soils is difficult and may cause construction hazards. If dewatering of excavation volumes is large, it may complicate implementation. The alternative also requires the design and construction of an on- or off-site storage facility to prevent contact and leaching of material. Although techniques required for construction of this facility are widely practiced, various complexities may be associated with siting, staging, and operation of the facility. Based on proper design procedures and adequate monitoring, the engineered storage facility should provide a highly reliable system. Agency approval is required. Constant maintenance and monitoring is required for this facility. The specialized equipment and personnel that are required for the construction (i.e., synthetic liners and skilled labor) should be readily available in the marketplace.

Cost

The capital cost estimate for this alternative is $76,909,500. It is estimated that the storage facility will require maintenance and monitoring for 10 years after construction and/or installation. The status of the intermediate storage will be reevaluated during the tenth year. The estimated annual O&M cost is $180,000 for ten years' maintenance and monitoring of storage. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $2,604,000. The total present worth of this alternative is estimated to be $79,514,000. These costs are presented in Tables C-7 and C-7B in Appendix C.

Summary

Alternative SS-2 does not provide final disposition of the contaminated materials. It would allow the flexibility to explore future treatment/disposal options that may be available at a later date. This alternative was retained as a fall-back option if other "permanent" treatment/disposal alternatives cannot be implemented due to difficulties in identifying facilities that will accept FEMP waste materials or because adequate treatment technologies are not readily available. The cost of a permanent disposal option is not included in SS-2, because the premise of SS-2 is that no satisfactory permanent solution is presently available. A period of 10 years was assumed to be sufficient time to evaluate additional permanent disposal or treatment options. Additional costs for treatment and/or permanent disposal will be incurred for year 11 and beyond, but these costs cannot be defined at the present time. If the time frame is different from 10 years (either more or less), governing agencies will be notified and updates will be made in cost estimates and all related areas.

Although it has difficulties in implementability, this alternative has rated high in effectiveness due to its short-term protectiveness of human health and the environment by excavating the contaminated materials. Its short-term protectiveness of human health and the environment is considered higher than those alternatives with soil treatment processes. However, this alternative will need to incorporate measures of final disposition for the contaminated materials in the intermediate storage facility. The storage facility may be either closed as a landfill per EPA and NRC requirements, or excavated and the contents disposed of at a permanent facility elsewhere. The cost of this alternative is moderate as compared to other alternatives. This alternative is retained for detailed analysis due to its high effectiveness and moderate cost, provided that the final disposition of the contents in the intermediate storage facility is not included.

7.3.3 Alternative SS-3: Institutional Actions, Excavation, Disposal (Option 1: On Site, Option 2: Off Site)

This alternative proposes the same institutional actions and excavation and removal process of the soils and sediments as those described in Alternative SS-2. The only difference between this alternative and Alternative SS-2 is that the excavated, untreated material will be transported and disposed of at an approved on-site or off-site facility.

Screening Evaluation

Effectiveness

This alternative's effectiveness is similar to Alternative SS-2, except that the excavated materials will be disposed of in an on-site or off-site disposal facility. Precautions would be required to minimize exposure to the community during hauling of the contaminated material. Truck traffic and risks in transportation are a concern. This alternative provides less short-term protectiveness but complete

long-term protectiveness of human health and the environment than Alternative SS-2, due to the final disposal of contaminated materials. This alternative constitutes a final remedy.

Implementability

It is estimated that excavation/disposal operations will occur for a period of 3 years. The excavation of soils from difficult access areas will create construction hazards. The constructibility and reliability of the operations, and maintenance of the disposal facility are not a problem. This assumes proper management of the permitted disposal facility. Local/government agency administrative acceptance may present a problem, particularly as they relate to transport of waste off site to a disposal site and acceptance by the host state. Additionally, there are a limited number of disposal sites permitted for acceptance of this material and these sites require specialized equipment and personnel.

Cost

Option 1: On-Site Disposal - The capital cost estimate for this alternative is $103,447,000. The estimated annual O&M cost is $220,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although monitoring and maintenance may continue beyond 30 years. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $3,476,000. The total present worth of this alternative is estimated to be $106,923,000. These costs are presented in Tables C-8 and C-8B in Appendix C.

Option 2: Off-Site Disposal - The capital cost estimate for this alternative is $200,374,000, assuming disposal at the NTS facility. If disposed of at a commercial facility (e.g., Envirocare), the total capital cost is estimated to be $328,638,000. The estimated annual O&M cost is zero, since it is estimated that this alternative will not last beyond excavation and disposal. Therefore, the total present worth of this alternative is estimated to be $200,374,000, if disposed of at the NTS facility; or $328,638,000, if disposed of at a commercial facility. These costs are presented in Tables C-9 and C-9B in Appendix C.

Summary

Similar to Alternative SS-2, this alternative is considered high in effectiveness and moderate in implementability. Potential problems related to implementability include local/government agency administrative acceptance for on-site or off-site disposal and the availability of a disposal facility. The cost of this alternative is high due to the packaging, transportation, and disposal fees. Nonetheless, this alternative is retained for further analysis due to its effectiveness and implementability.

7.3.4 Alternative SS-4: Institutional Actions, Excavation of Sediments, Multilayer Capping for Soils/Sediments

This alternative proposes similar institutional actions as discussed in Alternative SS-2, in addition to a multilayer cap for control/containment of contaminated soils and the excavation of sediments from the

SSOD and Paddys Run which would be placed underneath the multilayer cap. The contaminated areas (approximately 275,100 ft^2) of soils will be covered by a multilayer cap which consists of a combination of different types of low permeability covers, such as HDPE, concrete, asphalt, or clay. Topsoil will be placed over the entire area and vegetation will be restored when weather permits. Approximately 2,400 cubic yards of sediments would be excavated and placed under the cap.

Screening Evaluation

Effectiveness

Prevention of direct contact of contaminated sediments during excavation may be achieved by careful design and construction for the short-term protection of human health and the environment. The cap would prevent infiltration by precipitation, which would prevent the transfer of contaminants from the soils/sediments to the groundwater and subsequent off-site migration. This alternative does not reduce toxicity, mobility, and volume of the contaminants through treatment, but does contain and reduce the mobility of the contaminants in the soil/sediment, thereby reducing risks associated with the soil/sediment exposure pathways. Contaminated sediments would be removed from the surface water pathways. Long-term monitoring of downgradient off-site monitoring wells may be necessary to confirm the level of effectiveness of the cap and to assess the risk to human health and the environment. Long-term management and maintenance/repair of the cap is required to ensure its effectiveness. This alternative would not meet chemical-specific ARARs, resulting in no reduction in toxicity or volume of contaminated soils/sediments. This alternative would also limit the future use of the site. Long-term effectiveness is not fully provided due to the risks associated with the remaining toxicity and volume of contaminants in the environment.

Implementability

The implementation of this alternative is not expected to present any constructibility or reliability concerns. The cap system described above would be relatively simple to install. Several vendors would be available to install the HDPE liner and concrete, asphalt, or clay layer. It will be necessary to implement and exercise a long-term monitoring and maintenance/repair program to evaluate the integrity of the cap. The construction of the cap and excavation of sediments would utilize standard earthwork equipment and practices, and health and safety measures would be implemented to minimize potential contaminant exposure risks. Institutional administration would be required to receive the approval for the cap. It is estimated that this alternative will require two years to implement.

Cost

The capital cost estimate for this alternative is $19,014,000. The estimated annual O&M cost is approximately $240,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although monitoring and maintenance may continue beyond 30 years. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation

rate of 5 percent, is $3,792,000. The total present worth of this alternative is estimated to be $22,806,000. These costs are presented in Tables C-10 and C-10B in Appendix C.

Summary

This alternative is retained for further evaluation as a prime control/containment alternative, due to the short- and long-term effectiveness and technical and administrative implementability. Costs for implementing this alternative will be low as compared to alternatives that required treatment and/or disposal.

7.3.5 Alternative SS-5: Institutional Actions, Excavation, Soil Washing, Intermediate Storage of Residuals

This alternative proposes similar institutional actions as those described in Alternative SS-2. This alternative proposes the excavation and removal of the soils and sediments as described in Alternatives SS-2 and SS-3. For this alternative, however, the material will be stockpiled and temporarily stored in a designated storage facility before being treated or disposed of at an on- or off-site facility. The treatment option for this alternative is soil washing. The nature of the site soils and stream sediments (i.e., sandy till) should make them amenable to the soil-washing procedure. A treatability study would have to be conducted to confirm its effectiveness before implementation.

Screening Evaluation

Effectiveness

Amount of contaminated soil that needs to be excavated and treated is more than those alternatives utilizing the capping technology, but the same as the other alternatives requiring excavation and treatment. The potential for exposure to human and environmental media by this alternative in the short term (implementation period) is greater than other alternatives utilizing excavation and disposal, because of longer contact time by the soil washing process. From the perspective of the contaminated matrix materials (i.e., soils and sediments) soil washing achieves reduction in volume, mobility, and toxicity since the contaminants have been removed from the matrix, resulting in a clean matrix. A residual is generated (contaminated sludge, wash solution) that will require treatment and/or disposal which is anticipated in this alternative. Intermediate storage of the residuals will provide temporary storage and flexibility to this alternative. There are, however, uncertainties in the amount of time required to achieve ultimate cleanup. The short-term protection of human health and the environment during implementation will not be fully achieved due to the time and exposure risks associated with intermediate storage.

Since intermediate storage does not provide ultimate disposition of the treatment residuals, a certain amount of risk will remain after implementation of this alternative. The treatment technology, soil washing, is expected to meet cleanup criteria set forth in the PRGs. Long-term management and

monitoring of this alternative are needed. Disposal of the treatment residuals is uncertain. Therefore, long-term effectiveness of this alternative is not as good as other alternatives utilizing final disposal or treatment.

Implementability

This alternative will require the construction of a treatment unit and the establishment of a secure on- or off-site storage area for residuals. Assuming amenability of the material, treatment and storage operations should be fully constructible and reliable. Monitoring and maintenance of the treatment unit and storage facility are required. Agency approval for the treatment and storage option is expected. Equipment and expertise for this type of treatment system and storage facility are available. Both the technical and administrative implementability are promising for this alternative. It is estimated that this alternative would require 5 years to implement.

Cost

The capital cost estimate for this alternative is $130,569,100. The estimated annual O&M cost is $170,000 for the 10 years the storage facility is in operation. During year 10, the status of the intermediate storage of residuals will be reevaluated. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $1,328,000. Therefore, the total cost of this alternative is estimated to be $131,897,100. These costs are presented in Tables C-11 and C-11B in Appendix C.

Summary

If the effectiveness of a soil-washing process is confirmed through a treatability study and/or field demonstration, this alternative would provide long-term protectiveness of human health and the environment. Short-term protectiveness of human health and the environment may be improved by exercising necessary measures to reduce time and exposure risks by intermediate storage. Technical and administrative implementability of this alternative in terms of constructibility, availability of technology and TSD services, and agency acceptance are considered high. Costs associated with this alternative are considered in the range of low to medium as compared to other excavation and/or treatment alternatives. However, the amount of residuals remaining from the process is so minimal that a disposal facility can be readily located that would accept this small amount of material, and intermediate storage would not be cost-effective or necessary. Therefore, this alternative is eliminated from detailed analysis.

7.3.6 Alternative SS-6: Institutional Actions, Excavation, Soil Washing, Disposal of Residuals (Option 1: On Site, Option 2: Off Site)

This alternative proposes the same institutional actions, excavation process, and soil-washing treatment technology as discussed in Alternative SS-5. The difference is that the treatment residuals will be directly transported to an on-site or off-site disposal facility for permanent disposal as previously discussed in Alternative SS-3.

Screening Evaluation

Effectiveness

This alternative is similar to Alternative SS-5, except that the treatment residuals will be disposed of in an on-site or off-site disposal facility. It will require no further treatment of the residuals. Concerns related to intermediate storage have been eliminated. Therefore, this alternative provides short-term and long-term protection of human health and the environment.

Implementability

The construction requirements are similar to Alternative SS-5, except that this alternative requires on-site or off-site disposal of the treatment residuals. This alternative does not have technical difficulties in terms of constructibility, reliability, or monitoring/replacement. The removal and disposal of the residuals may be limited by the rate at which the material can be accepted at the disposal facility. Implementability of this alternative is high. It is estimated that this alternative will require 5 years to implement.

Cost

Option 1: On-Site Disposal - The capital cost estimate for this alternative is $133,227,000. The estimated annual O&M cost is $170,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although monitoring and maintenance may continue beyond 30 years. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $2,686,000. The total present worth of this alternative is $135,913,000. These costs are presented in Tables C-12 and C-12B in Appendix C.

Option 2: Off-Site Disposal - The capital cost estimate for this alternative is $164,939,500, if the residuals are to be disposed of at the NTS facility. The total capital cost will be $177,786,000, if the residuals are disposed of at a commercial facility. The estimated annual O&M cost is zero. The total present worth of this alternative is $164,939,500 for NTS disposal or $177,786,000 for commercial disposal. These costs are presented in Tables C-13 and C-13B in Appendix C.

Summary

This alternative can provide more favorable effectiveness and implementability than those for Alternative SS-5. Off-site disposal of the treatment residuals may raise concerns of long-term protectiveness due to uncertainties and risks of on-site or off-site disposal of concentrated waste without treatment. Costs for this alternative may be higher than those for Alternative SS-5 due to disposal. However, due to its effectiveness and implementability, this alternative is retained for detailed analysis.

7.3.7 Alternative SS-7: Institutional Actions, Excavation, Batch Vitrification, Backfilling of Vitrified Residuals

This alternative proposes similar institutional actions and the same excavation and removal processes of soils and sediments as described in Alternative SS-6. For this alternative, however, the treatment technology is batch vitrification.

Screening Evaluation

Effectiveness

The long- and short-term protectiveness of this alternative is considered lower than the alternatives utilizing soil washing because the inorganic/heavy metals and radionuclides are contained within the glass matrix and returned to the environment during backfilling operations. The long-term protectiveness of this alternative is considered higher than the alternative incorporating cement-based/pozzolan-based stabilization/solidification because of the greater long-term stability of the glass matrix. Short-term protectiveness is considered to be lower because of the disturbances to the environment and potential exposure to workers and residents during the implementation of this alternative. Effective dust control measures and air monitoring would be required during the implementation of this alternative to reduce airborne spreading of contaminants. Since this alternative incorporates on-site backfilling, no bulk transport of contaminants off site would be involved.

There is some question regarding the degree of risk remaining after this remedial action is implemented since the radionuclides and inorganics/metals contaminants are not removed from the environment and are not treated to reduce/eliminate contaminant toxicity.

Only radionuclide and inorganic/metals contaminant mobility is reduced/eliminated by physically incorporating the contaminants in a glass matrix. Long-term management, maintenance and monitoring would be required. This alternative's long-term effectiveness in protecting human health and the environment is moderate to high because of the long-term environmental stability of the glass matrix and it's resistance to leaching of the incorporated contaminants. It is assumed that the vitrified product will be able to be deposited back into the excavation.

Implementability

The technical and administrative feasibility of this alternative is considered lower than other alternatives, especially the alternative utilizing soil washing as a soil treatment process. The reactor for the batch vitrification process is complex in design and construction. The reliability of this alternative is considered favorable as compared with other alternatives. Technology, equipment, and expertise in the design, operation, or construction related to the batch vitrification is available. Long-term monitoring of the backfilled vitrified areas is required. This alternative is considered more favorable than those that require additional disposal options. It is estimated that 4 to 5 years would be required to implement this alternative.

Cost

The capital cost estimate for this alternative is $191,993,300. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although remediation may continue beyond 30 years. The estimated annual O&M cost is $130,000. The present worth of the annual O&M cost based on a present worth factor of 10 percent and an annual inflation rate of 5 percent is $2,054,000. The total present worth of this alternative is $194,047,100. These costs are presented in Tables C-14 and C-14B in Appendix C.

Summary

This alternative will achieve short-term effectiveness, although it may be varied in degree with other alternatives. Long-term effectiveness is not fully achieved due to the risks associated with the contaminants retained in the vitrified mass. Technical and administrative implementability poses no major problem but may not be as favorable as other alternatives using treatment process options that are easier to implement. Cost of this alternative may not be favorable than other alternatives using different process options for treatment or disposal. Due to its favorable rating for effectiveness and low disposal costs, this alternative is retained for detailed analysis.

7.3.8 Alternative SS-8: Institutional Actions, Excavation, Batch Vitrification, Disposal (Option 1: On Site, Option 2: Off Site)

This alternative proposes the same institutional actions, excavation, and removal processes and treatment technology as Alternative SS-7. The only difference is that the resulting vitrified mass is to be disposed of at an on-site or off-site disposal facility.

Screening Evaluation

Effectiveness

Similar to Alternative SS-7, this alternative has been considered high in long- and short-term protectiveness of human health and the environment. Long-term maintenance and monitoring

requirements are reduced. The vitrified mass will be disposed of at an on-site or off-site disposal facility upon completion of the vitrification process. Acceptance at the disposal facility is expected.

Implementability

The technical and administrative feasibility of this alternative is considered the same as Alternative SS-7. Permits or approvals for on-site or off-site disposal of the vitrified mass are expected. The availability of a disposal facility at the time of implementation is a concern.

Cost

Option 1: On-Site Disposal - The capital cost estimate for this alternative is $245,864,200. The estimated annual O&M cost is $170,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although monitoring and maintenance may continue beyond 30 years. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $2,686,000. The total present worth of this alternative is $248,550,000. These costs are presented in Tables C-15 and C-15B in Appendix C.

Option 2: Off-Site Disposal - The capital cost estimate for this alternative is $339,383,700, if the vitrified mass is disposed of at the NTS facility. The total capital cost will be $416,324,100, if the disposal facility is a commercial facility. The estimated annual O&M cost is zero. The total present worth of this alternative is $339,383,700 for NTS disposal or $416,342,100 for commercial disposal. These costs are presented in Tables C-16 and C-16B in Appendix C.

Summary

Similar to Alternative SS-7, this alternative has more difficulty and complexity in implementation although it is rated high in effectiveness as compared to other alternatives. The vitrified soil/waste mass will be disposed of at an on-site or off-site disposal facility at the time of implementing this alternative. The availability of disposal sites which would accept the vitrified residual and the quantities will need to be determined. Costs for disposal are considered higher than the cost associated with Alternative SS-7. However, this alternative is retained for detailed analysis due to its favorable rating for effectiveness.

7.3.9 Alternative SS-9: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Backfilling of Vitrified Residuals

This alternative proposes the same institutional actions, excavation, processes, and soil washing treatment technology as described in Alternatives SS-5 and SS-6. It also incorporates the same batch vitrification and backfilling technologies discussed in Alternative SS-7; however, in this alternative, the soil washing residuals, rather than the contaminated soils, are to be vitrified and backfilled.

Screening Evaluation

Effectiveness

Similar to Alternatives SS-5, SS-6, and SS-7 this alternative provides short-term and partial long-term protection of human health and the environment, provided the soil washing residual matrix is amenable to the vitrification process. If the contaminated residuals of the soil washing treatment technology results in a liquid or gelatinous form, the vitrification process may not be feasible. Treatability and pilot testing would have to be completed in order to determine the effectiveness of this alternative. If the residual matrix is in a solid form, the vitrification process would be effective in reducing the mobility of the radionuclide and inorganic/metals contaminants. Long-term management, maintenance, and monitoring would be required.

Implementability

The technical and administrative feasibility of this alternative is considered favorable. The reactor for the batch vitrification process is complex in design and construction. The reliability of this alternative is dependent on the outcome of treatability testing. Technology, equipment, and expertise in the design, operation, and construction related to both the soil washing and batch vitrification units are available. Long-term monitoring of the backfilled vitrified areas is required. It is estimated that four to five years would be required to implement this alternative.

Cost

The capital cost estimate for this alternative is $145,691,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although remediation may continue beyond 30 years. The estimated annual O&M cost is $180,000. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation of 5 percent, is $2,844,000. The total present worth of this alternative is $148,534,000. These costs are presented in Table C-17 and C-17B in Appendix C.

Summary

This alternative will achieve short-term effectiveness. Long-term effectiveness is not fully achieved due to the risks associated with the contaminants retained in the vitrified mass. The technical and administrative feasibility of this alternative is considered favorable, although the reliability of this alternative is fully dependent on the results of treatability pilot testing. The cost for this alternative is comparable to other alternatives. This alternative is retained for detailed analysis on the basis of its effectiveness, implementability and cost.

7.3.10 Alternative SS-10: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Disposal (Option 1: On Site, Option 2: Off Site)

This alternative is similar to Alternative SS-9, with the exception that the vitrified soil washing residuals are to be disposed of at an on-site or off-site engineered disposal facility.

Screening Evaluation

Effectiveness

Similar to Alternative SS-9, this alternative is considered high in short-term protectiveness of human health and the environment, dependent on the outcome of treatability testing. It is considered higher in long-term protectiveness of human health and the environment since the vitrified residuals are to be disposed of at an on- or off-site engineered disposal facility. Long-term maintenance and monitoring requirements are reduced.

Implementability

The technical and administrative feasibility of this alternative is considered similar to Alternative SS-9. Permits or approvals for on-site or off-site disposal of the vitrified mass are expected. The availability of a disposal facility at the time of implementation may not be as much of a concern as in Alternative SS-8, due to the minimal quantity of vitrified material to be disposed.

Cost

Option 1: On-Site Disposal - The capital cost for this alternative is $147,502,000. The estimated annual O&M cost is $220,000. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $3,476,000. The total present worth of this alternative is $150,977,400. These costs are presented in Table C-18 and C-18B in Appendix C.

Option 2: Off-Site Disposal - The capital cost estimate for this alternative is $201,019,000, if disposal facility is the NTS. The total capital cost will be $208,742,940 if the vitrified material is disposed of at a commercial facility. The estimated O&M cost is zero. The total present worth of this alternative is $201,019,000 for disposal at NTS facility or $208,742,940 for disposal at a commercial facility. These costs are presented in Tables C-19 and C-19B in Appendix C.

Summary

Similar to Alternative SS-9, this alternative is rated high in short-term effectiveness as compared to other alternatives. The vitrified soil washing residuals will be disposed of at an on-site or off-site disposal facility at the time of implementing this alternative, ensuring long-term protection of human health and the environment. The technical and administrative feasibility of this alternative is considered favorable, although the reliability of this alternative, similar to Alternative SS-9, is fully

dependent on the results of treatability pilot testing. The cost for this alternative is slightly higher than that for Alternative SS-9. Based on its effectiveness and implementability, this alternative is retained for detailed analysis.

7.3.11 Alternative SS-11: Institutional Actions; Pozzolanic-Based/Cement-Based Solidification/Stabilization

This alternative proposes similar institutional actions as Alternative SS-4 and in situ pozzolanic-based/cement-based solidification/stabilization as the treatment technology.

Screening

Effectiveness

In situ pozzolanic-based/cement-based solidification/stabilization has been a well-established treatment process for radiologically contaminated materials. Amounts of contaminated materials that need to be excavated and transported are the same as other alternatives requiring soil treatment. Long- and short-term protectiveness of this alternative is considered lower than the alternatives utilizing soil washing and vitrification. The long-term effectiveness and stability of the matrix is questionable due to the effects of weathering; therefore, long-term maintenance and monitoring would be required.

This alternative would result in a significant disturbance of the contaminated soils and sediments. Effective dust control measures and air monitoring would be required during the implementation of this alternative to reduce the airborne spreading of contaminants.

Since this alternative incorporates an on-site remedial option, no bulk transport of contaminants off site would be involved. It is estimated that 1 to 1½ years would be required to implement this alternative.

This option achieves short-term effectiveness in protecting human health and the environment. There is some question regarding the amount of risk remaining after this remedial action is implemented, since the contaminants are not removed or isolated from the environment and are not treated to reduce/eliminate contaminant toxicity and volume. Only contaminant mobility is reduced/eliminated by chemically and/or physically fixating the contaminants in a cement/pozzolan matrix. Long-term management, maintenance, and monitoring would be necessary. Therefore, this alternative is considered lower than other alternatives in its long-term effectiveness in protecting human health and the environment.

Implementability

The equipment required for this treatment includes standard cement mixing and handling equipment which is widely available. The techniques of cement mixing and handling are well-developed and the process is reasonably tolerant of variations in the waste stream and/or soil matrix. However,

modifications to the process include the use of more expensive cement types, and costly additives or coatings. In situ immobilization may require the use of special subsurface fixative injection equipment.

The key operation parameters include:

- Fixative-to-waste ratio
- Length of time for setting and curing (usually one to two weeks)
- Required structural integrity and minimized potential for leaching of the pollutants from the resultant solidified waste mass

Implementation of this alternative's procedures is quite mobile. Heavy equipment such as backhoes, specialized hydraulic augers, cement mixers, and dump trucks are used for specific excavation, mixing, and hauling needs. Many companies have developed specialized equipment such as injectors and augers that simultaneously inject cement and mix the matrix.

Portland cement is widely used because of its ready availability. Pozzolanic materials such as flyash are also readily available, but the regulations on land disposal of hazardous bulk liquids prohibit the use of materials such as flyash that do not fully immobilize the waste. The use of pozzolan-based/cement-based stabilization/solidification should be made only after it has been tested on sample material and the chemical and physical properties of the solidified waste have been extensively tested to ensure that contaminant immobilization is adequate. Vendors of pozzolan-based/cement-based stabilization/solidification will usually conduct pilot tests on sample material to ensure their process performs adequately.

Cost

The capital cost estimate for this alternative is $86,250,000. The estimated annual O&M cost is $200,000. Annual O&M costs are evaluated for a period of 30 years as per the guidance manuals, although monitoring and maintenance may continue beyond 30 years. The present worth of the annual O&M cost, based on a present worth factor of 10 percent and an annual inflation rate of 5 percent, is $3,160,000. The total present worth of this alternative is $89,409,700. These costs are presented in Tables C-20 and C-20B in Appendix C.

Summary

This alternative's long-term effectiveness in protecting human health and the environment is much lower as compared to batch vitrification, even though its implementability is higher. Due to its questionable long-term effectiveness, this alternative is eliminated and will not be retained for detailed analysis.

The initial screening of soil/sediment alternatives is summarized in Table 7-2.

7.4 ALTERNATIVES RETAINED FOR DETAILED ANALYSIS

In selecting the alternatives for consideration during detailed analysis of the media-specific alternatives, the evaluations in the above sections were considered. In addition, consideration was given to preserving a range of treatment and containment alternatives, where practical.

Of the seven groundwater alternatives evaluated, five, including the no-action alternative, were retained for future detailed analysis. The two alternatives not retained were Alternative GW-2 and Alternative GW-4:

- Alternative GW-2: Institutional Actions, Extraction/Injection Well, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, RO, Surface Water Discharge

- Alternative GW-4: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, RO, Reinjection Discharge

These two alternatives were eliminated due to concerns in implementability, and amount of residuals requiring disposal as compared to the other treatment alternatives using ion exchange or precipitation.

The alternatives retained for consideration for detailed analysis are:

- Alternative GW-1: No Action

- Alternative GW-3: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Surface Water Discharge

- Alternative GW-5: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Reinjection Discharge

- Alternative GW-6: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Surface Water Discharge

- Alternative GW-7: Institutional Actions, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Reinjection Discharge

Alternatives GW-3 and GW-5 were retained based on their abilities to achieve remedial action objectives, implementability, as well as their lower costs to implement. Alternatives GW-6 and GW-7 were retained for detailed analysis due to their promising effectiveness and implementability.

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TABLE 7-2
SUMMARY OF ALTERNATIVES SCREENING FOR SOIL AND SEDIMENT

Alternative	Effectiveness	Implementability	Cost ($ Millions)			Detailed Evaluation
			Capital	Annual O&M[a]	Total Cost[b]	
SS-1: No Action	1. Not protective to human health or the environment. 2. No reduction in volume, toxicity or mobility of contaminants. 3. Does not constitute a final remedy.	1. Easy to implement. 2. Agency administrative approval is not expected.	0	0	0	Retained
SS-2: Institutional Actions, Excavation, Intermediate Storage	1. Partially provides short-term protection of human health and the environment. 2. Long-term protection of human health and the environment is not applicable. 3. Mobility, toxicity, and volume of contaminants are confined.	1. Technically feasible; excavation and construction hazards exist. 2. Administratively feasible; design and construction of the storage facility is needed, special equipment required is readily available.	76.9	0.2 (10 yr)	79.5	Retained

See footnotes at end of table.

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TABLE 7-2
(Continued)

Alternative	Effectiveness	Implementability	Cost ($ Millions) Capital	Annual O&M[a]	Total Cost[b]	Detailed Evaluation
SS-3: Institutional Actions, Excavation, Disposal (Option 1: On-site, Option 2: Off-site)	1. Partially provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment. 3. Mobility, toxicity, and volume of contaminants are confined. 4. Constitutes a final remedy.	1. Technically feasible; excavation, transportation, and/or construction hazards exist. 2. Administratively feasible; equipment required is available, rate of removal limited by acceptance at the disposal facility.	Option 1: 103.4 Option 2: 200.4	0.2 0	106.9 200.4	Retained
SS-4: Institutional Actions, Excavation of Sediments, Multilayer Capping for Soils/Sediments	1. Partially provides short-term protection of human health and the environment. 2. Partially provides long-term protection of human health and the environment. 3. Reduces mobility of contaminants, but not toxicity or volume.	1. Technically feasible; provides constructability and reliability, long-term management and maintenance required. 2. Administratively feasible; standard equipment and trained personnel are readily available; approval for the cap system is expected.	19.0	0.2	22.8	Retained
SS-5: Institutional Actions, Excavation, Soil Washing, Intermediate Storage of Residuals	1. Partially provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment, but not as good as other alternatives. 3. Achieves reduction of toxicity, mobility, and volume by soil washing.	1. Technically feasible; treatability testing is needed to confirm soil washing technology. 2. Administratively feasible; treatment unit and storage facility are available.	130.6	0.2 (10 yr)	131.9	Eliminated

See footnotes at end of table.

TABLE 7-2
(Continued)

Alternative	Effectiveness	Implementability	Cost ($ Millions)			Detailed Evaluation
			Capital	Annual O&M[a]	Total Cost[b]	
SS-6: Institutional Actions, Excavation, Soil Washing, Disposal of Residuals (Option 1: On-Site, Option 2: Off-site)	1. Provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment. 3. Residuals will be disposed of permanently.	1. Technically feasible; provides constructability and reliability. 2. Administratively feasible; removal and treatment of residuals may be limiting factor.	Option 1: 133.2 Option 2: 164.9	0.2 0	135.9 164.9	Retained
SS-7: Institutional Actions, Excavation, Batch Vitrification, Backfilling of Vitrified Residuals	1. Provides short-term protection of human health and the environment. 2. Partially provides long-term protection of human health and the environment; risks of re-releasing contaminants exist, long-term monitoring required. 3. Achieves confinement of the radionuclear contaminants.	1. Technically feasible; concerns of constructability and monitoring exist. 2. Administratively feasible; specialized equipment and expertise needed.	192.0	0.1	194.0	Retained

See footnotes at end of table.

TABLE 7-2
(Continued)

Alternative	Effectiveness	Implementability	Cost ($ Millions)			Detailed Evaluation
			Capital	Annual O&M[a]	Total Cost[b]	
SS-8: Institutional Actions, Excavation, Batch Vitrification, Disposal (Option 1: On Site, Option 2: Off Site)	1. Provides short-term protection of human health and the environment. 2. Provides long-term protection of human health and the environment; long-term monitoring is reduced. 3. Achieves confinement of radionuclear contaminants.	1. Technically feasible; concern of construction exists. 2. Administratively feasible; specialized equipment and expertise needed. 3. Disposal facility availability is a concern.	Option 1: 245.9 Option 2: 339.4	0.2 0	248.5 339.4	Retained
SS-9: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Backfilling of Vitrified Residuals	1. Provides short-term protection of human health and the environment; treatability testing is required. 2. Partially provides long-term protection of human health and the environment; risks of re-releasing contaminants exist, long-term monitoring required. 3. Achieves reduction of mobility by confinement of the radionuclear contaminants and reduces volume.	1. Technically feasible; concerns of constructibility and monitoring exist. 2. Administratively feasible; specialized equipment and expertise needed.	145.7	0.2	148.5	

See footnotes at end of table.

TABLE 7-2
(Continued)

Alternative	Effectiveness	Implementability	Cost ($ Millions) Capital	Annual O&M[a]	Total Cost[b]	Detailed Evaluation
SS-10: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Disposal (Option 1: On Site, Option 2: Off Site)	1. Provides short-term protection of human health and the environment; treatability testing is required. 2. Provides long-term protection of human health and the environment; long-term monitoring is reduced. 3. Achieves reduction of toxicity, mobility, and volume.	1. Technically feasible; concerns of constructibility exist. 2. Administratively feasible; specialized equipment and expertise needed.	Option 1: 147.5 Option 2: 201.0	0.2 0	151.0 201.0	
SS-11: Institutional Actions, Pozzolanic-Based/Cement-Based Stabilization/ Solidification	1. Provides short-term protection of human health and the environment. 2. Long-term protection of human health and the environment is questionable. 3. Reduces mobility, but not toxicity or volume of contaminants.	1. Technically feasible; provides constructability and reliability, monitoring required. 2. Administratively feasible; specialized equipment and expertise are available.	86.2	0.2	89.4	Eliminated

[a]O&M - operation and maintenance cost.

[b]Present worth.

Of the 11 alternatives evaluated for soils/sediments, 9 were retained for development into the detailed screening of alternatives document based on comparative evaluation between alternatives.

The two alternatives not retained are:

- Alternative SS-5: Excavation, Soil Washing, Intermediate Storage of Residuals

- Alternative SS-11: Institutional Actions, Pozzolanic-Based/Cement-Based Stabilization

These alternatives were not retained due to their unfavorable comparisons of effectiveness.

The alternatives retained for detailed analysis are:

- Alternative SS-1: No Action

- Alternative SS-2: Institutional Actions, Excavation, Intermediate Storage

- Alternative SS-3: Institutional Actions, Excavation, Disposal (Option 1: On Site, Option 2: Off Site)

- Alternative SS-4: Institutional Actions, Excavation of Sediments, Multilayer Capping of Soils/Sediments

- Alternative SS-6: Excavation, Soil Washing, Disposal of Residuals (Option 1: On Site, Option 2: Off Site)

- Alternative SS-7: Institutional Actions, Excavation, Batch Vitrification, Backfilling of Vitrified Residuals

- Alternative SS-8: Institutional Actions, Excavation, Batch Vitrification, Disposal (Option 1: On Site, Option 2: Off Site)

- Alternative SS-9: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Backfilling of Vitrified Residuals

- Alternative SS-10: Institutional Actions, Excavation, Soil Washing, Batch Vitrification of Residuals, Disposal (Option 1: On Site, Option 2: Off Site)

These alternatives were retained based on their ability to achieve the desired remedial action objectives, as well as their greater degree of implementability as compared to the two alternatives not retained.

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APPENDIX A

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TABLE A-1

RADIOLOGICAL AND NONRADIOLOGICAL CONSTITUENTS IN BACKGROUND PERCHED GROUNDWATER ONGOING RI/FS AND RCRA SAMPLING

Constituent	Frequency of Detection	Range of Detection	Mean[a]
Radionuclides (pCi/L):			
RA-228	1/19	5.200 - 5.200	1.713
TH-228	3/27	1.040 - 1.600	0.597
TH-230	2/27	2.000 - 34.800	0.620
TH-TOTAL[b]	1/13	3.0 - 3.0	2.0
U-234	11/27	1.060 - 6.200	0.854
U-238	5/27	1.070 - 3.100	0.725
U-TOTAL[b]	19/27	0.8 - 11.0	2.0
Nonradiological (mg/L):			
Aluminum	4/4	0.121 - 0.337	0.180
Arsenic	1/20	0.003 - 0.003	0.036
Barium	20/23	0.034 - 0.112	0.074
Beryllium	3/4	0.001 - 0.002	0.001
Cadmium	4/20	0.003 - 0.007	0.003
Calcium	23/23	74.400 - 130.00	98.904
Chromium	10/23	0.020 - 0.120	0.021
Cobalt	1/4	0.013 - 0.013	0.007
Copper	7/23	0.013 - 0.190	0.010
Iron	17/23	0.005 - 4.900	0.443
Lead	7/23	0.002 - 0.006	0.005
Magnesium	23/23	20.400 - 47.800	35.674
Manganese	17/20	0.003 - 0.220	0.051
Mercury	3/20	0.000 - 0.004	0.000

See footnotes at end of table.

TABLE A-1
(Continued)

Constituent	Frequency of Detection	Range of Detection	Mean[a]
Molybdenum	1/19	0.020 - 0.020	0.013
Nickel	7/23	0.013 - 0.180	0.022
Potassium	18/20	0.891 - 31.500	6.824
Silver	6/23	0.011 - 0.052	0.005
Sodium	20/20	5.710 - 84.000	23.090
Vanadium	4/4	0.018 - 0.033	0.023
Zinc	4/4	0.032 - 0.042	0.039
Amonia	7/19	0.100 - 0.580	0.088
Chloride	21/23	1.400 - 35.700	8.809
Fluoride	23/23	0.200 - 1.350	0.713
Nitrate	14/23	0.037 - 0.300	0.128
Phosphorus (black, white, red)	13/19	0.026 - 0.640	0.107
Sulfate	21/22	3.240 - 239.00	72.897
Total Kjeldahl Nitrogen	8/9	0.150 - 0.700	0.323
Total Organic Carbon	2/4	3.266 - 4.690	2.239
Total Organic Halides	2/13	0.008 - 0.067	0.021
Total Organic Nitrogen	11/19	0.100 - 0.400	0.148
Acetone	3/3	0.002 - 0.029	0.011
Carbon disulfide	1/1	0.004 - 0.004	-[c]
Methylene chloride	2/3	0.010 - 0.010	0.008
N-Nitrosodiphenylamine	1/1	0.002 - 0.002	-[c]
Phenol	1/1	0.002 - 0.002	-[c]
Phenols	11/19	0.005 - 0.040	0.016

See footnotes at end of table.

TABLE A-1
(Continued)

[a]If the distribution is normal or if the distribution is log-normal, the number of detects ≥ 7, and frequency of detection $\geq 50\%$, an arithmetic mean is given. If the distribution is log-normal and either the number of detects < 7 or the frequency of detection is $< 50\%$, a geometric mean is given.

[b]Units are reported in µg/L.

[c]Not applicable when sample size is less than 2.

Note: Background groundwater data are based on the information reported in the Site-Wide Characterization Report (DOE 1992a). Revised and validated background groundwater data are projected for use in later stage Operable Unit 5 Reports.

TABLE A-2
WELLS WITH ELEVATED CONCENTRATIONS OF[a] TOTAL URANIUM, URANIUM ISOTOPES, AND TOTAL THORIUM FROM ONGOING RI/FS AND RCRA SAMPLING

Constituent (UTL)[b]	Wells with Elevated Concentrations[c]	Average Concentration Range (pCi/L)[d]
	Waste Storage Area	
Uranium-234 (2.89 pCi/L)	1011, 1019, 1021, 1022, 1025, 1027, 1028, 1030, 1031, 1032, 1033, 1038, 1042, 1073, 1075, 1076, 1077, 1080, 1081, 1082, 1083, 1084, 1643, 1644	2.9 - 964
Uranium-235/236 (Detection Limit)[e]	1019, 1021, 1022, 1027, 1032, 1073, 1075, 1076, 1078, 1082, 1083, 1084, 1643, 1644	0.68 - 120
Uranium-238 (2.05 pCi/L)	1008, 1011, 1019, 1021, 1022, 1025, 1027, 1028, 1030, 1031, 1032, 1033, 1034, 1038, 1042, 1073, 1074, 1075, 1076, 1077, 1078, 1080, 1081, 1082, 1083, 1084, 1643, 1644	2.11 - 4447
Total Uranium (6.0 µg/L[f])	1008, 1011, 1019, 1021, 1022, 1025, 1027, 1028, 1031, 1032, 1033, 1034, 1035, 1042, 1073, 1075, 1076, 1077, 1078, 1081, 1082, 1083, 1084, 1644	7.0 - 11,500[g]
Total Thorium (3.0 µg/L)	1008, 1010, 1021, 1022, 1025, 1039, 1074, 1081, 1084	4.0 - 34[g]
	Production Area	
Uranium-234 (2.89 pCi/L)	1053, 1054, 1055, 1064, 1086, 1087, 1088, 1089, 1090, 1148, 1149, 1161, 1195, 1196, 1197, 1199, 1208, 1209, 1211, 1212, 1213, 1214, 1218, 1219, 1220, 1224, 1227, 1228, 1231, 1232, 1233, 1234, 1236, 1324, 1411, 1676	4.83 - 50553
Uranium-235/236 (Detection Limit)[e]	1053, 1054, 1086, 1089, 1148, 1149, 1161, 1195, 1196, 1197, 1199, 1208, 1209, 1211, 1212, 1213, 1214, 1218, 1219, 1220, 1224, 1227, 1228, 1231, 1232, 1233, 1234, 1236, 1324, 1411	0.65 - 7494
Uranium-238 (2.05 pCi/L)	1041, 1053, 1054, 1055, 1064, 1086, 1087, 1088, 1089, 1090, 1148, 1149, 1161, 1195, 1196, 1197, 1199, 1208, 1209, 1211, 1212, 1213, 1214, 1218, 1219, 1220, 1224, 1227, 1228, 1231, 1232, 1233, 1234, 1236, 1324, 1411, 1676	2.15 - 59924

See footnotes at end of table.

TABLE A-2
(Continued)

Constituent (UTL)[b]	Wells with Elevated Concentrations[c]	Average Concentration Range (pCi/L)[d]
	Production Area (cont.)	
Total Uranium (6.0 µg/L[f])	1041, 1053, 1054, 1055, 1064, 1086, 1087, 1088, 1089, 1090, 1110, 1111, 1112, 1113, 1117, 1130, 1131, 1134, 1135, 1136, 1145, 1148, 1149, 1151, 1152, 1153, 1154, 1155, 1156, 1157, 1158, 1160, 1161, 1167, 1171, 1172, 1173, 1174, 1177, 1178, 1179, 1180, 1181, 1182, 1183, 1185, 1186, 1187, 1188, 1189, 1190, 1193, 1194, 1195, 1196, 1197, 1199, 1200, 1201, 1202, 1203, 1204, 1205, 1206, 1207, 1208, 1209, 1210, 1211, 1212, 1213, 1214, 1215, 1216, 1217, 1218, 1219, 1220, 1221, 1223, 1224, 1225, 1226, 1227, 1228, 1229, 1230, 1231, 1232, 1233, 1234, 1236, 1237, 1239, 1240, 1241, 1242, 1243, 1244, 1245, 1246, 1250, 1253, 1255, 1258, 1259, 1262, 1263, 1266, 1267, 1268, 1269, 1270, 1271, 1272, 1273, 1274, 1276, 1277, 1279, 1280, 1281, 1283, 1287, 1291, 1293, 1299, 1301, 1304, 1317, 1324, 1332, 1336, 1337, 1338, 1339, 1340, 1341, 1342, 1343, 1344, 1346, 1347, 1348, 1350, 1351, 1352, 1353, 1354, 1356, 1357, 1358, 1359, 1360, 1361, 1362, 1363, 1403, 1411, 1412, 1418, 1420, 1423, 1676	7.0 - 568,000[g]
Total Thorium (3.0 µg/L)	1053, 1054, 1055, 1148, 1149, 1153, 1157, 1161, 1197, 1199, 1208, 1209, 1212, 1213, 1220, 1231, 1232, 1234, 1324, 1411	5.0 - 370[g]
	Sewage Treatment Plant	
Uranium-234 (2.89 pCi/L)	1442, 1443, 1444, 1447, 1448	5.28 - 207
Uranium-235/236 (Detection Limit)[e]	1442, 1443, 1447, 1448	0.706 - 14.5
Uranium-238 (2.05 pCi/L)	1442, 1443, 1444, 1447, 1448	4.28 - 219
Total Uranium (6.0 µg/L[f])	1441, 1442, 1443, 1444, 1447, 1448	13.0 - 3,230[g]
Total Thorium (3.0 µg/L)	1443, 1447	11.0 - 21.0[g]

See footnotes at end of table.

TABLE A-2
(Continued)

Constituent (UTL)[b]	Wells with Elevated Concentrations[c]	Average Concentration Range (pCi/L)[d]
	Fire Training Area	
Uranium-234 (2.89 pCi/L)	1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515	2.94 - 47.1
Uranium-235/236 (Detection Limit)[e]	1508, 1509, 1510, 1511	1.2 - 3.7
Uranium-238 (2.05 pCi/L)	1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515	2.71 - 45.3
Total Uranium (6.0 µg/L[f])	1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515	14.0 - 117[g]
Total Thorium (3.0 µg/L)	1508, 1509, 1510, 1512, 1513	4.0 - 26[g]
	Other Areas	
Uranium-234 (2.89 pCi/L)	1020, 1046, 1047, 1048, 1124	3.05 - 14.5
Uranium-235/236 (Detection Limit)[e]	1020, 1046	0.7 - 1.3
Uranium-238 (2.05 pCi/L)	1020, 1045, 1046, 1047, 1048, 1124	2.15 - 20.6
Total Uranium (6.0 µg/L[f])	1020, 1045, 1046, 1047, 1048, 1124, 1516, 1517, 1518, 1523	8.0 - 490[g]
Total Thorium (3.0 µg/L)	1047, 1048, 1517	4 - 6[g]

[a]Based on data available in the Fernald Database as of December 1, 1991.
[b](UTL) = upper tolerance limit.
[c]Wells listed contain concentrations of the constituent that are above the UTL.
[d](pCi/L) = picoCuries per liter.
[e]Uranium-235/236 was not detected in any background sample.
[f](µg/L) = micrograms per liter.
[g]The unit is in µg/L.

TABLE A-3
DETECTIONS OF RADIOLOGICAL CONSTITUENTS IN PERCHED GROUNDWATER[a] FROM ONGOING RI/FS AND RCRA SAMPLING

Constituent	Concentration Range (pCi/L)[b]	Wells with Repeated Detections	Wells with Detection in the Only Sample[c]
		Waste Storage Area	
Radium-226	1.1 - 7.3	1031, 1073, 1075	1644
Radium-228	1.88	NA[d]	1644
Strontium-90	15.9	NA	1643
Technetium-99	30 - 2805	1025, 1073, 1075, 1083	NA
Thorium-228	1.1 - 4.0	1022, 1035, 1073, 1076, 1081, 1082, 1084	NA
Thorium-230	1.3 - 23.3	1021, 1022, 1035, 1073, 1074, 1075, 1076, 1077, 1082, 1084	1644
Thorium-232	1.1 - 23.1	1021, 1022, 1073, 1084	NA
		Production Area	
Radium-226	1.0 - 7.3	1053, 1212, 1213	1086, 1199, 1209, 1211, 1219, 1220, 1221, 1227, 1234, 1236, 1411
Radium-228	0.9 - 219.0	1149, 1161	1148, 1209, 1221, 1411
Strontium-90	5.4 - 6.8	NA	1221, 1411
Technetium-99	51 - 13230	1148, 1149, 1212, 1231, 1232, 1233, 1324, 1442	1195, 1196, 1197, 1199, 1208, 1209, 1211, 1214, 1219, 1220, 1221, 1227, 1228, 1234, 1236
Thorium-228	1.0 - 49.7	1041, 1055, 1149, 1232	1088, 1089, 1197, 1199, 1208, 1209, 1211, 1227, 1324, 1411
Thorium-230	1.0 - 16.6	1041, 1148, 1149, 1232	1089, 1196, 1197, 1199, 1208, 1209, 1224, 1234, 1324, 1411
Thorium-232	1.0 - 40.8	1053, 1055, 1149, 1232	1089, 1199, 1208, 1209, 1220, 1324, 1411

See footnotes at end of table.

TABLE A-3
(Continued)

Constituent	Concentration Range (pCi/L)[b]	Wells with Repeated Detections	Wells with Detection in the Only Sample[c]
		Sewage Treatment Plant	
Radium-226	1.17 - 1.19	NA	1441, 1448
Technetium-99	385 - 3185	NA	1441, 1444, 1447
Thorium-228	1.8 - 4.2	1447	NA
Thorium-230	3.3 - 10.5	1447	NA
Thorium-232	1.3 - 3.3	1447	NA
		Fire Training Area	
Radium-226	3.4 - 5.9	NA	1508, 1510
Thorium-228	1.3 - 3.4	NA	1508, 1513
Thorium-230	1.2 - 3.4	NA	1508, 1509, 1510, 1514
Thorium-232	1.3 - 2.8	NA	1508, 1510
		Other Areas	
Radium-226	1.6 - 1.9	1020	NA
Thorium-228	1.1 - 1.8	1020, 1046	NA
Thorium-230	1.1 - 7.8	1020, 1046	NA

[a]Excluding total thorium, uranium isotopes, and total uranium.
[b](pCi/L) = picoCuries per liter.
[c]Only one sample was collected from these wells for the analysis of the specific constituent.
[d]NA = Not applicable.

TABLE A-4

UPPER TOLERANCE LIMITS OF METALS DETECTED IN BACKGROUND PERCHED GROUNDWATER SAMPLES ONGOING RI/FS AND RCRA SAMPLING

Metal	Upper Tolerance Limit (mg/L)
Aluminum	0.720 mg/L
Arsenic	0.003 mg/L
Barium	0.132 mg/L
Beryllium	0.004 mg/L
Cadmium	0.009 mg/L
Calcium	128.017 mg/L
Chromium	0.076 mg/L
Cobalt	0.013 mg/L
Copper	0.046 mg/L
Iron	1.81 mg/L
Lead	0.054 mg/L
Magnesium	56.792 mg/L
Manganese	0.202 mg/L
Mercury	0.001 mg/L
Molybdenum	0.020 mg/L
Nickel	0.103 mg/L
Potassium	25.931 mg/L
Silver	0.050 mg/L
Sodium	59.615 mg/L
Vanadium	0.058 mg/L
Zinc	0.064 mg/L

NOTE: Background groundwater data are based on the information reported in the Site-Wide Characterization Report (DOE 1992a). Revised and validated background groundwater data are projected for use in later state Operable Unit 5 Reports.

TABLE A-5
1000 SERIES WELLS WITH ELEVATED METAL CONCENTRATIONS[a] FROM ONGOING RI/FS AND RCRA SAMPLING

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Waste Storage Area	
Aluminum	1081, 1083	0.74 - 1.18
Antimony[d]	1021	0.002
Arsenic[e]	1008, 1010, 1011, 1019, 1024, 1035, 1078, 1080	0.007 - 0.113
Barium	1008, 1011, 1019, 1021, 1029, 1031, 1039, 1042, 1073, 1075, 1078, 1081, 1083	0.136 - 0.368
Beryllium	1081, 1083	0.016 - 0.027
Cadmium	1025, 1073, 1075	0.01 - 0.014
Calcium	1010, 1011, 1019, 1022, 1025, 1028, 1030, 1031, 1032, 1038, 1039, 1073, 1075, 1078, 1079, 1081, 1082, 1083, 1084	128 - 1680
Chromium	1075	0.084
Cobalt[e]	1028, 1081, 1083	0.017 - 0.245
Iron	1011, 1075	4.19 - 11.2
Magnesium	1011, 1019, 1022, 1025, 1028, 1030, 1032, 1038, 1039, 1073, 1074, 1075, 1076, 1078, 1079, 1080, 1081, 1082, 1084	58 - 659
Manganese	1008, 1011, 1019, 1020, 1021, 1022, 1025, 1038, 1039, 1073, 1075, 1076, 1077, 1078	0.214 - 35.4
Mercury	1073	7.55
Molybdenum[e]	1008, 1031, 1038, 1042, 1073, 1075, 1082, 1084	0.023 - 0.607
Nickel	1030, 1074, 1075	0.136 - 0.271
Osmium[d]	1025, 1031, 1074	0.059 - 0.469
Potassium	1031, 1075	93 - 229
Selenium[d]	1010, 1021, 1029, 1031, 1032, 1034, 1076, 1079, 1081, 1082	0.002 - 0.058
Silver	1022, 1077	0.053 - 0.089
Sodium	1019, 1025, 1031, 1032, 1039, 1073, 1075, 1081	95 - 1094
Thallium[d]	1019	0.001
Vanadium	1028, 1081, 1083	0.061 - 0.275
Zinc	1025, 1081, 1083	0.113 - 0.259
	Production Area	
Aluminum	1149, 1186, 1199, 1324, 1675	0.768 - 8.37

See footnotes at end of table.

TABLE A-5
(Continued)

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
Antimony[d]	1085, 1087, 1088, 1149, 1186, 1199, 1208, 1209, 1212, 1213, 1287, 1324, 1423, 1675, 1676	0.0004 - 0.297
Barium	1041, 1149, 1208, 1213, 1324, 1411	0.135 - 0.589
Beryllium	1149, 1186, 1199, 1209, 1324, 1423	0.005 - 0.072
Cadmium	1149, 1186, 1199, 1212, 1283, 1324, 1423, 1675	0.01 - 0.04
Calcium	1041, 1089, 1149, 1186, 1193, 1199, 1208, 1212, 1246, 1250, 1283, 1287, 1324, 1423, 1675, 1676	138 - 976
Chromium	1149, 1186, 1199, 1208, 1209, 1212, 1213, 1324, 1423	0.1 - 2.11
Cobalt[e]	1149, 1186, 1199, 1208, 1209, 1212, 1213, 1324, 1423, 1675	0.014 - 0.205
Copper	1149, 1186, 1324	0.059 - 0.384
Iron	1411, 1675	2.65 - 4.6
Lead	1064	0.059
Magnesium	1041, 1053, 1064, 1087, 1089, 1149, 1199, 1283, 1287, 1363, 1423, 1675, 1676	58 - 251
Manganese	1041, 1085, 1086, 1087, 1089, 1149, 1182, 1193, 1199, 1203, 1208, 1212, 1213, 1283, 1287, 1324, 1411, 1412, 1423, 1675, 1676	0.205 - 1.93
Mercury	1183, 1212	0.002 - 0.004
Molybdenum[e]	1041, 1053, 1054, 1055, 1087, 1088, 1089, 1090, 1149, 1324, 1675, 1676	0.021 - 0.14
Nickel	1149, 1324	0.227 - 0.262
Selenium[d]	1055, 1250	0.002 - 0.011
Silicon[d]	1675, 1676	7.33 - 7.75
Silver	1149, 1186, 1199, 1324, 1423	0.073 - 0.824
Sodium	1149, 1324, 1423	79 - 207
Thallium[d]	1246, 1287, 1412	0.002 - 0.003
Vanadium	1149, 1186, 1199, 1324	0.081 - 0.67
Zinc	1149	0.268

See footnotes at end of table.

TABLE A-5
(Continued)

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Sewage Treatment Plant	
Aluminum	1443	1.01
Calcium	1447	151
Manganese	1441, 1443	0.55 - 0.59
Sodium	1447	74
	Fire Training Area	
Aluminum	1511	0.84
Calcium	1509, 1512	136 - 155
Manganese	1508, 1509, 1511, 1512, 1515	0.21 - 2.54
	Other Areas	
Arsenic[e]	1040, 1058	0.058 - 0.069
Barium	1040, 1046, 1048, 1058	0.133 - 0.444
Calcium	1016, 1124	139 - 189
Copper	1059	0.055
Iron	1040, 1058	2.94 - 3.15
Seleneium[d]	1012, 1016, 1046, 1124	0.002 - 0.027
Sodium	1012	241

[a]Based on data available in the Fernald Database as of December 1, 1991.
[b]Wells listed contain concentrations of the constituent that are above the UTL.
[c](mg/L) = milligrams per liter.
[d]This constituent was not detected in any background sample.
[e]This constituent has only been detected once in background samples.

TABLE A-6
1000 SERIES WELLS WITH ELEVATED GENERAL CHEMICAL CONCENTRATIONS[a] FROM ONGOING RI/FS AND RCRA SAMPLING

Parameter	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Waste Storage Area	
Ammonia	1031, 1073, 1075, 1076	0.507 - 189
Chloride	1019, 1021, 1025, 1028, 1031, 1032, 1039, 1042, 1073, 1074, 1075, 1078, 1083, 1643	44.3 - 6060
Cyanide[d]	1031	0.079
Fluoride	1021, 1073, 1075	1.68 - 6.02
Nitrate	1010, 1011, 1019, 1025, 1028, 1029, 1031, 1032, 1034, 1073, 1075, 1078, 1081, 1083	0.652 - 156
Phosphorus	1025, 1035, 1038, 1079, 1081, 1082, 1084	0.92 - 2.34
Sulfate	1019, 1021, 1022, 1025, 1028, 1032, 1073, 1075, 1079, 1081, 1082, 1084	245 - 1150
Sulfide[d]	1025	4.26
TKN[e]	1008, 1011, 1027, 1031, 1039, 1042, 1073, 1075, 1084	2.62 - 196
TOX[f]	1011, 1019, 1031, 1073, 1075	0.083 - 0.609
TON[g]	1008, 1010, 1011, 1022, 1035, 1042, 1073, 1075, 1078, 1082, 1083, 1084	0.44 - 21
	Production Area	
Ammonia	1053, 1149, 1643	1.02 - 2.5
Chloride	1041, 1149	51 - 289
Cyanide[d]	1149, 1199, 1208, 1209, 1212, 1213, 1246, 1324, 1675	0.002 - 0.248
Nitrate	1054, 1064, 1089, 1110, 1111, 1130, 1145, 1148, 1149, 1150, 1151, 1156, 1158, 1160, 1161, 1178, 1180, 1183, 1185, 1186, 1188, 1189, 1190, 1194, 1195, 1196, 1197, 1199, 1200, 1202, 1204, 1205, 1206, 1207, 1208, 1209, 1211, 1212, 1214, 1215, 1216, 1217, 1218, 1219, 1220, 1221, 1223, 1225, 1226, 1227, 1228, 1231, 1232, 1233, 1234, 1236, 1240, 1242, 1250, 1258, 1259, 1263, 1267, 1269, 1277, 1304, 1324, 1336, 1337, 1403, 1420, 1423, 1675, 1676	0.345 - 586
Phosphorus	1053, 1055, 1064, 1149	0.591 - 39.8
Sulfate	1055, 1064, 1085, 1089, 1643, 1675	213 - 345
TKN[e]	1041, 1053, 1064, 1149	1.89 - 8.45

See footnotes at end of table.

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TABLE A-6
(Continued)

Parameter	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Production Area (cont.)	
TOC[h]	1031, 1149	13.5 - 39.9
TOX[f]	1149	0.652
TON[g]	1053, 1054, 1055, 1064, 1089, 1149	0.58 - 5.1
	Sewage Treatment Plant	
Nitrate	1441, 1442, 1443, 1444, 1447	0.36 - 20
	Southfield Area	
Nitrate	1016, 1516, 1517	0.43 - 2.2
TKN[e]	1016	1.2
TOX[f]	1016	0.07
TON[g]	1016	0.55
	Other Areas	
Ammonia	1012, 1040, 1058	1.32 - 3.77
Chloride	1012, 1124	73.2 - 114
Nitrate	1012, 1020, 1124, 1518, 1523	0.55 - 2.02
TKN[e]	1012, 1040, 1058, 1124	0.98 - 4.27
TON[g]	1020, 1040, 1058	0.49 - 1.7

[a]Based on data available in the Fernald Database as of December 1, 1991.
[b]Wells listed contain concentrations of the parameter that are above the upper tolerance limit.
[c](mg/L) = milligrams per liter.
[d]This constituent has not been detected in any background sample.
[e]TKN = total Kjeldahl nitrogen.
[f]TOX = total organic halides.
[g]TON = total organic nitrogen.
[h]TOC = total organic carbon.

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TABLE A-7
ORGANIC COMPOUNDS DETECTED IN 1000 SERIES WELLS[a] DURING ONGOING RI/FS AND RCRA SAMPLING

Compound	Well Location	Concentrations (mg/L)[b]
	Waste Storage Area	
Acetone	1019, 1024, 1025, 1027, 1028, 1031, 1038, 1052, 1073, 1074, 1075, 1076, 1078, 1079, 1080, 1081, 1082, 1083, 1643	0.002 - 0.029
Benzene	1031, 1643	0.003 - 0.005
Bromochloromethane	1010	0.050
2-Butanone	1031, 1643	0.003 - 0.005
Carbon Disulfide	1052, 1074, 1079	0.002 - 0.13
Chloroethane	1643	0.025
Chloroform	1031	0.002
1,1-Dichloroethane	1019, 1031, 1073, 1083, 1643	0.002 - 0.076
1,2-Dichloroethane	1031, 1643	0.002 - 0.009
1,1-Dichloroethene	1031, 1073, 1643	0.002 - 0.005
trans-1,2-Dichloroethene	1031	0.018
1,2-Dichloroethylene	1019, 1643	0.01 - 0.025
Methylene Chloride	1019, 1024, 1025, 1027, 1028, 1030, 1031, 1038, 1052, 1073, 1074, 1075, 1076, 1078, 1079, 1080, 1081, 1082, 1083, 1643	0.002 - 0.018
Tetrachloroethene	1031	0.3
Toluene	1027, 1031, 1038, 1081, 1083, 1643	0.001 - 0.002
1,1,1-Trichloroethane	1025, 1073	0.002 - 0.005
Trichloroethene	1025, 1031, 1078, 1083	0.001 - 0.53
Vinyl Chloride	1019, 1031, 1643	0.002 - 0.016
Xylene (Total)	1031	0.002
bis(2-Ethylhexyl)phthalate	1079, 1080	0.003 - 0.004
Butyl benzyl phthalate	1025, 1073, 1078	0.001 - 0.003
Diethyl phthalate	1025, 1079, 1083	0.002 - 0.004
Di-n-butyl phthalate	1021, 1025, 1073, 1074, 1075, 1076, 1078	0.004 - 0.012
4,6-Dinitro-2-methylphenol	1031	0.006
4-Methyl-2-pentanone	1031	0.006
2-Nitrophenol	1031	0.012
4-Nitrophenol	1031	0.011

See footnotes at end of table.

TABLE A-7
(Continued)

Compound	Well Location	Concentrations (mg/L)[b]
	Waste Storage Area (cont.)	
N-Nitrosodiethylamine	1031	0.004
N-Nitrosodiphenylamine	1025, 1031, 1052, 1074, 1079, 1080	0.002 - 0.003
Naphthalene	1031	0.002
Pentachlorophenol	1031	0.003
Phenol	1052	0.002
Phenols	1008, 1010, 1011, 1019, 1022, 1024, 1025, 1027, 1029, 1031, 1032, 1033, 1034, 1035, 1038, 1039, 1041, 1042, 1052, 1073, 1074, 1075, 1076, 1077, 1078, 1079, 1080, 1081, 1082, 1083, 1084, 1149	0.005 - 0.24
2,3,4,6-Tetrachlorophenol	1031	0.004
	Production Area	
Acetone	1085, 1086, 1088, 1149, 1172, 1182, 1183, 1186, 1193, 1199, 1206, 1208, 1209, 1212, 1213, 1246, 1250, 1287, 1324, 1363, 1412, 1423, 1441, 1442, 1447, 1448, 1509, 1517	0.002 - 0.059
Benzene	1149, 1172	0.001 - 0.014
2-Butanone	1149, 1172, 1182, 1183, 1186, 1193, 1199, 1208, 1209, 1212, 1213, 1246, 1250, 1287, 1324, 1412, 1423, 1441, 1443, 1447, 1448	0.001 - 0.067
Carbon Tetrachloride	1149	0.005
Carbon Disulfide	1182, 1183	0.002 - 0.003
Chloroform	1149, 1784	0.001 - 0.026
1,1-Dichloroethane	1149, 1172, 1182, 1186, 1199, 1203, 1206, 1208, 1212, 1213, 1246, 1283, 1287, 1324, 1411, 1412, 1423	0.001 - 0.68
1,2-Dichloroethane	1149, 1283, 1412, 1423	0.001 - 0.086
1,1-Dichloroethene	1149, 1199, 1206, 1212, 1283, 1287, 1324, 1411, 1412, 1423	0.001 - 0.46
1,2-Dichloroethylene	1149, 1172, 1203, 1206, 1246, 1250, 1283, 1287, 1324, 1411, 1423	0.001 - 0.59
Ethylbenzene	1172	0.038

See footnotes at end of table.

TABLE A-7
(Continued)

Compound	Well Location	Concentrations (mg/L)[b]
	Production Area (cont.)	
Methylene Chloride	1088, 1149, 1182, 1183, 1186, 1193, 1199, 1203, 1206, 1208, 1209, 1212, 1213, 1246, 1283, 1287, 1324, 1363, 1411, 1412, 1423	0.001 - 0.028
Tetrachloroethene	1149, 1206, 1209, 1246, 1250, 1287, 1324, 1363, 1411	0.001 - 0.35
Toluene	1083, 1172, 1324, 1411	0.001 - 0.006
1,1,1-Trichloroethane	1149, 1186, 1199, 1206, 1208, 1209, 1212, 1246, 1250, 1283, 1287, 1324, 1411, 1412, 1423	0.002 - 0.31
1,1,2-Trichloroethane	1324	0.002
Trichloroethene	1149, 1186, 1193, 1206, 1246, 1250, 1283, 1287, 1324, 1411, 1423	0.001 - 6.4
Vinyl Acetate	1172	0.001 - 0.002
Vinyl Chloride	1206, 1411, 1423	0.002 - 0.007
Xylene (Total)	1172	0.3 - 0.4
bis(2-Ethylhexyl) Phthalate	1088	0.006
1,2-Dichlorobenzene	1209	0.004
Di-n-butyl Phthalate	1441	0.003
2,6-Dinitrotoluene	1324	0.006
4-Methyl-2-pentanone	1172, 1183, 1186	0.002 - 0.01
Phenol	1246, 1287, 1363	0.001 - 0.001
Phenols	1053, 1054, 1055, 1064	0.008 - 0.08
Tributyl phosphate	1180	0.41 - 0.45
Heptachlor Epoxide	1324	0.000058
	Sewage Treatment Plant	
Carbon Disulfide	1443, 1447, 1448	0.002 - 0.002
1,1-Dichloroethane	1441, 1442	0.001 - 0.001
1,2-Dichloroethylene	1441, 1442	0.01 - 0.045
Methylene Chloride	1442, 1443, 1447, 1448	0.002 - 0.021
Tetrachloroethene	1441, 1442	0.005 - 0.008
1,1,1-Trichloroethane	1441	0.004
Trichloroehtene	1441, 1442	0.006 - 0.006
Phenol	1447	0.001

See footnotes at end of table.

TABLE A-7
(Continued)

Compound	Well Location	Concentrations (mg/L)[b]
	Fire Training Area	
Chloroethane	1509	0.11
1,1-Dichloroethane	1508, 1509, 1515	0.001 - 2.5
1,2-Dichloroethane	1509	0.019
1,1-Dichloroethene	1509	0.49
1,2-Dichloroethylene	1509	1.5
Ethylbenzene	1509	0.013
Methylene Chloride	1508, 1509, 1511, 1513, 1514	0.001 - 0.026
Tetrachloroethene	1509	0.28
Toluene	1509	0.26
1,1,1-Trichloroethane	1509	2.9
Trichloroethene	1509	0.098
Xylene (Total)	1509	0.055
Benzoic Acid	1509	0.025
Benzyl Alcohol	1509	0.005
bis(2-Ethylhexyl) Phthalate	1509	0.004
2,4-Dimethylphenol	1509	0.04
4-Methylphenol	1509	0.015
	Other Areas	
1,1-Dichloroethane	1517	0.009
1,2-Dichloroethylene	1517	0.005
1,1,1-Trichloroethane	1016, 1517	0.002 - 0.005
Trichloroethene	1517	0.007
Phenols	1016, 1018, 1040, 1046, 1047, 1058, 1059, 1060, 1065, 1124	0.005 - 0.1

[a]Based on data available in the Fernald Database as of December 1, 1991.
[b](mg/L) = milligrams per liter.

TABLE A-8
DETECTIONS OF RADIOLOGICAL CONSTITUENTS IN THE GREAT MIAMI AQUIFER[a] FROM ONGOING RI/FS AND RCRA SAMPLING

Constituent	Concentration Range (pCi/L)[b]	Wells with Repeated Detections	Wells with Detection in the Only Sample[c]
		Waste Storage Area	
Strontium-90	6.8 - 38.5	2021	2649
Technetium-99	123 - 5510	2019, 2021, 2022, 2028	2643, 2649
Thorium-228	1.18 - 4.29	2020	2032
Thorium-230	14.7	NA[d]	2032
		Production Area	
Radium-226	1.1 - 1.3	3055	NA
	1.7 - 1.9	4101	NA
		South Plume Area[e]	
Radium-226	1.0 - 7.7	2014, 2094, 2095, 2559, 2561	NA
	3.3 - 4.8	3094	NA
Radium-228	3.1 - 3.6	2094	NA
	4.5 - 7.1	3094	NA
Strontium-90	7.61 - 38.5	2021, 2128	NA
Technetium-99	46.9	NA	3390
Thorium-228	1.05 - 2.97	2049, 2065, 2094, 2095, 2129, 2391, 2392, 2550, 2551, 2555, 2561	2385, 2554
	1.2 - 2.7	3125, 3128, 3396	NA
	1.2 - 1.7	4125	NA
Thorium-232	1.6 - 2.3	2049	NA
		Other Areas	
Radium-226	1.2 - 8.5	3043, 3066	NA
Radium-228	4.0 - 5.4	2044	NA
Thorium - 228	1.18 - 1.2	2020	NA
Thorium-230	1.04 - 1.8	2018, 2020	NA

[a]Excluding total thorium, uranium isotopes, and total uranium.
[b](pCi/L) = picoCuries per liter.
[c]Only one sample was collected from these wells for the analysis of the specific constituent.
[d]NA = Not applicable.
[e]South Plume Area includes the vicinity of the storm sewer outfall ditch, the Southfield, along Paddys Run south of the FEMP property, and along the local industries on Paddys Run Road.

TABLE A-9
URANIUM SPECIES AND TOTAL THORIUM IN THE GREAT MIAMI AQUIFER[a] FROM ONGOING RI/FS AND RCRA SAMPLING

Constituent	Wells with Elevated Concentrations[b]	Average Concentration Range (pCi/L)[c]
	Waste Storage Area	
Uranium-234	2004, 2008, 2010, 2011, 2019, 2021, 2022, 2024, 2027, 2028, 2032, 2033, 2034, 2037, 2042, 2052, 2084, 2643, 2648, 2649	0.6 - 13.6
	3001, 3003, 3004, 3005, 3010, 3019, 3024, 3032, 3037, 3054, 3084	0.65 - 13.1
	4011	2.44
Uranium-235/236	2032, 2034, 2648	0.62 - 1.93
	3084	0.85
Uranium-238	2004, 2008, 2010, 2019, 2021, 2022, 2024, 2027, 2028, 2033, 2034, 2037, 2042, 2052, 2084, 2643, 2648, 2649	0.85 - 13.4
	3001, 3003, 3004, 3005, 3008, 3010, 3019, 3024, 3032, 3034, 3037, 3084	0.574- 22.8
	4011	2.23
Total Uranium	2004, 2008, 2010, 2021, 2022, 2024, 2027, 2028, 2032, 2033, 2034, 2037, 2042, 2084, 2643, 2648, 2649	3 - 40[d]
	3001, 3003, 3004, 3005, 3010, 3019, 3024, 3032, 3037, 3084	3 - 62[d]
Total Thorium	2010, 2033, 2084	2 - 4[d]
	3004, 3005, 3011, 3019	2 - 3[d]
	Production Area	
Uranium-234	2006, 2007, 2013, 2053, 2054, 2055, 2064, 2109, 2118, 2120, 2388, 2389	0.818 - 14.3
	3013	27.1
	4013, 4102, 4103	0.657 - 8.305
Uranium-235/236	2389	1.45
	3013	1.51
Uranium-238	2006, 2007, 2013, 2053, 2054, 2055, 2064, 2109, 2118, 2120, 2388	0.82 - 6.8
	3013, 3054	0.65 - 28.3
	4013, 4102, 4103	0.57 - 8.8

See footnotes at end of table.

TABLE A-9
(Continued)

Constituent	Wells with Elevated Concentrations[b]	Average Concentration Range (pCi/L)[c]
	Production Area (cont.)	
Total Uranium	2006, 2007, 2013, 2053, 2054, 2055, 2109, 2118, 2120, 2388, 2389	3 - 71[d]
	3013	67[d]
	4013	24[d]
Total Thorium	3054	2[d]
	South Plume Area[e]	
Uranium-234	2014, 2015, 2016, 2017, 2045, 2046, 2047, 2048, 2049, 2060, 2061, 2065, 2069, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2385, 2386, 2387, 2390, 2391, 2392, 2393, 2394, 2396, 2550, 2551, 2555, 2556, 2558, 2559, 2561	0.635 - 150
	3014, 3015, 3016, 3017, 3046, 3049, 3062, 3069, 3095, 3106, 3125, 3126, 3127, 3128, 3385, 3387, 3390, 3391, 3396	0.7 - 24.3
	4015, 4125	0.6 - 1.6
Uranium-235/236	2014, 2015, 2045, 2046, 2049, 2060, 2061, 2094, 2095, 2106, 2125, 2385, 2387, 2390, 2550, 2551	0.68 - 7.4
	3014, 3015, 3125, 3128, 3390, 3396	0.63 - 1.1
Uranium-238	2014, 2015, 2016, 2017, 2045, 2046, 2048, 2049, 2060, 2061, 2065, 2069, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2385, 2386, 2390, 2391, 2394, 2396, 2550, 2551, 2555, 2556, 2558, 2559	0.67 - 157
	3014, 3015, 3016, 3062, 3069, 3095, 3106, 3108, 3125, 3126, 3127, 3128, 3387, 3390, 3391, 3396	0.7 - 25.3
Total Uranium	2014, 2015, 2016, 2017, 2045, 2046, 2049, 2060, 2061, 2065, 2069, 2094, 2095, 2106, 2125, 2127, 2128, 2129, 2385, 2386, 2387, 2390, 2391, 2392, 2393, 2396, 2550, 2551, 2555, 2556, 2558, 2559	2 - 580[d]
	3014, 3015, 3016, 3062, 3069, 3095, 3125, 3126, 3128, 3385, 3387, 3390, 3391	2 - 45[d]
	4125	4[d]
Total Thorium	2045, 2049, 2127, 2129, 2387, 2391, 2392	2 - 8[d]
	3014, 3069, 3125, 3385	2 - 5[d]

See footnotes at end of table.

TABLE A-9
(Continued)

Constituent	Wells with Elevated Concentrations[b]	Average Concentration Range (pCi/L)[c]
	Other Areas	
Uranium-234	2009, 2018, 2022, 2044, 2051, 2067, 2092, 2097, 2098, 2107, 2108, 2383, 2397	0.65 - 85.5
	3009, 3018, 3068, 3070, 3107, 3108	0.62 - 10.8
	4097, 4108	0.775 - 14.1
Uranium-235/236	2397	7.1
	4108	0.78
Uranium-238	2009, 2018, 2020, 2044, 2047, 2051, 2067, 2092, 2097, 2107, 2108, 2397	0.67 - 85.2
	3009, 3018, 3107, 3068	0.6 - 1.5
	4096, 4108	0.76 - 12.3
Total Uranium	2009, 2018, 2044, 2047, 2092, 2098, 2107, 2108, 2383, 2397	2 - 242[d]
	3009, 3108	3 - 32[d]
	4097, 4108	2 - 18[d]
Total Thorium	2092, 2018, 2020, 2383	2 - 5[d]
	3009	2[d]

[a]Based on data available in the Fernald Database as of December 1, 1991.
[b]Wells listed contain concentrations of the constituent that are above the UTL.
[c](pCi/L) = picoCuries per liter.
[d]The unit is in µg/L.
[e]South Plume Area includes the vicinity of the storm sewer outfall ditch, the South Field, along Paddys Run south of the FEMP property, and along the local industries along Paddys Run Road.

TABLE A-10
ELEVATED METAL CONCENTRATIONS[a] IN THE GREAT MIAMI AQUIFER GROUNDWATER FROM ONGOING RI/FS AND RCRA SAMPLING

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Waste Storage Area	
Aluminum	4001, 4008, 4010	0.096 - 0.114
Antimony[d]	2011, 2052	0.001 - 0.001
Barium	4001, 4010	0.078 - 0.43
Beryllium	4001, 4008, 4010	0.001 - 0.002
Cadmium	3034	0.01
	4001, 4010	0.004 - 0.004
Calcium	2010, 2019, 2021, 2022, 2024, 2027, 2028, 2084	148 - 291
	3010, 3019, 3037, 3084	259 - 282
	4001	106
Chromium	2084	0.041
Cobalt[d]	2010, 2027, 2084	0.007 - 0.009
Iron	2024, 2027	5.0 - 5.9
	3037	12.5
	4001, 4008, 4010	2.4 - 5.1
Magnesium	2022, 2027, 2028, 2034, 2084	51.6 - 77.6
	3037, 3084	63.6 - 78.9
	4010	31.4
Manganese	2010, 2024, 2027, 2037, 2084	0.28 - 0.86
	3001, 3003, 3004, 3005, 3008, 3010, 3019, 3024, 3037, 3084	0.30 - 4.02
Mercury	3004	0.00241
	4001, 4010	0.00014 - 0.00025
Molybdenum	4001, 4008	0.024 - 0.03
Nickel	2011	0.035
	3024	0.141
	4001, 4008, 4010	0.013 - 1.93
Osmium[d]	3084	0.094
Potassium	2021, 2022, 2084	5.5 - 14.3
	3010, 3019, 3037, 3084	7.1 - 16.0
	4001, 4008	3.2 - 4.8

See footnotes at end of table.

TABLE A-10
(Continued)

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Waste Storage Area (cont.)	
Silicon[d]	2028, 2032, 2033	2.6 - 4.8
	3032	2.98
	4010	6.43
Silver	2028	0.021
Sodium	4001, 4008, 4010, 4023	8.6 - 30
Thallium[d]	2084	0.001
	3019	0.002
Vanadium	2084	0.051
	3037, 3084	0.036 - 0.041
	4001, 4008, 4010	0.015 - 0.02
Zinc	2004, 2008, 2010, 2019, 2021, 2022, 2027, 2034, 2037, 2042, 2052, 2084	0.013 - 0.111
	3037	0.153
	4001, 4008, 4010	0.017 - 0.028
	Production Area	
Aluminum	4013, 4064, 4101, 4103	0.064 - 0.196
Antimony[d]	2109	0.003
Barium	4013, 4064, 4101, 4102, 4103	0.052 - 0.241
Beryllium	4013, 4101	0.001 - 0.002
Cadmium	2055	0.025
	4013, 4064, 4101, 4103	0.002 - 0.007
Calcium	2051, 2052, 2053, 2054, 2064, 2109, 2118	141 - 304
	3013, 3051, 3055	137 - 179
	4013, 4064, 4101	123 - 227
Chromium	2053, 2054, 2109, 2118	0.042 - 0.073
	4013, 4064	0.039 - 0.046
Cobalt[d]	4101	0.004
Iron	3013, 3055	6.28 - 6.81
	4013, 4064, 4101, 4102, 4103	2.7 - 7.3
Magnesium	2109	55.9
	4013, 4064, 4101	31.1 - 80.2

See footnotes at end of table.

TABLE A-10
(Continued)

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Production Area (cont.)	
Manganese	2051, 2053, 2054, 2064, 2109, 2118, 2120	0.274 - 355
	3013	0.37
	4102	9.44
Mercury	4013, 4064, 4103	0.00013 - 0.00065
Molybdenum	3013, 3064	0.03 - 0.058
	4013, 4101, 4103	0.014 - 0.04
Nickel	2054, 2109	0.036 - 0.038
	4013, 4064, 4101	0.014 - 0.029
Potassium	2064	7.94
	3053, 3054, 3055	17.6 - 55.8
	4013, 4101, 4102	2.1 - 4.6
Silicon[d]	2006, 2007, 2053, 2055, 2109, 2120, 2388, 2389	3.2 - 5.9
	3120	5.0
	4013, 4064, 4103	6.25 - 6.42
Silver	2120	0.016
Sodium	4013, 4064, 4101, 4102, 4103	8.02 - 64.4
Vanadium	2109	0.037
	4013, 4064, 4101	0.014 - 0.036
Zinc	2006, 2007, 2013, 2053, 2054, 2109, 2118	0.015 - 0.27
	4013, 4101	0.009 - 0.074
	South Plume Area[e]	
Aluminum	2014, 2015, 2016, 2017, 2045, 2049, 2060, 2061, 2069, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2392, 2393, 2396, 2550, 2551, 2555, 2556, 2558, 2559, 2561	0.038 - 0.387
	3014, 3015, 3016, 3017, 3062, 3069, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3391, 3396	0.068 - 25.9
	4125	0.059
Antimony[d]	2015	0.008
Barium	2015, 2094, 2127, 2392, 2396, 2555, 2559, 2561	0.056 - 1.06
	3016, 3017, 3062, 3069, 3094, 3125, 3127, 3128, 3391, 3396	0.052 - 5.22
	4014, 4015, 4125	0.07 - 0.113
Beryllium	2094, 2129	0.001 - 0.001
	3126	0.002

See footnotes at end of table.

TABLE A-10
(Continued)

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	South Plume Areas (cont.)	
Cadmium	2014, 2015, 2016, 2017, 2045, 2048, 2049, 2060, 2061, 2065, 2069, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2385, 2390, 2393, 2396, 2550, 2551, 2555, 2556, 2558, 2561	0.002 - 0.007
	3014, 3015, 3016, 3017, 3049, 3062, 3069, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3391, 3396	0.002 - 0.643
	4014, 4015, 4016, 4125	0.002 - 0.005
Calcium	2017, 2045, 2049, 2065, 2126, 2385, 2392, 2393, 2555, 2558, 2559	106 - 167
	3126, 3127, 3391, 3396	108 - 19014
	4015, 4016	105 - 106
Chromium	2016, 2017, 2385, 2555	0.031 - 0.04
	3046, 3069, 3093, 3126, 3127, 3396	0.031 - 4.78
Copper	3127	1.0
Iron	2094, 2559	9.9 - 16.3
	3017, 3062, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3391, 3396	0.88 - 20.6
	4014, 4015, 4016, 4125	1.3 - 2.6
Lead	2127	0.253
	3127	0.725
Magnesium	2017, 2065, 2094, 2129, 2385, 2392, 2393, 2555, 2559	29.7 - 49.6
	3094, 3095, 3126, 3127, 3396	29.7 - 4881
Manganese	3127	15.3
Mercury	2014, 2016, 2017, 2045, 2048, 2049, 2060, 2069, 2094, 2095, 2125	0.00013 - 0.025
	3014, 3017, 3049, 3062, 3069, 3094, 3095, 3106, 3126, 3127	0.00017 - 0.0213
	4014, 4015	0.00053 - 0.00475
Molybdenum	2014, 2060, 2061, 2069, 2094, 2129, 2393	0.012 - 0.048
	3049, 3094, 3106, 3391	0.011 - 0.02
	4015	0.016
Nickel	2014, 2017, 2049, 2093, 2094, 2095, 2126, 2127, 2129, 2385, 2393, 2550, 2551, 2555, 2556	0.01 - 0.67
	3017, 3046, 3069, 3093, 3094, 3095, 3106, 3125, 3126, 3127, 3391, 3396	0.011 - 2.01
	4015	0.014

See footnotes at end of table.

TABLE A-10
(Continued)

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	South Plume Areas (cont.)	
Potassium	2014, 2015, 2016, 2045, 2049, 2060, 2061, 2069, 2093, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2392, 2393, 2396, 2550, 2551, 2555, 2556, 2558, 2559, 2561	2.1 - 600
	3014, 3015, 3016, 3017, 3049, 3062, 3069, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3391	2.34 - 537
	4014	2.37
Selenium	2014, 2045, 2049, 2061, 2106, 2129	0.001 - 0.041
	3014, 3015, 3016, 3069, 3127	0.021 - 0.203
	4014	0.002
Silicon[d]	2014, 2016, 2017, 2045, 2046, 2048, 2049, 2061, 2065, 2069, 2093, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2385, 2386, 2387, 2390, 2391, 2392, 2393, 2394, 2396, 2397, 2550, 2551, 2555, 2556, 2558, 2559, 2561	2.1 - 17.4
	3014, 3015, 3016, 3017, 3046, 3049, 3062, 3065, 3069, 3093, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3385, 3387, 3390, 3391, 3396	2.106 - 1540
	4125	6.12
Silver	3127	3.89
Sodium	2014, 2016, 2017, 2045, 2049, 2060, 2061, 2069, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2390, 2392, 2393, 2396, 2550, 2551, 2555, 2556, 2558, 2559, 2561	6.5 - 87.8
	3014, 3015, 3016, 3017, 3049, 3062, 3069, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3391, 3396	9.23 - 1268
	4014, 4015, 4016, 4125	5.12 - 13.3
Thallium[d]	3126	0.002
Vanadium	2014, 2015, 2016, 2017, 2045, 2049, 2061, 2069, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2393, 2555, 2556, 2558, 2561	0.008 - 0.02
	3014, 3015, 3016, 3017, 3062, 3069, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3391, 3396	0.01 - 2.6
	4125	0.01
Zinc	2014, 2015, 2016, 2060, 2094, 2095, 2106, 2129, 2393, 2558	0.017 - 2.3
	3126	0.03

See footnotes at end of table.

TABLE A-10
(Continued)

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Other Areas	
Aluminum	2044, 2096, 2098	0.066 - 0.098
	3044, 3096	0.062 - 0.066
	4097, 4108	0.035 - 0.073
Barium	2044, 2096, 2104	0.058 - 0.076
	3044	0.055
	4023, 4067, 4091, 4097	0.052 - 0.092
Cadmium	2018, 2044, 2104, 2384, 2397	0.002 - 0.008
	3044, 3096	0.003 - 0.005
	4067, 4091, 4096, 4097, 4108	0.002 - 0.006
Calcium	2096, 2104, 2383, 2384, 2397	119 - 159
	3066	158
Chromium	2384	0.043
Copper	2091	0.086
Iron	2096, 2098, 2104	0.166 - 2.85
	3009, 3044, 3066	0.77 - 14.7
	4067, 4091, 4097, 4108	0.68 - 3.6
Magnesium	2096, 2104, 2384	30.3 - 44.4
	3108	128
Manganese	3068, 3091, 3092, 3097	0.27 - 0.46
Mercury	2009, 2044, 2070, 2091, 2096, 2104	0.00015 - 0.0018
	3044, 3108	0.00032 - 0.00401
	4067, 4091, 4097	0.00023 - 0.00076
Molybdenum	2104	0.014
	3044	0.016
	4097	0.017
Nickel	2067, 2096, 2104	0.01 - 0.052
	3044, 3068, 3092, 3096	0.012 - 0.059
	4096	0.013
Potassium	2044, 2091, 2104	2.4 - 5.3
	3044, 3096	2.2 - 3.8
	4023, 4097, 4108	2.1 - 2.3
Selenium	2044, 2098	0.003 - 0.022
	3098	0.002
	4067, 4096, 4097	0.001 - 0.002

See footnotes at end of table.

TABLE A-10
(Continued)

Metal	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Other Areas (cont.)	
Silicon[d]	2018, 2020, 2044, 2047, 2068, 2070, 2091, 2092, 2096, 2097, 2098, 2104, 2107, 2108, 2383, 2384	1.5 - 33.7
	3018, 3020, 3044, 3068, 3070, 3091, 3092, 3096, 3097, 3107, 3108	1.8 - 5.5
	4097, 4108	3.5 - 4.8
Sodium	2044, 2096, 2104	6.3 - 16.4
	3044, 3066	12.4 - 285
	4067, 4091, 4097, 4108	9.4 - 16.8
Vanadium	2044, 2096, 2098	0.011 - 0.018
	3044, 3096	0.01 - 0.011
Zinc	2051	0.065

[a]Based on data available in the Fernald Database as of December 1, 1991.
[b]Wells listed contain concentrations of the constituent that are above the UTL.
[c](mg/L) = milligrams per liter.
[d]This constituent was either not detected or not analyzed for in background samples.
[e]South Plume Areas include the vicinity of the storm sewer outfall ditch, the South Field, along Paddys Run south of the FEMP property, and along the local industries on Paddys Run Road.

TABLE A-11
UPPER TOLERANCE LIMITS OF METALS IN THE GREAT MIAMI AQUIFER[a] FROM ONGOING RI/FS AND RCRA SAMPLING

Metal	Dry Fork Group (mg/L)[b]	Shandon Group (mg/L)	Dry Fork-Shandon Divide Group (mg/L)	Ross Group (mg/L)
Aluminum	NA[c]	0.303	0.303	NA
Arsenic	0.28	0.385	0.369	0.376
Barium	0.051	1.05	0.95	0.079
Beryllium	NA	0.004[d]	0.004[d]	NA
Cadmium	ND[e]	0.007	0.005	0.01[d]
Calcium	104	136	129	112
Chromium	0.030	0.039	0.034	0.025
Cobalt	NA	ND	ND	NA
Copper	0.09	0.022[d]	0.03	0.154
Iron	0.602	4.13	3.69	0.126
Lead	0.037	0.051	0.046	0.059
Magnesium	28.0	47.0	41.6	38.0
Manganese	1.03	0.265	0.742	0.035
Mercury	ND	0.00072	0.00047	0.00027
Molybdenum	0.01[d]	0.029	0.021	0.055
Nickel	ND	0.026	0.023	0.022
Potassium	2.04	5.07	6.24	3.09
Selenium	ND	0.13	0.13	ND
Silver	0.061	0.014	0.032	0.033[d]
Sodium	4.77	100	145	28.7
Thallium	NA	ND	ND	NA
Vanadium	NA	0.034	0.034	NA
Zinc	NA	0.109	0.109	NA

See footnotes at end of table.

TABLE A-11
(Continued)

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[a]Upper tolerance limits for each constituent were calculated from the analytical results of background samples from the ongoing RI/FS and RCRA sampling programs available in the Fernald Database as of December 1, 1991.

[b](mg/L) = milligrams per liter.

[c]NA = This constituent was not analyzed for in background samples from this well group.

[d]This constituent was detected only once at this concentration in samples from this well group.

[e]ND = This constituent was not detected in background samples from this well group.

NOTE: Background groundwater data are based on the information reported in the Site-Wide Characterization Report (DOE 1992a). Revised and validated background groundwater data are projected for use in later stage Operable Unit 5 Reports.

TABLE A-12
UPPER TOLERANCE LIMITS OF GENERAL CHEMICAL PARAMETERS[a] IN THE GREAT MIAMI AQUIFER GROUNDWATER FROM ONGOING RI/FS AND RCRA SAMPLING

Parameter	Dry Fork Group (mg/L)[b]	Shandon Group (mg/L)	Dry Fork-Shandon Divide Group (mg/L)	Ross Group (mg/L)
Ammonia	0.37	7.13	6.00	0.18
Chloride	30.1	110	103	105
Cyanide	NA[c]	ND[d]	ND	NA
Fluoride	0.47	1.33	1.27	0.37
Nitrate	19.4	1.53	7.99	21.7
Phosphate	NA	1.0	1.0	NA
Phosphorus	0.16	0.73	0.45	0.13
Sulfate	60	130	153	131
Sulfide	NA	ND	ND	NA
TKN[e]	0.58	6.63	8.08	0.63
TOC[f]	NA	11.9	11.9	NA
TOX[g]	ND	0.096	0.078	ND
TON[h]	0.31	2.12	1.17	0.40

[a]Upper tolerance limits for each constituent were calculated from the analytical results of background samples from the ongoing RI/FS and RCRA sampling programs available in the Fernald Database as of December 1, 1991.

[b](mg/L) = milligrams per liter.

TABLE A-12
(Continued)

[c]NA = This constituent was not analyzed for in background samples from this well group.
[d]ND = This constituent was not detected in background samples from this well group.
[e]TKN = total Kjeldahl nitrogen.
[f]TOC = total organic carbon.
[g]TOX = total organic halides.
[h]TON = total organic nitrogen.

NOTE: Background groundwater data are based on the information reported in the Site-Wide Characterization Report (DOE 1992a). Revised and validated background groundwater data are projected for use in later stage Operable Unit 5 Reports.

TABLE A-13
ELEVATED GENERAL CHEMICAL CONCENTRAITONS[a] IN THE GREAT MIAMI AQUIFER GROUNDWATER FROM ONGOING RI/FS AND RCRA SAMPLING

Parameter	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Waste Storage Area	
Ammonia	3037	12.2
	4010	2.96
Chloride	2022, 2084	137 - 188
	3037, 3084	184 - 210
	4010	36
Fluoride	4010	0.5
Nitrate	2008, 2019, 2021, 2022, 2028, 2032, 2033, 2034, 2084	1.9 - 52
	3008, 3010, 3019, 3032, 3034, 3084	3.1 - 13.9
Phosphate	2010	3.6
	4008	0.68
Phosphorus	2010, 2024, 2027, 2032, 2033, 2034, 2052	0.89 - 174.4
	3011, 3034	0.94 - 139
	4001, 4008, 4010	0.17 - 0.25
Sulfate	2010, 2024, 2027, 2037, 2052, 2084	144 - 534
	3010, 3019, 3037, 3084	385 - 559
	4001	65.4
Sulfide	2033	8.0
	4010	25.8
TKN[d]	3037	17.7
	4001, 4010	2.8 - 3.3
TOC[e]	4001, 4008, 4010	1.6 - 12.2
TOX[f]	4010	0.03
TON[g]	2021	2.5
	3037	4.2
	4001	2.01
	Production Area	
Ammonia	4013, 4064, 4101, 4102	0.47 - 3.91
Chloride	4013, 4064, 4101, 4102, 4103	30.1 - 295
Cyanide	2054	0.003

See footnotes at end of table.

TABLE A-13
(Continued)

Parameter	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Production Area (cont.)	
Fluoride	3120	11.6
	4013	0.49
Phosphate	3013	1.2
	4101, 4102, 4103	0.16 - 0.20
Phosphorus	2007, 2053, 2055, 2118, 2388	0.77 - 9.5
	4064, 4103	0.208 - 0.225
Sulfate	2006, 2007, 2053, 2054, 2055, 2064, 2118, 2388, 2389	130 - 666
	3013, 3055	269 - 324
	4013, 4064, 4101, 4103	62.5 - 322
Sulfide	2006, 2007, 2053, 2055, 2109	12.8 - 90.2
	3120	1.8
	4064, 4103	17 - 40
TKN	4013, 4064, 4101, 4102	0.69 - 5.14
TOC	2055	13.6
	4013	2.6
TOX	2006	0.27
	4013, 4101	0.019 - 0.039
TON	2055	2.9
	3055	2.7
	4101	1.12
	South Plume Areas[h]	
Ammonia	2094, 2127, 2559	0.58 - 1.37
	3094	2.3
Chloride	2069, 2094, 2396, 2555, 2559	36 - 133
	3069, 3094	32 - 114
	4015	31.2
Fluoride	2015, 2060, 2094	0.47 - 0.75
Nitrate	2126, 2128, 2555, 2556	21.6 - 100.6
	3126	112.6
Phosphate	2014, 2016, 2017	0.01 - 0.30
	3017	0.01

See footnotes at end of table.

TABLE A-13
(Continued)

Parameter	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	South Plume Areas (cont.)	
Phosphorus	2014, 2045, 2048, 2049, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2386, 2390, 2391, 2392, 2393, 2396, 2550, 2551, 2555, 2556, 2558, 2559, 2561	0.185 - 20.3
	3017, 3049, 3069, 3094, 3095, 3106, 3126	0.168 - 92
	4125	0.295
Sulfate	2014, 2015, 2016, 2017, 2065, 2069, 2094, 2106, 2126, 2127, 2129, 2392, 2393, 2396, 2555, 2558	60 - 5431
	3015, 3016, 3017, 3049, 3069, 3094, 3095, 3106, 3125, 3128, 3391, 3396	65 - 275
	4014, 4015, 4016	65 - 104
Sulfide	2014, 2046, 2048, 2126, 2127, 2129, 2386, 2390	0.135 - 12.8
	3046, 3069, 3127	0.5 - 7.1
TKN	2014, 2069, 2094, 2127, 2129	0.63 - 2.1
	3062, 3094, 3128	0.58 - 4.1
TOC	2014, 2015, 2016, 2017, 2045, 2049, 2060, 2069, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2385, 2386, 2390, 2392, 2393, 2396, 2550, 2551, 2555, 2556, 2558, 2559, 2561	0.98 - 87
	3014, 3015, 3016, 3017, 3049, 3095, 3106, 3125, 3126, 3127, 3128, 3391, 3396	0.75 - 4.5
	4125	3.3
TOX	2014, 2015, 2017, 2045, 2060, 2094, 2095, 2106, 2127, 2128, 2386, 2551, 2556, 2558, 2559	0.006 - 6.9
	3014, 3015, 3017, 3049, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3385, 3387, 3391, 3396	0.01 - 2.3
	4016	0.013
TON	2014, 2045, 2049, 2095, 2106, 2125, 2127, 2128, 2129, 2390, 2550, 2551	0.32 - 1.16
	3062, 3069	0.35 - 1.7
	Other Areas	
Ammonia	3066	17.0
	4108	0.69
Chloride	2044	36.9
	3066	605
Nitrate	2091, 2092, 2097	2.3 - 6.4
Phosphate	3066	1.1

See footnotes at end of table.

TABLE A-13
(Continued)

Parameter	Wells with Elevated Concentrations[b]	Average Concentration Range (mg/L)[c]
	Other Areas (cont.)	
Phosphorus	2044, 2067, 2068, 2070, 2096, 2097, 2098, 2107, 2108	0.24 - 107
	3044, 3066, 3068, 3070, 3092, 3096	0.24 - 110
	4067, 4096	0.23 - 0.37
Sulfate	2044, 2096, 2104, 2051, 2097, 2383, 2397	77 - 303
	3044	99.8
Sulfide	2047, 2097, 2098, 2107, 2108	9.5 - 44.2
	3098, 3107, 3108	22.5 - 28.0
	4097	19.5
TKN	3066	14.6
TOC	2044, 2104	1.0 - 1.0
	3096	1.0
	4108	2.2
TOX	2098	0.014
	3096, 3098	0.013 - 0.018
	4067, 4091, 4096, 4097	0.02 - 0.07
TON	2096, 2108	0.41 - 1.8
	4108	0.64

[a]Based on data available in the Fernald Database as of December 1, 1991.
[b]Wells listed contain concentrations of the constituent that are above the UTL.
[c](mg/L) = milligrams per liter.
[d]TKN = total Kjeldahl nitrogen.
[e]TOC = total organic carbon.
[f]TOX = total organic halides.
[g]TON = total organic nitrogen.
[h]South Plume Areas include the vicinity of the storm sewer outfall ditch, the South Field, along Paddys Run south of the FEMP property, and along the local industries on Paddys Run Road.

TABLE A-14

ORGANIC COMPOUNDS DETECTED IN THE GREAT MIAMI AQUIFER GROUNDWATER[a] DURING ONGOING RI/FS AND RCRA SAMPLING

Compound	Well Location	Concentrations (mg/L)[b]
	Waste Storage Area	
Acetone	2010, 2011, 2019, 2021, 2027, 2034, 2037, 2042, 2052, 2084	0.002 - 0.037
	3001, 3008, 3019, 3024, 3037, 3084	0.003 - 0.037
	4001, 4008, 4010	0.001 - 0.035
Benzene	2010, 2037	0.001 - 0.001
	3001	0.004
2-Butanone	2004, 2019	0.001 - 0.002
	3019	0.003
Carbon Disulfide	2011, 2027, 2037	0.001 - 0.011
Ethylbenzene	2034	0.002
	3001	0.002
Methylene Chloride	2004, 2006, 2008, 2010, 2011, 2019, 2021, 2027, 2034, 2037, 2042, 2084	0.001 - 0.022
	3001, 3008, 3019, 3024, 3037, 3084	0.002 - 0.011
	4001, 4008, 4010	0.001 - 0.011
Toluene	2010, 2011, 2019, 2021	0.002 - 0.005
	3001, 3008, 3019, 3037	0.002 - 0.01
	4001, 4008, 4010	0.002 - 0.005
Trichloroethene	3037	0.003
Trichlorofluoromethane	2019	0.066
	3019	0.072
Xylene (Total)	2034	0.003
	3001	0.003
bis(2-Ethylhexyl)phthalate	2008, 2010, 2019, 2021, 2022, 2027, 2037	0.001 - 0.05
	3019, 3037	0.002 - 0.005
	4001	0.005
Butyl benzyl phthalate	2034	0.001 - 0.001
	3037	0.003
Diethyl phthalate	2010, 2021	0.001 - 0.007
	3037	0.002

See footnotes at end of table.

TABLE A-14
(Continued)

Compound	Well Location	Concentrations (mg/L)[b]
	Waste Storage Area (cont.)	
Di-n-butyl phthalate	2004, 2008, 2010, 2034, 2037	0.003 - 0.008
	3001, 3084	0.002 - 0.005
2,6-Dinitrotoluene	4001	0.002
Isophorone	2011	0.002
3-Nitroaniline	2011	0.05
4-Nitrophenol	2021	0.003
N-Nitrosodiphenylamine	2011, 2019, 2027, 2037	0.002 - 0.01
	3019, 3037	0.002 - 0.003
Phenol	2008	0.002
	3037	0.017
Phenols	2004, 2008, 2010, 2011, 2019, 2021, 2022, 2024, 2027, 2032, 2033, 2034, 2037, 2042, 2052, 2084	0.006 - 0.17
	3001, 3003, 3004, 3005, 3010, 3011, 3013, 3019, 3024, 3032, 3034, 3037	0.006 - 1.2
	4001, 4008, 4010	0.017 - 0.068
alpha-BHC	2022	0.0001
Aldrin	2022	0.00011
Heptachlor	2022	0.00007
	Production Area	
Acetone	2006, 2007, 2053, 2055	0.005 - 0.018
	3010, 3013, 3055	0.004 - 0.035
	4013, 4101, 4103	0.001 - 0.005
2-Butanone	2006, 2007, 2053	0.002 - 0.004
2-Hexanone	4101	0.003
Methylene Chloride	2007, 2013, 2053, 2055	0.008 - 0.012
	3010, 3013, 3055	0.002 - 0.01
	4013	0.012
4-Methyl-2-pentanone	3001	0.003
	4101	0.003

See footnotes at end of table.

TABLE A-14
(Continued)

Compound	Well Location	Concentrations (mg/L)[b]
	Production Area (cont.)	
Toluene	2006, 2055	0.002 - 0.003
	3010, 3055	0.002 - 0.002
Trichloroethene	3010	0.002
bis(2-Ethylhexyl) phthalate	2109	0.014
Di-n-butyl phthalate	2054, 2109	0.004 - 0.01
n-Nitrosodiphenylamine	2109	0.003
Phenol	2007	0.014
Phenols	2006, 2007, 2013, 2053, 2054, 2055, 2118, 2120, 2389	0.012 - 0.227
	3053, 3054, 3055, 3064, 3120	0.007 - 0.165
	4013, 4064, 4101, 4102, 4103	0.007 - 0.028
	South Plume Areas	
Acetone	2014, 2015, 2060, 2094, 2095, 2106, 2129	0.002 - 0.011
	3126	0.007
Benzene	2094	0.16
	3126	0.001
2-Butanone	2015, 2060, 2095, 2106, 2129	0.004 - 0.035
	3126	0.004
Chloroform	2015	0.002
Ethylbenzene	2094	0.001
2-Hexanone	2095	0.001
Methylene chloride	2015, 2060, 2094, 2095, 2106	0.002 - 0.047
	3126	0.002
Toluene	2094	0.004
	3126	0.005
1,1,1-Trichloroethane	2015, 2060, 2095, 2106	0.001 - 0.01
Xylene (Total)	2094	0.007 - 0.19
Trichloroethene	2106	0.002
bis(2-Ethylhexyl)phthalate	2014, 2015, 2016	0.001 - 0.004

See footnotes at end of table.

TABLE A-14
(Continued)

Compound	Well Location	Concentrations (mg/L)[b]
	South Plume Areas (cont.)	
Di-n-butyl phthalate	2094	0.003
Diethyl phthalate	2065	0.02
Phenols	2014, 2017, 2045, 2046, 2047, 2048, 2049, 2060, 2061, 2065, 2069, 2094, 2095, 2106, 2125, 2126, 2127, 2128, 2129, 2387, 2391, 2394, 2396, 2550, 2551, 2555, 2559	0.005 - 0.34
	3014, 3015, 3017, 3049, 3062, 3065, 3069, 3094, 3095, 3106, 3125, 3126, 3127, 3128, 3391	0.01 - 11.5
	4014, 4015, 4016, 4125	0.01 - 0.1
	Other Areas	
Acetone	2051	0.003 - 0.028
	3043, 3051, 3066	0.004 - 0.084
Carbon disulfide	3043	0.003
Methylene chloride	2051	0.002 - 0.009
	3043, 3051, 3066	0.001 - 0.009
Toluene	2051	0.002
	3043, 3051, 3066	0.002 - 0.008
Trichloroethene	3043, 3051	0.002 - 0.009
N-Nitrosodiphenylamine	2020	0.021
Di-n-butyl phthalate	3043	0.01
Phenols	2009, 2018, 2020, 2044, 2051, 2064, 2067, 2068, 2070, 2091, 2092, 2093, 2096, 2097, 2104, 2107, 2383, 2384	0.01 - 0.22
	3009, 3018, 3020, 3043, 3044, 3051, 3068, 3070, 3092, 3093, 3096, 3097, 3098, 3107	0.006 - 0.37
	4023, 4091, 4096, 4097, 4108	0.008 - 0.172
bis(2-Ethylhexyl)phthalate	3043	0.015

[a]Based on data available in the Fernald Database as of December 1, 1991.
[b](mg/L) = milligrams per liter.

TABLE A-15
URANIUM CONCENTRATIONS IN SOIL WITHIN THE FEMP PRODUCTION AREA

Quadrant	Depths of Contamination (ft)					
	0 - 1.5	1.5 - 3	3 - 5.5	5.5 - 10	10 - 15	15 - 20
Open Areas						
Northeast Quadrant - Graphite Furnace and Oil Burner Area	X[a]	Y[b]	Z[c]	Z[c]	Z[c]	Z[c]
Northeast Quadrant - Area South of NE Scrap Meal Pile and PCB Area	Y[b]	Z[c]	Z[c]	Z[c]	Z[c]	Z[c]
Northeast Quadrant - Buffer Zone and Area East of Plant 9	X[a]	Z[c]	Z[c]	Z[c]	Z[c]	Z[c]
Northwest Quadrant - Plant 1 Drum Storage Pad and Storage Areas	Y[b]	Z[c]	Z[c]	Z[c]	Z[c]	Z[c]
Northwest Quadrant - Thorium Storage Area	X[a]	Z[c]	Z[c]	Z[c]	Y[b]	Y[b]
Southwest Quadrant - Area Between Plant 2/3 and Plant 4	Y[b]	Z[c]	Z[c]	Z[c]	Z[c]	Z[c]
Southwest Quadrant - Plant 8 Area	X[a]	Z[c]	Y[b]	Y[b]	Y[b]	Y[b]
Southwest Quadrant - Laboratory Areas	X[a]	Z[c]	Z[c]	Z[c]	Z[c]	Z[c]
Southeast Quadrant - Area East and West of Plant 5	X[a]	Z[c]	Y[b]	Z[c]	Z[c]	Y[b]
Southeast Quadrant - Areas South of Garage and East of Heavy Equipment Building	X[a]	Y[b]	Z[c]	Z[c]	Z[c]	Z[c]
Southeast and Southwest Quadrant - Area Along First Street	X[a]	Y[b]	Y[b]	Y[b]	Y[b]	Y[b]
Southeast and Northeast Quadrant - Area Between Plant 4 and Plant 5[d]	Y[b]	Y[b]	Z[c]	Z[c]	Z[c]	X[a]
Under Facilities						
Northeast Quadrant - Plant 9, Special Products Plant	X[a]	X[a]	X[a]	X[a]	Y[b]	Z[c]
Southwest Quadrant - Plant 2/3, Refinery	X[a]	X[a]	X[a]	X[a]	X[a]	X[a]
Southwest Quadrant - Building 39A, Incinerator	X[a]	X[a]	X[a]	X[a]	Y[b]	X[a]
Southwest Quadrant - Pilot Plant and Pilot Plant Tank Farm	X[a]	Y[b]	Y[b]	Y[b]	X[a]	Z[c]
Southeast Quadrant - Plant 4, Green Salt Plant	X[a]	Z[c]	Z[c]	Z[c]	Z[c]	Z[c]
Southeast Quadrant - Plant 6 Pickling and Chip Pickling Areas	X[a]	X[a]	X[a]	X[a]	X[a]	X[a]

X[a] - Concentration greater than 135 pCi/g.

Y[b] - Concentration between 35 and 135 pCi/g.

Z[c] - Concentration less than 35 pCi/g.

[d] note should be made that this table indicates uranium levels greater than 35 pCi/g in this area. However, Table A-26 of this report oes not show such elevated concentrations. A discrepancy as to the actual uranium levels for this area presently exists. However, this discrepancy will be resolved in the Operable Unit 5 RI Report.

TABLE A-16

MAXIMUM AND BACKGROUND CONCENTRATION OF RADIONUCLIDES IN SOIL PRODUCTION AND SUSPECT AREAS RI/FS SAMPLING PROGRAM[a]

(Results are in pCi/g)

Radionuclide	Northwest Quadrant	Northeast Quadrant	Southwest Quadrant	Southeast Quadrant	Fire Training Area	Incinerator/ Sewage Treatment	Clearwell Line/K-65 Slurry Line	Background
Total uranium[b]	457	3,504	3,880	90,350	67.9	4,210	5.7	4.2
Total thorium[b]	NA[c]	NA	NA	NA	NA	NA	17.1	[d]
Uranium-234	3,857	177	13,262	970[e]	361	10,977	9.52	1.4
Uranium-235/236	204	14.3	950	41.6[e]	0.7	1,730	[d]	.06
Uranium-238	4,108	179	14,321	986[e]	10.0	25,670	2.59	1.4
Thorium-228	31.2	40.9	315	7.5[e]	0.9	24.8	2.85	1.0
Thorium-230	2,749	17	288	40.3[e]	1.6	806	26.9	1.4
Thorium-232	31.4	34	283	9.1[e]	0.8	61.9	1.9	1.0
Radium-226	2,720	1.4	27.2	2.2[e]	1.2	57.4	1.01	1.5
Radium-228	56.2	105	546	5.4[e]	1.2	18.0	0.67	1.0
Cesium-137	0.5	1.0	2.9	14.4[e]	0.7	1.1	[d]	~ 0
Technetium-99	1.4	8.1	78.8	2.0[e]	[d]	228	[d]	~ 0
Strontium-90	3.1	2.7	26.3	3.6[e]	5.0	1.9	5.97	~ 0
Neptunium-237	[d]	[d]	2.6	[d]	[d]	[d]	[d]	~ 0
Plutonium-238	[d]	[d]	6.1	[d]	[d]	[d]	[d]	~ 0
Plutonium-239/240	[d]	1.5	0.9	[d]	[d]	[d]	1.04	~ 0

[a]The stated values are sampling area maximums for each analyte and are not necessarily indicative of soil chemistry at a single sample location.

[b]Results in µg/g.

[c]NA - Not analyzed.

[d]No detected concentrations were noted.

[e]Soil removed during construction program.

TABLE A-17

ISOTOPIC DISTRIBUTION[a] OF RADIOACTIVE ELEMENTS IN FEMP PRODUCTION AREA SOILS
(Results are in pCi/g)

Location[b]	U-234	U-235/236	U-238	Th-230	Th-228	Th-232	Ra-226	Ra-228
Southeast Quadrant								
West of Plant 6	31.3	2.0	35.2	3.8	0.7	<0.6[c]	0.9	0.9
East of Plant 5	1.5	<0.6[c]	1.5	1.0	0.6	<0.6[c]	0.6	0.8
Between Service Building and Health and Safety Building	970	41.6	986	40.3	7.5	9.1	2.2	5.4
Engine House/Garage and Heavy Equipment Building	41.5	3.3	52.3	6.3	1.5	1.7	1.8	1.3
Southwest Quadrant								
North of Plant 2/3	2039	398	2014	127	2.85	2.29	21.9	2.27
East of Plant 8	44.8	3.5	41.6	1.7	0.9	0.7	0.7	0.7
West of Plant 8	26.3	1.3	24.7	23.9	1.3	1.0	1.1	1.2
West of Pilot Plant	222	21	238	55.6	26.1	20.4	27.2	28.5
Northeast of Pilot Plant	55.2	4.3	47.4	0.8	<0.6[c]	<0.6[c]	0.6	1.3
North of Pilot Plant	29.2	2.7	27.4	3.8	5.3	5.2	0.9	5.0
South of Pilot Plant	8.4	0.9	7.6	1.3	2.0	1.0	1.0	1.2
Laboratory	13262	950	14321	288	315	283	2.0	546
Along First Street	114	5.5	116	22.2	5.9	5	2.6	5.3

TABLE A-17
(Continued)

Location	U-234	U-235/236	U-238	Th-230	Th-228	Th-232	Ra-226	Ra-228
	Northeast Quadrant							
Graphite Furnace/ Oil Burner Area	177.0	14.3	179	17.0	2.0	1.8	1.4	1.8
North of Maintenance Building	117	8.6	118	6.7	1.8	1.8	1.2	1.8
Southwest Corner of Plant 9	40.3	2.5	35.0	<0.6[c]	2.3	2.2	0.9	4.6
South-Southeast of Plant 9	NA	NA	NA	1.9	1.1	1.0	0.9	0.9
Northwest of Building 65	19.3	1.3	19.9	12.6	40.9	39.5	1.3	42.3
South of Buildings 64 and 65	24.8	2.4	27.9	12.8	29.3	34	1.0	105
	Northwest Quadrant							
Plant 1 Pad	3857	204	4108	2749	31.2	31.4	2720	56.2

[a]This table presents the maximum detected concentration of each isotope in a given area.

[b]See Figures A-1, A-3, A-4, A-6 and A-8 for approximate locations of buildings/facilities within each quadrant.

[c]"<0.6" means sample tested at or below detection limits.

TABLE A-18

INORGANIC CHEMICAL CONSTITUENTS DETECTED IN PRODUCTION AND SUSPECT AREA SOILS

Constituent	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Preliminary Remediation Goal Concentration (mg/kg)	Background[a] (mg/kg)
Aluminum	1920	16,800	[b]	57,000
Arsenic	2.2	26.5	130 (RfD[c])	7.4
Barium	15.4	3610	6400 (RfD)	420
Beryllium	0.57	2.4	0.2 (CSF[d])	0.85
Cadmium	2.6	8	130 (RfD)	1.7
Calcium	4850	205,000	[b]	6300
Chromium (total)	11.2	75.5	640[e] (RfD)	52
Cobalt	6.4	26	330 (RfD)	9.2
Copper	1.9	69.4	[b]	22
Iron	6800	38,900	[b]	25,000
Lead	7.2	440	90 (RfD)	17
Magnesium	2830	55,100	[b]	4600
Manganese	285	1770	12,800 (RfD)	640
Mercury	0.11	0.65	40 (RfD)	0.12
Molybdenum	2.3	5.7	510 (RfD)	0.79
Nickel	20.6	72.2	2600 (RfD)	18
Potassium	413	1770	[b]	12,000
Silver	2.2	17.2	380 (RfD)	3
Sodium	85.3	2360	[b]	7800
Thallium	0.26	0.39	9 (RfD)	0.25
Vanadium	17.7	35.6	900 (RfD)	66
Zinc	336	75.3	25,600 (RfD)	52

[a]Sources for background are: Shacklette, H.T. and J.G. Boerngen, 1984, Elemental Concentrations in Soils and Other Surficial Materials of the Conterminous United States, Washington, DC, and U.S. Geological Survey Professional Paper 1270, U.S. Dept. of the Interior, Kabato-Pendias, A. and H. Pendias, 1984, Trace Element in Soils and Plants, CRC Press, Inc., Boca Raton, FL, p. 34.

[b]Indicates no available appropriate criterion.

[c]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

[d]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

[e]The value presented is for Chromium VI.

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TABLE A-19

ORGANIC CHEMICAL CONSTITUENTS DETECTED IN PRODUCTION AND SUSPECT AREA SOILS

Constituent	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Preliminary Remediation Goal Concentration (mg/kg)[a]
Volatiles			
beta-BHC	0.046	0.22	b
PCB-1254	0.085	8.6	50 (TBC[c])
PCB-1260	0.150	2.2	50 (TBC)
Benzene	0.002	0.005	20 (CSF[d])
2-Butanone	0.001	2.4	6400 (RfD[e])
Carbon disulfide	0.002	0.006	12,800 (RfD)
Chlorobenzene	b	0.005	2560 (RfD)
Chloroform	0.002	0.046	100 (RfD)
1,1-Dichloroethane	0.006	0.31	12,800 (RfD)
1,1-Dichloroethene	0.001	0.013	1 (CSF)
1,2-Dichloroathane (total)	0.001	1.6	8 (CSF)
Ethylbenzene	0.018	0.14	1280 (RfD)
Methylene Chloride	0.003	6.7	90 (CSF)
4-Methyl-2-pentanone	0.003	0.33	6400 (RfD)
2-Propanone (acetone)	0.003	2.7	12,800 (RfD)
1,1,2,2-Tetrachloroethane	f	0.35	4 (CSF)
Tetrachloroethene	0.001	17	10 (CSF)
Toluene	0.001	0.19	25,610 (RfD)
Total Xylenes	0.082	31	256 (RfD)
1,1,1-Trichloroethane	0.001	0.21	11,530 (RfD)
Trichloroethene	0.001	150	60 (CSF)
Semivolatiles			
2-Methylnaphthalene	0.100	0.76	b
Acenaphthene	0.110	4.8	7680 (RfD)
Anthracene	0.060	6.2	38,400 (RfD)
Benzoic Acid	0.049	0.088	512,000 (RfD)
Benzo(a)anthracene	0.051	19	b
Benzo(a)pyrene	0.046	24	0.06 (CSF)
Benzo(b)fluoranthene	0.090	39	b
Benzo(g,h,i)perylene	0.067	12	b
Benzo(k)fluoranthene	0.081	5	b
bis(2-ethylhexyl)phthalate	0.038	1.1	50 (CSF)

See footnotes at end of table.

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TABLE A-19
(Continued)

Constituent	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Preliminary Remediation Goal Concentration (mg/kg)[a]
Semivolatiles (cont.)			
Chrysene	0.083	18	b
Dibenzofuran	0.055	2	b
Dibenzo(a,h)anthracene	0.14	6.9	b
Di-n-butyl phthalate	0.046	1.4	12,800 (RfD)
Fluoranthene	0.043	33	5120 (RfD)
Fluorene	0.044	3.3	5120 (RfD)
Indeno(1,2,3-cd)pyrene	0.049	13	b
Naphthalene	0.089	1.3	510 (RfD)
N-Nitrosodiphenylamine	0.046	0.63	100 (CSF)
Pentachlorophenol	0.098	0.26	6 (CSF)
Phenanthrene	0.079	22	b
Phenol	0.069	0.2	76,800 (RfD)
Pyrene	0.083	22	3800 (RfD)

[a]The letters following the numbers identify the source of the PRG levels.

[b]Indicates no available appropriate criterion.

[c]TBC - Chemical-specific guidance "to be considered" refers to pertinent suggested, nonregulatory concentration levels that represent health-based, recommended levels to be evaluated in the absence of ARARs.

[d]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

[e]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

[f]This constituent was detected only once.

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TABLE A-20

CHEMICAL CONSTITUENTS IN EXCESS OF PRELIMINARY REMEDIATION GOAL CONCENTRATIONS IN SOILS FROM THE SOUTHWEST QUADRANT

Constituent	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Preliminary Remediation Goal Concentration (mg/kg)
	Plant 2/3 Area[a]		
Beryllium	1	2.4	0.2 (CSF[b])
Lead	161	440	90 (RfD[c])
	Pilot Plant Area[d]		
Beryllium	0.82	1.7	0.2 (CSF)
Lead	26.7	117	90 (RfD)
Tetrachloroethene	0.001	17	10 (CSF)
Benzo(a)anthracene	0.43	5.4	e
Benzo(a)pyrene	0.32	5.1	0.06 (CSF)
Benzo(b)fluoranthene	0.09	4.7	e
Benzo(k)fluoranthene	0.51	5.0	e
Dibenzo(a,h)anthracene	0.14	1.5	e
Indeno(1,2,3-cd)pyrene	0.16	2.9	e
	Laboratory Area[f]		
Beryllium	g	1.2	0.2 (CSF)
Benzo(a)pyrene	0.046	0.079	0.06 (CSF)

[a]The Plant 2/3 area includes Sampling Locations 1183, 1213, 1193, and 1412 (see Figure 3-11 for general facility location).

[b]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

[c]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

[d]The Pilot Plant area includes Sampling Locations 1250, 1252, 1260, and 1411 (see Figure 3-11 for general facility location).

[e]Indicates no available appropriate criterion.

[f]The Laboratory area includes Sampling Location 1266 only (see Figure 3-11 for general facility location).

[g]This constituent had only one detected concentration.

TABLE A-21

CHEMICAL CONSTITUENTS IN EXCESS OF PRELIMINARY REMEDIATION GOAL CONCENTRATIONS IN SOILS FROM THE NORTHEAST QUADRANT

Constituent	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Preliminary Remediation Goal Concentration (mg/kg)
	Maintenance Building Area[a]		
Beryllium	0.96	1.7	0.2 (CSF[b])
Lead	22.8	334	90 (RfD[c])
Trichloroethene	0.007	150	60 (CSF)
Benzo(a)anthrancene	0.66	19	d
Benzo(a)pyrene	0.64	24	0.06 (CSF)
Benzo(b)fluoranthene	0.84	39	d
Benzo(k)fluoranthene	0.79	3.1	d
Chrysene	0.90	18	d
Dibenzo(a,h)anthracene	0.69	6.9	d
Indeno(1,2,3-cd)pyrene	1.5	13	d
	Graphite Furnace and Oil Burner Area[e]		
Beryllium	0.87	1.8	0.2 (CSF)

[a]The Maintenance Building area includes Sampling Locations 1307, 1308, 1316, 1317, and 1327 (see Figure 3-11 for general facility location).

[b]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

[c]RfD - Chemical-specific "reference dose," from U.S. EPA Health Effect Assessment Tables (HEAST) and the Integrated Risk Information System (IRIS) data, used with a hazard index factor of 0.20.

[d]Indicates no available appropriate criterion.

[e]The Graphite Furnace and Oil Burner area includes Sampling Locations 1283, 1287, 1288, and 1363 (see Figure 3-11 for general facility location).

TABLE A-22
CHEMICAL CONSTITUENTS IN EXCESS OF PRELIMINARY REMEDIATION GOAL CONCENTRATIONS IN SOILS FROM THE NORTHWEST QUADRANT

Constituent	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Preliminary Remediation Goal Concentration (mg/kg)
	Shot Blaster Area[a]		
Beryllium	1	1.5	0.2 (CSF[b])

[a]The Shot Blaster area includes Sampling Locations 1345 and 1346 (see Figure 3-11 for general facility location).

[b]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

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TABLE A-23
PRODUCTION AREA SOIL SAMPLING DEPTH

Area	Sampling Location	Sampling Depth (ft)
Southeast Quadrant		
Plant 6	1148	4.5 - 5.0
Garage and Engine House/Heavy Equipment Building	1172	10.0 - 10.5
Southwest Quadrant		
Plant 2/3	1183	0.0 - 1.0
	1193	6.0 - 7.3
	1213	6.5 - 7.0
	1412	5.5 - 6.0
Plant 8	1234	0.0 - 0.5
Pilot Plant	1250	0.0 - 1.0
	1252	0.0 - 1.0
	1260	0.0 - 1.0
	1411	9.5 - 10.5
Laboratory	1266	0.0 - 1.0
Northeast Quadrant		
Maintenance Building	1307	0.0 - 4.5
	1308	0.0 - 1.0
	1316	2.0 - 2.5
	1317	1.0 - 2.0
	1327	0.5 - 1.0
Graphite Furnace and Oil Burner Area	1283	0.0 - 1.0
	1287	0.0 - 1.0
	1288	0.0 - 1.0
	1363	0.0 - 1.0
Plant 9	1324	4.5 - 5.0
	1565	2.0 - 16.0
Northwest Quadrant		
Shot Blaster	1345	1.0 - 2.0
	1346	1.0 - 2.0

TABLE A-24

CHEMICAL CONSTITUENTS IN EXCESS OF PRELIMINARY REMEDIATION GOAL CONCENTRATIONS IN SOILS FROM THE SUSPECT AREAS

Constituent	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Preliminary Remediation Goal Concentration (mg/kg)
	Fire Training Area[a]		
Beryllium	1.4	1.9	0.2 (CSF[b])
	Clearwell Line/K-65 Slurry Line[c]		
Beryllium	-	1.2	0.2 (CSF)

[a]The Fire Training area includes Sampling Locations 1508, 1509, 1510, 1511, 1512, 1513, 1514, and 1515 (see Figure 3-11 for general facility location).

[b]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

[c]The Clearwell Line/K-65 Slurry Line includes the Trench Sample No. 1482 only.

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TABLE A-25
CHEMICAL CONSTITUENTS IN EXCESS OF PRELIMINARY REMEDIATION GOAL CONCENTRATIONS IN SOILS FROM THE NORTHEAST QUADRANT
(1991 Additional Sampling)

Constituent	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Preliminary Remediation Goal Concentration (mg/kg)
	Northwest of Maintenance Building		
Beryllium	0.49	1.7	0.2 (CSF[a])
Benzo(a)anthracene	0.5	5.1	b
Benzo(b)fluoranthene	0.29	8.0	b
Benzo(a)pyrene	0.079	3.4	0.06 (CSF)
Dibenzo(a,h)anthracene	c	1.1	b
Indeno(1,2,3-cd)pyrene	c	2.2	b
	Southeast of Maintenance Building		
Beryllium	0.77	1.2	0.2 (CSF)
Benzo(a)pyrene	c	0.49	0.06 (CSF)
Indeno(1,2,3-cd)pyrene	c	0.33	b

[a]CSF - Chemical-specific "cancer slope factor," from U.S. EPA HEAST and IRIS, used with a 10^{-6} risk level.

[b]Indicates no available appropriate criterion.

[c]This constituent had only one detected concentration.

TABLE A-26

VOLUME OF SOIL CONTAINING URANIUM ABOVE THE PRG (35 pCi/g) FOR THE SOUTHEAST QUADRANT OPERABLE UNIT 5

AREA ID[a]	AREA	DEPTH (ft) 0.0 – 1.5	1.5 – 3.0	3.0 – 5.5	5.5 – 10	10 – 15	15 – 20	VOLUME (yd³)
SE1	AREA BETWEEN PLANT 4 AND PLANT 5	-- / 500'X225'	-- / --	50' DIA[b] / 100' DIA	-- / --	-- / --	-- / --	7,000
SE2	AREA ALONG 1st STREET	250'X100' 150'X150' 125'X75' 300'X100' / 1550'X200'	-- / 400'X100'	-- / 150'X50'	-- / 150'X50'	-- / 75' DIA	-- / 2@50' DIA	23,000
SE3	AREAS SOUTH OF GARAGE AND EAST OF HEAVY EQUIPMENT BUILDING	2@50' DIA / 200'X100' 150'X100'	-- / 2@100' DIA	-- / --	-- / --	-- / --	-- / --	2,800
SE4	AREA EAST OF PLANT 5, METALS PRODUCTION PLANT	100'X50' / 250'X100'	-- / --	-- / 75' DIA	-- / --	-- / --	-- / 75' DIA	2,600
SE5	BUFFER ZONE AND AREA EAST OF PLANT 9	-- / 1200'X300'	-- / --	-- / --	-- / --	-- / --	-- / --	20,000
SE6	SOUTH AND WEST FENCELINE	-- / 3@50' DIA	-- / --	-- / --	-- / --	-- / --	-- / --	230
SE7	PLANT 4, GREEN SALT PLANT	50' DIA / 100' DIA	-- / --	-- / --	-- / --	-- / --	-- / --	440
SE8	PLANT 6 PICKLING AREA	200'X75' 75' DIA / 350'X300'	200'X75' 50' DIA / 350'X300'	200'X250' / 350'X300'	200'X250' / 350'X300'	2@50' DIA / 350'X300'	150'X250' / 350'X250'	74,600
SE9	PLANT 6 CHIP PICKLING AREA	75' DIA / 250'X100'	-- / 150'X150'	50' DIA / 100' DIA	-- / --	-- / --	-- / --	3,400
							TOTAL VOLUME (yd³)	134,000

NOTE:

MEASUREMENT–DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS > 135 pCi/g

MEASUREMENT–
DIMENSION OF CONTAMINATED MATERIAL
WITH URANIUM CONCENTRATIONS BETWEEN
35 AND 135 pCi/g

-- = URANIUM CONCENTRATIONS LESS THAN 35 pCi/g

[a] SEE FIGURE 3-11 FOR AREA ID.
[b] DIA = DIAMETER

TABLE A-27

VOLUME OF SOIL CONTAINING URANIUM ABOVE THE PRG (35 pCi/g) FOR THE SOUTHWEST QUADRANT OPERABLE UNIT 5

AREA ID[a]	AREA	DEPTH (ft) 0.0 – 1.5	1.5 – 3.0	3.0 – 5.5	5.5 – 10	10 – 15	15 – 20	VOLUME (yd³)
SW1	AREA BETWEEN PLANT 2/3 AND PLANT 4	150'X100'	--	--	--	--	--	830
SW2	AREA WEST OF PLANT 8 HYDROCHLORIC ACID METAL DISSOLVER	--	--	75' DIA[b]	75' DIA	100' DIA	100' DIA	4,100
SW3	AREA ALONG 1st STREET	(TOTAL VOLUME ACCOUNTED FOR IN SOUTHEAST QUADRANT (SE2))						
SW4	AREA NORTH OF PLANT 8	50' DIA 100'X150'	--	75' DIA	75' DIA	75' DIA	--	2,800
SW5	PLANT 8 LOADING DOCK	--	--	--	--	50'X100' 150'X100'	100' DIA	4,200
SW6	AREA BETWEEN LABORATORY AND PILOT PLANT	2@50' DIA 300'X150'	--	--	--	--	--	2,500
SW7	AREAS AROUND LABORATORY	100' DIA · 50' DIA 75'X50' 150'X50'	--	--	--	--	--	1,100
SW8	AREAS NORTH OF PILOT PLANT	2@75' DIA	--	--	--	--	--	490
SW9	SOUTH AND WEST FENCELINE	(TOTAL VOLUME ACCOUNTED FOR IN SOUTHEAST QUADRANT (SE8))						
SW10	BUILDING 39A, INCINERATOR	2@50' DIA 200'X200'	100' DIA 150'X75'	150'X50' 200'X100'	150'X50' 200'X100'	-- 100'X75'	100' DIA 200'X100'	13,100
SW11	PILOT PLANT AND PILOT PLANT TANK FARM	25' DIA 125'X150'	-- 75' DIA	-- 75' DIA	-- 75' DIA	50'X125' 100'X150'	--	5,200
SW12	PLANT 2/3, REFINERY	200'X100' 3@100' DIA 50' DIA 600'X300'	50' DIA 150'X75' 75' DIA	2@50' DIA 200'X100' 200'X75'	2@50' DIA 200'X75' 200'X100'	2@50' DIA 100' DIA 200'X100' 250'X100'	2@50' DIA 200'X150' 3@75' DIA	37,700
						TOTAL VOLUME (yd³)		72,000

NOTE:

MEASUREMENT–DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS > 135 pCi/g

MEASUREMENT–DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS BETWEEN 35 AND 135 pCi/g

-- = URANIUM CONCENTRATIONS LESS THAN 35 pCi/g

[a] SEE FIGURE 3–12 FOR AREA ID.

[b] DIA = DIAMETER

TABLE A-28

VOLUME OF SOIL CONTAINING URANIUM ABOVE THE PRG (35 pCi/g) FOR THE NORTHEAST QUADRANT OPERABLE UNIT 5

AREA ID [a]	AREA	DEPTH (ft) 0.0 – 1.5	1.5 – 3.0	3.0 – 5.5	5.5 – 10	10 – 15	15 – 20	VOLUME (yd^3)
NE1	AREA SOUTH OF PLANT 9	425'X200'	100'X100'	--	--	--	50' DIA[b] 150'X75'	7,400
NE2	AREAS WEST OF TANK FARM AND SUMP	50' DIA 100' DIA	--	--	--	--	--	540
NE3	GRAPHITE FURNACE AND OIL BURNER AREA	200'X100' 50' DIA 600'X700'	50' DIA 2@100' DIA	--	--	--	--	24,200
NE4	AREA SOUTH OF NORTHEAST SCRAP METAL PILE	450'X450'	--	--	--	--	--	11,300
NE5	AREA SOUTH TO KC-2 WAREHOUSE	550'X150'	--	--	--	--	--	4,600
NE6	DRUM BAILING AREA	200'X150' 500'X400'	--	50' DIA	--	--	--	11,300
NE7	SCRAP METAL PILE AREA (N.E. QUADRANT)	150'X100' 400'X250'	--	50' DIA	--	--	--	5,700
NE8	PLANT 9, SPECIAL PRODUCTS PLANT	2@50' DIA 150'X100'	50' DIA 100' DIA	50' DIA 75' DIA	50' DIA 75' DIA	75' DIA	--	3,200
						TOTAL VOLUME (yd^3)		68,200

NOTE:

MEASUREMENT–DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS > 135 pCi/g

MEASUREMENT–DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS BETWEEN 35 AND 135 pCi/g

-- = URANIUM CONCENTRATIONS LESS THAN 35 pCi/g

[a] SEE FIGURE 3-13 FOR AREA ID.
[b] DIA = DIAMETER

TABLE A-29

VOLUME OF SOIL CONTAINING URANIUM ABOVE THE PRG (35 pCi/g) FOR THE NORTHWEST QUADRANT OPERABLE UNIT 5

AREA ID[a]	AREA	DEPTH (ft) 0.0 – 1.5	1.5 – 3.0	3.0 – 5.5	5.5 – 10	10 – 15	15 – 20	VOLUME (yd³)
NW1	PLANT 1 DRUM STORAGE PAD AND STORAGE AREAS	200'X100' 100' DIA[b] 500'X250'	-- --	-- 50' DIA	-- --	-- --	-- --	7,600
NW2	THORIUM STORAGE AREA	150'X100' 200'X100' 250'X250'	-- --	-- --	-- --	-- 75' DIA	-- 100' DIA	6,900
NW3	AREAS WEST OF TANK FARM AND SUMP	(TOTAL VOLUME ACCOUNTED FOR IN NORTHEAST QUADRANT (NE2))						
NW4	SCRAP METAL PILE AREA (N.W. QUADRANT)	150'X50' 250'X100'	-- --	-- 300'X300'	-- --	-- --	-- --	10,200
NW5	CONSTRUCTION RUBBLE MOUND	-- 400'X150'	-- --	-- --	-- --	-- --	-- --	3,300
						TOTAL VOLUME (yd³)		28,000

NOTE:

MEASUREMENT–DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS > 135 pCi/g

MEASUREMENT–
DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS BETWEEN 35 AND 135 pCi/g

-- = URANIUM CONCENTRATIONS LESS THAN 35 pCi/g

[a] SEE FIGURE 3–14 FOR AREA ID.
[b] DIA = DIAMETER

TABLE A-30
VOLUME OF SOIL CONTAINING URANIUM ABOVE THE PRG (35 pCi/g) FOR THE SUSPECT AREAS OPERABLE UNIT 5

AREA ID[a]	AREA	DEPTH (ft) 0.0 – 1.5	1.5 – 3.0	3.0 – 5.5	5.5 – 10	10 – 15	15 – 20	VOLUME (yd^3)
SA1	FIRE TRAINING AREA	100' DIA[b]	--	--	--	--	--	440
SA2	SEWAGE TREATMENT PLANT /INCINERATOR AREA	100' DIA 350'X450'	50' DIA 150'X100'	150'X75'	150'X75'	100' DIA	--	14,000
SA3	INCINERATOR (SEWAGE TREATMENT PLANT AREA)	100' DIA 100' DIA	--	--	--	--	--	440
SA4	K-65 SLURRY LINE	1000'X50'	--	--	--	--	--	2800
						TOTAL VOLUME (yd^3)		17,700

NOTE:

MEASUREMENT–DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS > 135 pCi/g

MEASUREMENT–DIMENSION OF CONTAMINATED MATERIAL WITH URANIUM CONCENTRATIONS BETWEEN 35 AND 135 pCi/g

-- = URANIUM CONCENTRATIONS LESS THAN 35 pCi/g

[a] SEE FIGURES 3–15, 3–16, AND 3–17 FOR AREA ID.

[b] DIA = DIAMETER

TABLE A-31
RADIONUCLIDES IN SOIL OUTSIDE THE PRODUCTION AND SUSPECT AREAS 1991 RI/FS SAMPLING PROGRAM

Radionuclide	Range of Detected Concentrations (pCi/g)	Background Concentration[a] (pCi/g)
Cesium-137	[b]	~ 0 [c]
Neptunium-237	[b]	~ 0 [c]
Plutonium-238	[b]	~ 0 [c]
Plutonium-239/240	[b]	~ 0 [c]
Radium-226	0.3 - 1.7	1.5 [d]
Radium-228	0.4 - 1.3	1.0 [e]
Ruthenium-106	[b]	~ 0 [c]
Strontium-90	0.8 [f]	~ 0 [c]
Technetium-99	[b]	~ 0 [c]
Thorium-228	0.7 - 7.6	1.0 [e]
Thorium-230	0.6 - 2.0	1.4 [e]
Thorium-232	0.6 - 1.1	1.0 [d]
Uranium-234	0.6 - 6.5	1.4 [g]
Uranium-235/236	[b]	0.06 [g]
Uranium-238	0.7 - 6.1	1.4 [d]

[a]Background radionuclide concentrations in soil are based on regional data and not FEMP-specific data.

[b]No detected concentrations were reported.

[c]Not naturally occurring; background is assumed to be zero.

[d]Myrick, T.E. et al., (1983), "Determination of Concentrations of Selected Radionuclides in Surface Soil in the U.S.," Health Physics, Vol. 45, No. 3, pp. 631-642.

[e]Equilibrium is assumed with activity of parent.

[f]Only one detected concentration was noted.

[g]Derived assuming natural isotopic ratios of uranium.

TABLE A-32
URANIUM IN SOIL DATA FROM ROUTINE SOIL SAMPLING LOCATIONS[a]
(Samples taken from 0-4 inches)

	Along FEMP Boundary		Outside FEMP Boundary	
Year	No. of Samples	Concentration Range (pCi/g)	No. of Samples	Concentration Range (pCi/g)
1975	6	4.0 - 39		
1976	6	3.1 - 39	NS[b]	c
1977	6	3.2 - 45	NS	c
1978	6	3.7 - 35	NS	c
1979	6	3.7 - 37	NS	c
1980	6	3.0 - 21	NS	c
1981	7	1.0 - 45	NS	c
1982	7	1.3 - 21	NS	c
1983	7	2.7 - 53	8	2.0 - 16
1984	7	3.3 - 69	8	1.8 - 14
1985	7	0.42 - 36	8	0.35 - 14
1986	7	3.4 - 46	7	1.4 - 2.5
1987	7	4.1 - 56	7	1.4 - 7.7
1988[d]	9	5.1 - 73	19	1.4 - 5.4
1989[d]	9	3.1 - 79	21	2.2 - 15
1990[d]	9	6.4 - 41	21	1.1 - 7.2

[a]FMPC Environmental Monitoring Reports.

[b]Not sampled.

[c]Not applicable.

[d]Includes two on-site samples.

TABLE A-33
RADIONUCLIDES IN SOIL OUTSIDE FEMP BOUNDARY[a]

Radionuclide	Number of Samples	Minimum Concentration (pCi/g)	Maximum Concentration (pCi/g)
Neptunium-237	25	0.0	0.0
Plutonium-238	25	0.0	0.0
Plutonium-239,240	25	0.0	0.0
Technetium-99	25	0.0	4.0
Thorium-228	25	0.3	1.6
Thorium-230	25	0.4	2.0
Thorium-232	25	0.4	1.7
Uranium	25	1.4	11.8

[a]Environmental Monitoring Report, 1984.

TABLE A-34
TOTAL URANIUM CONCENTRATION IN PARALLEL VEGETATION AND SOIL SAMPLING[a]

Year	Number of Samples	Concentration Range (pCi/g)
1985	10 on site	1.3 - 65
	11 on site	1.1 - 5.7
1986	NS[b]	
1987	9 on-site	2.0 - 2.4
	9 off-site	1.2 - 6.5

[a]FMPC Environmental Monitoring Reports.

[b]Not sampled.

NOTE: In 1988, the parallel vegetation and soil sampling program was combined with the routine soil sampling program. Therefore, from 1988 to present, the concentration ranges are covered in Table A-15, Routine Soil Sampling Locations.

TABLE A-35
RADIONUCLIDES IN SURFACE WATER[a]

Radionuclide	Location[b]	Concentration Range (pCi/L)					
		1985	1986	1987	1988	1989	1990
Gross alpha	GMR[c]	0.81 - 7.21	1 - 8	<0.9[d] - 8.1	0.9 - 8.6		
	PR[e]	0.45 - 428.38	0.81 - 639	<0.9 - 16	0.45 - 824		
	SSOD[f]	NS[g]	NS	NS	NS		
Gross beta	GMR	0.81 - 17.12	0.81 - 55	2.7 - 108	3.6 - 36		
	PR	0.90 - 140.09	0.54 - 164	1.4 - 32	1.8 - 369		
	SSOD	NS	NS	NS	NS		
Cesium-137	GMR	<2.43 - <5.41	<5 - <10.0	<2.00 - <4.16	<3.9 - <7.5	<8.0 - <11	<4.7 - <11
	PR	NS	NS	NS	NS	NS	NS
	SSOD	NS	NS	NS	NS	NS	NS
Radium-226	GMR	<0.45 - 0.45	<0.5 - <0.5	<0.5 - <0.5	<0.45 - 0.45	<0.001 - 0.001	<0.10 - 0.38
	PR	<0.45 - 0.45	<0.5 - <0.8	<0.5 - <0.5	<0.45 - 0.90	<0.001 - 0.001	0.00061 - 0.58
	SSOD	NS	NS	NS	NS	NS	NS
Radium-228	GMR	<0.45 - 0.45	<0.5 - <1	<0.5 - <0.9	<0.45 - 090	<0.001 - 0.003	0.42 - 5.1
	PR	<0.45 - 0.45	<0.5 - <1	<0.5 - <0.9	<0.45 - 0.90	<0.001 - 0.001	0.77 - 1.2
	SSOD	NS	NS	NS	NS	NS	NS
Strontium-90	GMR	0.27 - 1.89	<1.1 - 2.4	<0.6 - <0.7	0.08 - 0.33	<0.17 - 0.19	0.22 - 1.6
	PR	NS	NS	NS	NS	NS	NS7
	SSOD	NS	NS	NS	NS	NS	NS
Technetium-99	GMR	1.08 - 4.86	2 - 7	<11.9 - <20.9	<9.1 - <10.6	<16 - <21	<15 - <18
	PR	NS	NS	NS	NS	NS	NS
	SSOD	NS	NS	NS	NS	NS	NS
Uranium-234	GMR	3.40 - 4.58	0.81 - 1.1	1.0 - 1.3	0.78 - 1.2		
	PR	NS	NS	NS	NS		
	SSOD	NS	NS	NS	NS		
Uranium-235/236	GMR	0.15 - 0.20/0.04 - 0.07	0.030/0.0050 - 0.027	<0.2 - 0.2	<0.02 - <0.02		

See footnotes at end of table.

TABLE A-35
(Continued)

Radionuclide	Location[b]	Concentration Range (pCi/L)					
		1985	1986	1987	1988	1989	1990
	PR	NS	NS	NS	NS		
	SSOD	NS	NS	NS	NS		
Uranium-238	GMR	3.41 - 4.65	0.81 - 1.1	0.8 - 1.2	0.73 - 1.1		
	PR	NS	NS	NS	NS		
	SSOD	NS	NS	NS	NS		
Total uranium	GMR	0.88 - 15.57	0.81 - 4.6	0.74 - 3.9	0.61 - 2.9	0.95 - 2.4	0.81 - 2.0
	GMR	-	0.40 - 1.60[h]	<0.67 - 3.35[i]	-	-	-
	PR	0.47 - 1827.90	0.54 - 718	0.47 - 88	0.27 - 812	0.47 - 640	0.68 - 1100
	PR	-	0.95 - 7.06[h]	-	-	-	-
	SSOD	NS	NS	NS	2905	NS	NS

[a]All data from FMPC Environmental Monitoring Reports, except where noted.

[b]See Figure 3-12 for Environmental Monitoring Program sampling locations.

[c]Great Miami River.

[d]Concentration less than reported detection limit.

[e]Paddys Run.

[f]Storm Sewer Outfall Ditch.

[g]Not sampled.

[h]From IT Interim Report: Air, Soil, Water, and Health Risk Assessment in the Vicinity of the FMPC (Exhibit D).

[i]From IT Hydrogeological Study of FMPC Discharge to the Great Miami River, August 1988.

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TABLE A-36
RADIONUCLIDES IN SURFACE WATER
RI/FS SAMPLING

		Concentration Ranges (pCi/L)			
		1988		1989	
Radionuclide	Location	Filtered[a]	Unfiltered	Filtered	Unfiltered
Uranium-234	GMR[b]	<1.0-1.9	<1.0-2.2	<1.0	<1.0-1.0
	PR[c]	NS[d]	NS	1.2-4.0	1.3-5.0
	SSOD[e]	NS	NS	<1.0-15.9	<1.0
Uranium-235/236	GMR	<1.0	<1.0	<1.0	<1.0-<1.1
	PR	NS	NS	<1.0	<1.0
	SSOD	NS	NS	<1.0	<1.0
Uranium-238	GMR	<1.0-1.8	<1.0-2.0	<1.0	<1.0-1.2
	PR	NS	NS	2.8-6.2	2.0-6.8
	SSOD	NS	NS	<1.0-15.9	1.3
U-Sum[f]	GMR	<1.0-3.60	<1.0-4.10	<1.0	<1.0-1.20
	PR	NS	NS	5.0-10.10	3.30-11.80
	SSOD	NS	NS	0.00-31.80	1.30
U-Total[g]	GMR	<1.00-5.00	<1.00-5.00	1.00	<1.00-3.00
	PR	NS	NS	9.00-25.00	5.00-19.00
	SSOD	NS	NS	2.00-44.0	2.00-24.00
Radium-226	GMR	<1.0	<1.0	<1.0	<1.0-2.4
	PR	NS	NS	<1.0	<1.0
	SSOD	NS	NS	<1.0	<1.0
Radium-228	GMR	<3.0-<3.4	<3.0-5.0	<3.0	<3.0
	PR	NS	NS	<3.0	<3.0
Radium-228 (cont.)	SSOD	NS	NS	<3.0	<3.0
Technetium-99	GMR	<30.0-48.4	<30.0-95.9	<30.0-<92.6	<30.0

See footnotes at end of table.

TABLE A-36
(Continued)

Radionuclide	Location	Concentration Ranges (pCi/L) 1988 Filtered[a]	1988 Unfiltered	1989 Filtered	1989 Unfiltered
	PR	NS	NS	<30.0	<30.0
	SSOD	NS	NS	<30.0	<30.0
Plutonium-238	GMR	<1.0	<1.0	<1.0	<1.0
	PR	NS	NS	<1.0	<1.0
	SSOD	NS	NS	<1.0	<1.0
Plutonium-239/240	GMR	<1.0	<1.0	<1.0	<1.0
	PR	NS	NS	<1.0	<1.0
	SSOD	NS	NS	<1.0	<1.0
Thorium-228	GMR	<1.0-2.4	<1.0-2.6	<1.0	<1.0
	PR	NS	NS	<1.0	<1.0
	SSOD	NS	NS	<1.0	<1.0
Thorium-230	GMR	<1.0	<1.0	<1.0	<1.0-1.3
	PR	NS	NS	<1.0	<1.0
	SSOD	NS	NS	<1.0	<1.0
Thorium-232	GMR	<1.0	<1.0	<1.0	<1.0
	PR	NS	NS	<1.0	<1.0
	SSOD	NS	NS	<1.0	<1.0
Strontium-90	GMR	<5.0	<5.0	<5.0	<5.0
	PR	NS	NS	<5.0	<5.0
Strontium-90 (cont.)	SSOD	NS	NS	<5.0	<5.0
Cesium-137	GMR	<20.0	<20.0	<20.0	<20.0-<30.0
	PR	NS	NS	<20.0	<20.0
	SSOD	NS	NS	<20.0	<20.0

See footnotes at end of table.

TABLE A-36
(Continued)

Radionuclide	Location	Concentration Ranges (pCi/L) 1988 Filtered[a]	1988 Unfiltered	1989 Filtered	1989 Unfiltered
Nobelium-237	GMR	<1.0	<1.0	<1.0	<1.0
	PR	NS	NS	<1.0	<1.0
	SSOD	NS	NS	<1.0	<1.0
Ruthenium-106	GMR	<150.0	<150.0	<150.0	<150.0
	PR	NS	NS	<150.0	<150.0
	SSOD	NS	NS	<150.0	<150.0

[a]The data are presented for filtered and unfiltered water samples.

[b]Great Miami River.

[c]Paddys Run.

[d]Not sampled.

[e]Storm sewer outfall ditch.

[f]U-Sum is the additive total of U-234, U-235/236, and U-238 concentrations.

[g]Analyzed for total uranium; units µg/L.

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TABLE A-37
AVERAGE TOTAL URANIUM CONCENTRATION IN PADDYS RUN SURFACE WATER 1975 THROUGH 1989
(Results are in µg/L)

Year	Sampling Locations[a]				Source
	W5	W7	W10	W11	
1975	6	27	NA[b]	NA	c
1976	4	16	NA	NA	c
1977	8	14	NA	NA	c
1978	8	22	NA	NA	c
1979	3	15	NA	NA	c
1980	4	28	NA	NA	d
1981	4	31	NA	NA	d
1982	<4	17	NA	NA	d
1983	2	112[e]	NA	NA	d
1984	2	23	NA	NA	f
1985	2.4	64.7[e]	351.5[e]	14.7	g
1986	1.6	73.1[e]	16.4	43.3[e]	g
1987	1.5	8.7	10.1	8.7	g
1988	1.2	10.4	58.2[e]	8.5	g
1989	NA	12	8.5	14	h
1989	1.3	9.6	104.5	10.0	g
1990	1.1	9.7	113.4	13.3	g

[a] Sampling locations are as follows: W5, immediately north of Ohio Route 126; W7, Paddys Run at Willey Road; W10, near K-65 silos; and W11, just upstream of Paddys Run and storm sewer outfall ditch confluence.

TABLE A-37
(Continued)

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Data not available.

[c]Dames and Moore Ground Water Study, Task C Report, 1985.

[d]FMPC Environmental Monitoring Reports for 1980, 1981, 1982, and 1983.

[e]Average value is probably too high due to a single high reading which is included in the average.

[f]FMPC Environmental Monitoring Report for 1984. Converted from pCi/L to µg/L by 1 pCi = 1.4925 µg.

[g]FMPC Environmental Monitoring Reports for 1985, 1986, 1987, 1988, 1989, and 1990. Converted from pCi/L to µg/L by 1 pCi = 1.4925 µg.

[h]FEMP RI/FS, average of two rounds, nonfiltered data used.

TABLE A-38

URANIUM CONCENTRATIONS IN SURFACE WATER OF THE GREAT MIAMI RIVER (REPORTED IN FMPC ENVIRONMENTAL MONITORING REPORTS)

Sampling Point	Year	Number of Samples	Concentration Range (pCi/L)	Average
W1	1984	52	0.68 - 25.7	1.6
W3		52	0.68 - 16.2	1.6
W4		52	0.68 - 19.0	1.6
W1	1985	52	0.95 - 8.8	1.6
W3		52	0.95 - 2.6	1.6
W4		52	0.88 - 15.6	1.9
W1	1986	52	0.81 - 3.0	1.2
W3		52	0.81 - 2.4	1.4
W4		52	0.81 - 4.6	1.4
W1	1987	52	0.74 - 2.2	1.2
W3		52	0.88 - 3.9	1.6
W4		52	1.0 - 3.0	1.7
W1	1988	52	0.61 - 1.6	0.98
W3		52	0.81 - 2.8	1.5
W4		52	0.81 - 2.9	1.4
W1	1989	51	0.95 - 2.2	1.4
W3		51	1.0 - 2.4	1.5
W4		38	1.0 - 2.2	1.5
W1	1990	52	0.81 - 2.0	1.2
W3		49	0.88 - 2.0	1.4
W4		46	0.81 - 1.8	1.3

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TABLE A-39

SURFACE WATER SUMMARY DATA[a]
RADIONUCLIDES DETECTED DURING RI/FS SAMPLING

Location	Stats	U-234[b]	U235/236	U-238	U-SUM	Ra-226	Ra-228	Tc-99	Pu-238	Pu-239/240	Th-228	Th-230	Th-232	U-Tot (ug/l)
GMR[c] above	min	<1.0	<1.0	<1.0	0.00	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.00
effluent	max	1.1	<1.0	<1.0	1.10	<1.0	<3.0	<92.6	<1.0	<1.0	<1.0	<1.0	<1.0	1.00
GMR below	min	<1.0	<1.0	<1.0	0.00	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.00
effluent	max	1.9	<1.0	1.8	3.70	2.4	<3.8	<30.0	<1.0	<1.0	<1.8	<1.0	<1.0	5.00
GMR below	min	<1.0	<1.0	<1.0	0.00	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.00
CON W/PR[d]	max	1.8	<1.0	2.0	3.80	<1.0	<5.0	<30.0	<1.0	<1.0	<2.6	1.3	<1.0	5.00
PR above	min	1.2	<1.0	2.0	3.30	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	5.00
SSOD[e]	max	5.0	<1.0	6.8	11.80	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	19.00
SSOD	min	<1.0	<1.0	<1.0	0.00	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.00
	max	15.9	<1.0	15.9	31.80	1.5	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	1829.00
PR below	min	1.6	<1.0	4.0	5.6	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	9.00
SSOD	max	3.2	<1.0	6.1	10.10	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	20.00
MH[f]-175	min	153.0	16.5	168.0	337.5	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	715.00
	max	375.0	37.0	339.0	751.00	<1.0	5.5	21887.0	<1.0	<1.0	<1.0	1.2	4.7	1021.00

See footnotes at end of table.

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TABLE A-39
(Continued)

Location	Stats	U-234[b]	U235/236	U-238	U-SUM	Ra-226	Ra-228	Tc-99	Pu-238	Pu-239/240	Th-228	Th-230	Th-232	U-Tot (ug/l)
Misc.	min	<1.0	<1.0	2.9	4.50	<1.0	<3.0	<30.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.00
ditches	max	653.0	51.5	2840.0	3544.50	16.3	127.2	206.0	<1.0	<1.0	<1.0	<1.0	<1.0	9318.00

[a]Surface water and sediment (Table A-46) samples were collected from similar locations; refer to Figure 3-12 for sampling locations. Summary of the laboratory results consist of 199 surface water samples collected in 1988 and 1989.

[b]The results are presented in pCi/L with the exception of U-total (ug/L).

[c]Great Miami River

[d]Paddys Run

[e]Storm Sewer Outfall Ditch

[f]Manhole 175

TABLE A-40
CHEMICALS IDENTIFIED IN SURFACE WATER OF PADDYS RUN

Chemical	Frequency of Detection	Range of Sample Detection Limits[a]	Range of Detected Site-Influenced Concentrations[a]	Average Site-Influenced Concentrations[a,b,c]	Range of Detected Background Levels[d,e]
Organics (ug/L)					
Bis(2-ethylhexyl)phthalate	2/3	<10	2.0 - 4.0	5.3	NA
Diethylphthalate	1/2	<10	2.0	6.0	NA
N-nitrosodiphenylamine	1/2	<10	4.0	7.0	NA
Inorganics (ug/L)					
Aluminum	4/5	<60	76.4-451.0	164.8	NA
Antimony	1/2	<0.5	2.5	[d]	NA
Arsenic	1/7	<2	18.8	[d]	ND (<2 - <5)
Barium	7/7	[b]	26.7 - 65.8	40.7	49.3 - 100 (79.2)
Beryllium	2/2	[b]	1.1 - 1.2	1.2	NA
Cadmium	4/7	<2	1.6 - 3.2	2.4	3.1 - 9.8 (4.7)
Chromium	3/6	<10	13.9 - 24.3	14.3	6.1
Cobalt	0/2	<10	ND	ND	NA
Copper	3/7	<10	8.1 - 14.7	10.4	9.1 - 11.9 (10.2)
Lead	6/7	< 2	2.1 - 9.3	4.9	2.1 - 10 (5.9)
Magnesium	7/7	[b]	9,970 - 21,400	15.52	21,400 - 38,951 (28,033)
Manganese	7/7	[b]	9.7 - 46.2	22.5	8.9 - 80 (48.2)
Mercury	4/7	<0.3	0.2 - 0.8	0.3	0.7 - 9.5 (1.8)

See footnotes at end of table.

TABLE A-40
(Continued)

Chemical	Frequency of Detection	Range of Sample Detection Limits[a]	Range of Detected Site-Influenced Concentrations[a]	Average Site-Influenced Concentrations[a,b,c]	Range of Detected Background Levels[d,e]
Inorganics (cont.)					
Molybdenum	1/2	<3	20.5	[d]	7 - 20 (16.8)
Nickel	1/7	<20	8.0	[d]	10.5 - 13.1 (17.3)
Selenium	1/7	<2	16.9	[d]	ND (<2 - <3)
Silver	0/7 (<0.5 - <10.0)	ND	ND	10 - 30 (10.2)	
Vanadium	2/5	<10	13.6 - 17.7	12.3	NA
Zinc	2/2	[b]	11.1 - 36.8	24.0	NA

[a]Calculated from single and double rounds at sampling sites of W-7, W-10, W-11, ASIT-3, and ASIT-9.

[b]When determining average concentrations,nondetected chemicals were assumed to be at the detection limit.

[c]Averages were not determined with less than two positive hits.

[d]Background values are calculated using data from sampling locations GMR-1 and W-1. When two or more data points are given, arithmetic mean is given in brackets.

[e]Some detection limits for background samples were eliminated from consideration as being too high. This lowered the average background values of background detection limits for arsenic, lead, molybdenm, and selenium.

ND - Not detected.

NA - Not analyzed.

TABLE A-41
CHEMICALS IDENTIFIED IN SURFACE WATER OF THE GREAT MIAMI RIVER

Chemical	Frequency of Detection	Range of Sample Detection Limits[a]	Range of Detected Site-Influenced Concentrations[a]	Average Site-Influenced Concentrations[a,b,c]	Range of Detected Background Levels[d,e]
Organics (µg/L)	None detected				
Inorganics (ug/L)					
Aluminum	0/0	NA	NA	NA	NA
Antimony	0/0	NA	NA	NA	NA
Arsenic	2/7	<2 - <5	2.1 - 6.0	3.4	ND (<2 - <5)
Barium	9/9	b	37.9 - 106.0	82.8	8.9 - 100 (52.8)
Beryllium	0/0	NA	NA	NA	NA
Cadmium	4/9	<2 - <5	1.8 - 5.0	3.2	3.1 - 9.8 (4.7)
Chromium	2/3	<2	2.0 - 3.7	2.6	6.1
Cobalt	0/0	NA	NA	NA	NA
Copper	3/9	<10	6.9 - 14.2	10.1	9.1 - 11.9 (10.2)
Lead	6/6	b	2.2 - 14.0	8.5	2.1 - 10 (5.9)
Magnesium	9/9	b	16,500 - 36,900	28,288.9	21,400 -33,900 (28,033)
Manganese	9/9	b	7.8 - 100	56.4	8.9 - 80 (48.2)
Inorganics (cont)					
Mercury	2/9	<0.2	0.6 - 1.0	0.3	0.7 - 9.5 (1.8)
Molybdenum	1/3	<3	20.0	c	7 - 20 (16.8)
Nickel	3/9	<20	7.2 - 11.4	16.7	10.5 - 13.1 (17.3)

See footnotes at end of table.

TABLE A-41
(Continued)

Chemical	Frequency of Detection	Range of Sample Detection Limits[a]	Range of Detected Site-Influenced Concentrations[a]	Average Site-Influenced Concentrations[a,b,c]	Range of Detected Background Levels[d,e]
Selenium	1/6	<2 - <32.0	c	ND	(<2 - <3)
Silver	0/9	<0.5 - <10	ND	ND	10 - 30 (10.2)
Vanadium	0/0	NA	NA	NA	NA
Zinc	0/0	NA	NA	NA	NA

[a]Based on data from sampling locations GMR-2, GMR-3, and GMR-4.

[b]When determining average concentrations, nondetected chemicals were assumed to be at the detection limit.

[c]Average were not determined with less than two positive hits.

[d]Background values are based on data from sampling locations GMR-1 and W-1. In some cases average concentration may be lower than the minimum detected concentration.

[e]Some detection limits for background samples were eliminated from consideration as being too high. This lowered the average background values or range of background detection limits for arsenic, lead, molybdenum, and selenium.

ND - Not detected.

NA - Not analyzed.

TABLE A-42
SURFACE WATER SAMPLING RESULTS
DRUM BALING AREA

Location[a]	Total Uranium (µg/L)
1	4850.0
2	4780.0
3	4270.0
4	700.0
5	2200.0
6	3650.0
7	5420.0
8	7660.0
9	7580.0
10	1680.0
11	14260.0
12	16100.0
13	780.0
14	1250.0
15	3670.0

[a]See Figure 3-21 for samling locations.

TABLE A-43

RADIONUCLIDES IN SEDIMENTS OF PADDYS RUN (REPORTED IN FMPC ENVIRONMENTAL MONITORING REPORTS)

		North[a]			South[b]		
Radionuclide	Year	Concentration Range (pCi/g)	Number of Samples	Average Concentration	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
Uranium-234	1984	NA[c]	d	NA	NA	d	NA
	1985	NA	d	NA	NA	d	NA
	1986	0.17 - 3.8	IU[e]	0.44	0.28 - 21.0	IU	3.4
	1987	0.24 - 0.69	IU	0.41	0.34 - 0.59	IU	0.45
	1988	0.04 - 1.3	IU	0.53	0.06 - 2.8	IU	0.68
	1989	<1.0[f] - 2.2	74	<1.1	<1.0 - 3.6	53	<1.1
	1990	0.41 - 10.0	70	0.86	0.49 - 29	54	0.83
Uranium-235/236	1984	NA	-	NA	NA	-	NA
	1985	NA		NA	NA	-	NA
	1986	0.0029 - 0.85[g]/ 0.0014 - 1.3[h]	IU	0.0028[g]/0.042[h]	0.0074 - 1.2[g]/ 0.30 - 1.0[h]	IU	0.18[g]/0.53[i]
	1987	<0.02 - <0.14	IU	<0.051	0.02 - 0.08	IU	0.05
	1988	<0.01 - 0.10	IU	<0.05	<0.05 - 0.23	IU	0.06
	1989	<1.0 - <1.0	74	<1.0	<1.0 - <1.0	53	<1.0
	1990	<0.075 - <2.6	70	<0.72	<0.067 - 3.4	54	<0.26

See footnotes at end of table.

TABLE A-43
(Continued)

Radionuclide	Year	North[a] Concentration Range (pCi/g)	North[a] Number of Samples	North[a] Average Concentration	South[b] Concentration Range (pCi/g)	South[b] Number of Samples	South[b] Average Concentration (pCi/g)
Uranium-238	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.0007 - 5.7	IU	0.75	0.35 - 37.0	IU	5.2
	1987	0.2 - 0.82	IU	0.43	0.04 - 0.59	IU	0.22
	1988	0.24 - 1.5	IU	0.62	0.32 - 3.1	IU	0.77
	1989	<1.0 - 606	74	<1.2	<1.0 - 3.9	53	<1.1
	1990	<0.46 - 8.7	70	1.4	0.41 - 30	54	0.81
Uranium-Total	1984	0.89 - 42.31	10	9.12	9.00 - 296.53	2	152.76
	1985	0.5 - 46.2	11	7.2	1.1 - 10.2	4	4.8
	1986	NA	-	NA	NA	-	NA
	1987	NA	-	NA	NA	-	NA
	1988	NA	-	NA	NA	-	NA
	1989	NA	-	NA	NA	-	NA
	1990	NA	-	NA	NA	-	NA
Radium-223	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.078 - 0.48	IU	0.22	0.095 - 0.40	IU	0.23

See footnotes at end of table.

TABLE A-43
(Continued)

Radionuclide	Year	North[a] Concentration Range (pCi/g)	North[a] Number of Samples	North[a] Average Concentration	South[b] Concentration Range (pCi/g)	South[b] Number of Samples	South[b] Average Concentration (pCi/g)
Radium-223 (continued)	1987	NA	-	NA	NA	-	NA
	1988	NA	-	NA	NA	-	NA
	1989	NA	-	NA	NA	-	NA
	1990	NA	-	NA	NA	-	NA
Radium-224	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.19 - 1.3	IU	0.51	0.20 - 1.7	IU	0.54
	1987	<0.0792 - <0.511	IU	<0.2313	<0.10 - <0.403	IU	0.54
	1988	0.26 - 0.80	IU	0.45	0.19 - 0.90	IU	<0.23
	1989	0.21 - 0.82	74	0.44	<0.032 - 0.92	53	0.41
	1990	0.26 - 2.3	70	0.57	0.237 - 1.1	54	0.51
Radium-226	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.4 - 4.5	IU	0.86	049 - 1.9	IU	0.83
	1987	<0.188 - <3.73	78	0.741	<0.25 - 4.85	48	0.702
	1988	<0.206 - 13.70	72	0.886	0.42 - 2.1	54	0.693
	1989	<0.1 - 1.1	74	0.63	<0.038 - 1.3	53	0.50

See footnotes at end of table.

TABLE A-43
(Continued)

Radionuclide	Year	North[a] Concentration Range (pCi/g)	North[a] Number of Samples	North[a] Average Concentration	South[b] Concentration Range (pCi/g)	South[b] Number of Samples	South[b] Average Concentration (pCi/g)
Radium-226 (continued)	1990	<0.25 - 3.7	70	0.89	0.44 - 1.2	54	0.70
Radium-228	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.2 - 1.1	IU	0.52	0.23 - 1.3	IU	0.53
	1987	<0.154 - <0.523	IU	<0.322	<0.11 - <0.486	IU	<0.28
	1988	0.19 - 1.1	IU	0.41	0.23 - 0.85	IU	0.41
	1989	<0.17 - 0.73	74	0.43	<0.15 - 1.0	53	0.42
	1990	<0.18 - 2.0	70	0.54	0.25 - 0.95	54	0.46
Thorium-228	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.04 - 2.7	IU	0.48	0.0058 - 2.3	IU	0.28
	1987	0.18 - 0.74	IU	0.35	0.13 - 0.45	IU	0.32
	1988	0.17 - 0.66	IU	0.36	0.10 - 0.74	IU	0.34
	1989	<1.0 - 4.3	74	<1.1	<1.0 - 6.6	53	<1.2
	1990	0.28 - 5.1	70	1.3	0.27 - 1.3	54	0.58
Thorium-230	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA

See footnotes at end of table.

TABLE A-43
(Continued)

Radionuclide	Year	North[a] Concentration Range (pCi/g)	North[a] Number of Samples	North[a] Average Concentration	South[b] Concentration Range (pCi/g)	South[b] Number of Samples	South[b] Average Concentration (pCi/g)
Thorium-230 (continued)	1986	0.22 - 2.4	IU	0.47	0.22 - 3.4	IU	0.78
	1987	0.34 - 1.1	IU	0.63	0.44 - 0.9	IU	0.64
	1988	0.32 - 2.5	IU	0.63	0.21 - 4.8	IU	0.67
	1989	<1.0 - 2.6	74	<1.1	<1.0 - 11	53	<1.3
	1990	0.27 - 9.8	70	1.1	0.21 - 1.8	54	0.84
Thorium-232	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.03 - 0.84	IU	0.22	0.0094 - 0.58	IU	0.22
	1987	0.17 - 0.54	IU	0.33	0.16 - 0.43	IU	0.31
	1988	0.17 - 01.87	IU	0.35	0.07 - 1.0	IU	0.32
	1989	<1.0 - 2.1	74	<1.0	<1.0 - 1.3	53	<1.0
	1990	0.19 - 5.4	70	0.75	0.13 - 1.1	54	0.44
Plutonium-238	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.0012 - 0.043	IU	0.0096	0.0050 - 0.057	IU	0.016
	1987	<0.02 - <0.04	IU	<0.02	<0.02 - <0.04	IU	<0.02
	1988	<0.002 - <0.003	IU	<0.003	<0.01 - <0.05	IU	<0.01

See footnotes at end of table.

TABLE A-43
(Continued)

Radionuclide	Year	North[a] Concentration Range (pCi/g)	North[a] Number of Samples	North[a] Average Concentration	South[b] Concentration Range (pCi/g)	South[b] Number of Samples	South[b] Average Concentration (pCi/g)
Plutonium-238 (continued)	1989	<0.012 - 0.46	74	<0.024	<0.012 - 0.032	53	<0.015
	1990	<0.021 - 0.22	70	<0.059	<0.019 - 0.090	54	<0.047
Plutonium-239/240	1984	NA	-	NA	NA	-	NA
	1985	NA	-	NA	NA	-	NA
	1986	0.00099 - 0.52	IU	0.024	0.0015 - 0.077	IU	0.015
	1987	<0.02 - <0.03	IU	<0.02	<0.02 - <0.02	IU	<0.02
	1988	<0.002 - <0.003	IU	<0.003	<0.01 - <0.05	IU	<0.01
	1989	<0.012 - 0.056	74	<0.016	<0.012 - 0.097	53	<0.016
	1990	<0.014 - 0.28	70	<0.060	<0.019 - <0.012	54	<0.044
Technetium-99	1984	0.70	1	0.70	30.0	1	30.0
	1985	0.0 - 5.1	4	1.4	2.3	1	2.3
	1986	-	IU	4.6[i]	0.81 - 38.0	IU	11.0
	1987	<1.0 - <1.3	IU	<1.	<1.1 - <1.3	IU	<1.2
	1988	<1.0 - <1.0	IU	<1.0	<0.90 - <0.90	IU	<0.90
	1989	<0.90 - <0.90	74	<0.90	<0.90 - 0.96	53	<0.90
	1990	<0.53 - <1.2	70	<0.71	<0.58 - <0.97	54	<0.77

See footnotes at end of table.

TABLE A-43
(Continued)

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[a]Paddys Run sampled above confluence with the Storm Sewer Outfall Ditch.

[b]Paddys Run sampled below confluence with the Storm Sewer Outfall Ditch.

[c]Not analyzed.

[d]Not applicable.

[e]Information unavailable.

[f]Concentration less than stated detection limit.

[g]U-235.

[h]U-236.

[i]All samples less than detectable, except one sample at the confluence of Paddys Run and the Storm Sewer Outfall Ditch.

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TABLE A-44

RADIONUCLIDES IN SEDIMENTS OF THE STORM SEWER OUTFALL DITCH
(Reported in FMPC Environmental Monitoring Reports)

Radionuclide	Year	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
Uranium-234	1984	NA[a]	-[b]	NA
	1985	NA	-	NA
	1986	1.7-24.0	IU[c]	6.2
	1987	0.34-10.60	IU	2.76
	1988	0.81-25	IU	4.5
	1989[d]	<1.0[e]-19	24	4.3
Uranium-235/236	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.055-1.0[f]/0.024-1.5[g]	IU	0.24[g]/0.35[h]
	1987	0.04-0.59	IU	0.22
	1988	<0.05-2.6	IU	0.38
	1989	<1.0-1.8	24	<1.1
Uranium-238	1984	NA	-	NA
	1985	NA	-	NA
	1986	2.0-31.0	IU	7.8
	1987	0.44-10.3	IU	3.33
	1988	0.92-38	IU	5.6
	1989	<1.0-22	24	5.0
Uranium-total	1984	2.82-214.61	16	77.35
	1985	4.2-33.5	5	17.9
	1986	NA	-	NA
	1987	NA	-	NA
Uranium-total (cont.)	1988	NA	-	NA
	1989			

See footnotes at end of table.

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TABLE A-44
(Continued)

Radionuclide	Year	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
Radium-223	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.10-0.64	IU	0.29
	1987	NA	-	NA
	1988	NA	-	NA
	1989	NA	-	NA
Radium-224	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.064-1.3	IU	0.57
	1987	<0.110-<2.96	IU	<0.763
	1988	0.32-1.7	IU	0.77
	1989	0.29-1.9	24	0.70
Radium-226	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.17-1.3	IU	0.68
	1987	0.549-1.92	IU	0.806
	1988	0.21-0.98	IU	0.72
	1989	0.39-2.4	24	0.76
Radium-228	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.30-1.8	IU	0.74
	1987	0.342-2.860	IU	0.901
	1988	0.35-1.8	IU	0.74
	1989	<0.33-2.0	24	0.68
Thorium-228	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.45-2.6	IU	0.84

See footnotes at end of table.

TABLE A-44
(Continued)

Radionuclide	Year	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
	1987	0.29-2.81	IU	0.80
	1988	0.29-1.7	IU	0.64
	1989	<1.0-1.2	24	<1.0
Thorium-230	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.38-4.7	IU	1.3
	1987	0.34-1.1	IU	0.63
	1988	0.49-1.8	IU	0.91
	1989	<1.0-3.4	24	<1.5
Thorium-232	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.13-3.4	IU	0.63
	1987	0.30-2.19	IU	0.75
	1988	0.30-1.7	IU	0.64
	1989	<1.0-1.1	24	<1.0
Plutonium-238	1984	NA	-	NA
	1985	NA	-	NA
	1986	0.0023-0.17	IU	0.028
	1987	<0.020	IU	<0.020
	1988	<0.001-0.02	IU	<0.004
	1989	<0.012-1.0	24	<0.06
Plutonium-239/240	1984	NA	-	NA
	1985	NA	-	NA
Plutonium-239/240 (cont.)	1986	0.0048-0.11	IU	0.024
	1987	<0.020-<0.030	IU	<0.02
	1988	<0.001-0.05	IU	<0.005
	1989	<0.012-1.0	24	<0.07

See footnotes at end of table.

TABLE A-44
(Continued)

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Radionuclide	Year	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
Technetium-99	1984	4.3-16.0	2	10.2
	1985	2.5-6.9	2	4.7
	1986	0.11-5.4	IU	1.5
	1987	<1.1-<1.3	IU	<1.2
	1988	<1.0	IU	<1.0
	1989	<0.90	24	<0.90

[a]Not analyzed.
[b]Not applicable.
[c]Information unavailable.
[d]All 1989 data is draft.
[e]Concentration less than stated detection limit.
[f]U-235.
[g]U-236.

TABLE A-45

RADIONUCLIDES OF CONCERN IN SEDIMENTS
1987 TO 1988 FMPC ENVIRONMENTAL MONITORING PROGRAM

Radionuclide	Year	Location	Distance (m)[b]	Concentration pCi/g Bank Location[a] North/West	Middle	South/East
Total Uranium	1987	Paddys Run (PR)	0	1.21	1.04	1.55
			0	38.50	2.08	7.49
			100U[c]	1.12	1.28	3.32
			100D[d]	2.43	0.84	1.49
		Storm Sewer Outfall Ditch (SSOD)	0	5.67	3.07	7.06
	1988	Storm Sewer Outfall Ditch	600	15.96	4.53	10.99
			700	12.66	8.28	65.41
			750	14.04	6.91	4.76
Radium-226	1988	Paddys Run	1,500U	0.729	0.607	1.390
			1,600U	1.100	0.683	13.700
			1,700U	0.452	0.524	0.508

[a]See Figure 3-12.

[b]Distance (meters) corresponds to distance along the streambed from the confluence of the SSOD and Paddys Run with zero meters being the location of the confluence.

[c]U - Upstream.

[d]D - Downstream.

TABLE A-46
URANIUM CONCENTRATIONS IN GREAT MIAMI RIVER SEDIMENTS
RI/FS SAMPLING 1988-1989

		Concentration (pCi/g)			
Sample Location	Year	U-234	U-235/236	U-238	U-SUM
W1E	1988	<0.6[a]	<0.6	<0.6	0.00
WIE	1989	0.6	<0.6	<0.6	0.60
W3E	1988	<0.6	<0.6	<0.6	0.00
W3E	1989	<0.6	<0.6	<0.6	0.00
W4E	1988	<0.6	<0.6	<0.6	0.00
W4E	1989	<0.6	<0.6	<0.6	0.00
GMR1E	1988	<0.6	<0.6	0.6	0.60
GMR1E	1989	<0.6	<0.6	<0.6	0.00
GMR2E	1988	0.7	<0.6	0.6	1.30
GMR2E	1989	<0.6	<0.6	<0.6	0.00
GMR3W	1988	1.4	<0.6	1.1	2.50
GMR3W	1989	<0.6	<0.6	<0.6	0.00
GMR4W1/4	1988	0.7	<0.6	0.9	1.60
GMR4W	1989	<0.6	<0.6	<0.6	0.00

[a]Not detected at the given detection limit.

TABLE A-47
RADIONUCLIDES IN SEDIMENTS OF THE GREAT MIAMI RIVER
(REPORTED IN ENVIRONMENTAL MONITORING REPORTS)

Radionuclide	Year	Above FEMP Effluent Line			Below FEMP Effluent Line, Above Paddys Run			Below Paddys Run			From Above FEMP Effluent Line to Below Paddys Run		
		Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
Uranium-234	1984	NA[a]	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	d	c	c	c	c	c	0.16 0.46	IU[d]	NA
	1987	c	c	c	c	c	c	c	c	c	0.38 0.75	IU	0.57
	1988	0.40	0.60	IU	0.53	IU	0.69	0.38 0.63	IU	0.51	e	e	e
	1989	<1.0[f]	3	<1.0	<1.0	3	<1.0	<1.0	2	<1.0	e	e	e
	1990	074 1.2	3	0.93	0.65 1.5	4	0.93	076 0.77	2	0.77	e	e	e
Uranium-235/236	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.0028 0.0090[g]/ 0.0027 0.031[h]	IU	0.0066[h]/0.01[i]
	1987	c	c	c	c	c	c	c	c	c	<0.02 <0.1	IU	<0.06
	1988	<0.01 <0.05	IU	<0.04	<0.05	IU	<0.05	<0.05	IU	<0.05	e	e	e

See footnotes at end of table.

TABLE A-47
(Continued)

Radionuclide	Year	Above FEMP Effluent Line			Below FEMP Effluent Line, Above Paddys Run			Below Paddys Run			From Above FEMP Effluent Line to Below Paddys Run		
		Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
	1989	<1.0	3	<1.0	<1.0	3	<1.0	<1.0	2	<1.0	c	c	c
	1990	<0.11 0.38	3	0.20	<0.088 <0.038	4	<0.20	<0.081 0.089	2	<0.085	c	c	c
Uranium-238	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.16 0.61	IU	0.25
	1987	c	c	c	c	c	c	c	c	c	0.31 0.84	IU	0.59
	1988	0.52 0.95	IU	0.69	0.63 0.85	IU	0.71	0.37 0.58	IU	0.48	c	c	c
	1989	<1.0	3	<1.0	<1.0	3	<1.0	<1.0	2	<1.0	c	c	c
	1990	070 1.0	3	0.83	0.58 1.6	4	0.89	077 0.81	2	0.79	c	c	c
Uranium-Total	1984	0.00 2.62	2	1.31	0.00 2.96	4	1.86	1.36	1	1.36	c	c	c
	1985	0.8 1.5	4	1.1	0.6 2.6	4	1.6	0.7	1	0.7	c	c	c
	1986	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1987	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1988	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA

See footnotes at end of table.

TABLE A-47
(Continued)

Radionuclide	Year	Above FEMP Effluent Line: Concentration Range (pCi/g)	Above FEMP Effluent Line: Number of Samples	Above FEMP Effluent Line: Average Concentration (pCi/g)	Below FEMP Effluent Line, Above Paddys Run: Concentration Range (pCi/g)	Below FEMP Effluent Line, Above Paddys Run: Number of Samples	Below FEMP Effluent Line, Above Paddys Run: Average Concentration (pCi/g)	Below Paddys Run: Concentration Range (pCi/g)	Below Paddys Run: Number of Samples	Below Paddys Run: Average Concentration (pCi/g)	From Above FEMP Effluent Line to Below Paddys Run: Concentration Range (pCi/g)	From Above FEMP Effluent Line to Below Paddys Run: Number of Samples	From Above FEMP Effluent Line to Below Paddys Run: Average Concentration (pCi/g)
	1989	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1990	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
Radium-223	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.16 0.31	IU	0.22
	1987	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1988	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
Radium-223	1989	NA	b	NA	NA	c	NA	NA	b	NA	NA	b	NA
	1990	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
Radium-224	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.25 0.82	IU	0.48
	1987	c	c	c	c	c	c	c	c	c	<0.0739 <0.892	IU	<0.502
	1988	0.37 0.81	IU	0.62	0.36 1.1	IU	0.69	0.24 0.75	IU	0.49	e	e	e

See footnotes at end of table.

TABLE A-47
(Continued)

Radionuclide	Year	Above FEMP Effluent Line			Below FEMP Effluent Line, Above Paddys Run			Below Paddys Run			From Above FEMP Effluent Line to Below Paddys Run		
		Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
	1989	0.53 0.71	3	0.61	0.34 0.46	3	0.38	0.46 0.56	2	0.51	e	e	e
	1990	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
Radium-226	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.39 1.1	IU	0.75
	1987	c	c	c	c	c	c	c	c	c	0.116 1.01	IU	0.688
	1988	0.52 0.80	IU	0.71	0.50 1.0	IU	0.76	0.42 0.77	IU	0.59	e	e	e
	1989	057 0.81	3	0.65	0.40 0.59	3	0.47	0.51 0.74	2	0.62	e	e	e
	1990	0.64 0.68	3	0.67	0.53 0.84	4	0.71	0.54 0.93	2	0.73	e	e	e
Radium-228	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	d	c	c	0.19 0.78	IU	0.49
Radium-228	1987	c	c	c	c	c	c	c	c	c	<0.147 <0.764	IU	0.515
	1988	0.39 , 0.73	IU	0.60	0.36 0.82	IU	0.54	0.21 0.77	IU	0.49	e	e	e
	1989	<0.67 0.54	3	<0.57	0.28 0.43	3	0.34	0.33 0.59	2	0.46	e	e	e

See footnotes at end of table.

TABLE A-47
(Continued)

Radionuclide	Year	Above FEMP Effluent Line: Concentration Range (pCi/g)	Above FEMP Effluent Line: Number of Samples	Above FEMP Effluent Line: Average Concentration (pCi/g)	Below FEMP Effluent Line, Above Paddys Run: Concentration Range (pCi/g)	Below FEMP Effluent Line, Above Paddys Run: Number of Samples	Below FEMP Effluent Line, Above Paddys Run: Average Concentration (pCi/g)	Below Paddys Run: Concentration Range (pCi/g)	Below Paddys Run: Number of Samples	Below Paddys Run: Average Concentration (pCi/g)	From Above FEMP Effluent Line to Below Paddys Run: Concentration Range (pCi/g)	From Above FEMP Effluent Line to Below Paddys Run: Number of Samples	From Above FEMP Effluent Line to Below Paddys Run: Average Concentration (pCi/g)
	1990	0.48 0.56	3	0.51	0.42 0.82	4	0.60	0.46 0.63	2	0.54	c	c	c
Thorium-228	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.33 0.64	IU	0.51
	1987	c	c	c	c	c	c	c	c	c	0.41 1.07	IU	0.71
	1988	014 0.62	IU	0.38	0.12 0.46	IU	0.28	0.12 0.34	IU	0.23	c	c	c
	1989	<1.0	3	<1.0	<1.0	3	<1.0	<1.0	2	<1.0	c	c	c
	1990	1.3 1.5	3	1.4	1.1 1.4	4	1.2	1.0 1.3	2	1.1	c	c	c
Thorium-230	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.15 1.3	IU	0.55
	1987	c	c	c	c	c	c	c	c	c	0.63 1.16	IU	0.92
	1988	0.36 0.87	IU	0.66	0.32 0.59	IU	0.44	0.33 0.54	IU	0.44	c	c	c
	1989	<1.0 1.7	3	<1.2	<1.0	3	<1.0	<1.0	2	<1.0	c	c	c
	1990	0.91 1.2	3	1.0	0.75 1.3	4	1.0	0.95 1.1	2	1.0 c	c	c	c

See footnotes at end of table.

TABLE A-47
(Continued)

Radionuclide	Year	Above FEMP Effluent Line			Below FEMP Effluent Line, Above Paddys Run			Below Paddys Run			From Above FEMP Effluent Line to Below Paddys Run		
		Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
Thorium-232	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.090 0.31	IU	0.21
	1987	c	c	c	c	c	c	c	c	c	0.33 1.08	IU	0.72
	1988	0.13 0.44	IU	0.32	0.10 0.47	IU	0.25	0.11 0.32	IU	0.22	e	e	e
	1989	<1.0 1.1	3	<1.0	<1.0	3	<1.0	<1.0	2	<1.0	e	e	e
	1990	0.42 0.60	3	0.52	0.29 0.57	4	0.47	0.47 0.62	2	0.55	e	e	e
Plutonium-238	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.0047 0.032	IU	0.013
	1987	c	c	c	c	c	c	c	c	c	<0.01 <0.05	IU	<0.03
	1988	<0.01	IU	<0.01	<0.01	IU	<0.01	<0.01	IU	<0.01	e	e	e
	1989	<0.012	3	<0.012	<0.012	3	<0.012	<0.012	2	<0.012	e	e	e
	1990	<0.014 <0.11	3	<0.054	<0.037 <0.076	4	<0.055	<0.031 <0.033	2	<0.032	e	e	e

See footnotes at end of table.

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TABLE A-47
(Continued)

Radionuclide	Year	Above FEMP Effluent Line			Below FEMP Effluent Line, Above Paddys Run			Below Paddys Run			From Above FEMP Effluent Line to Below Paddys Run		
		Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)	Concentration Range (pCi/g)	Number of Samples	Average Concentration (pCi/g)
Plutonium-239/240	1984	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1985	NA	b	NA	NA	b	NA	NA	b	NA	NA	b	NA
	1986	c	c	c	c	c	c	c	c	c	0.0018 0.0062	IU	0.0035
	1987	c	c	c	c	c	c	c	c	c	0.01 0.04	IU	0.03
	1988	<0.01	IU	<0.01	<0.01	IU	<0.01	<0.01	IU	<0.01	e	e	e
Plutonium-239/249	1989	<0.012 0.014	3	<0.013	<0.012	3	<0.012	<0.012	2	<0.012	e	e	e
	1990	<0.014 0.043	3	<0.032	<0.027 <0.10	4	<0.046	<0.031 <0.085	2	<0.058	e	e	e
Technetium-99	1984	0.00	1	0.00	0.80 1.30	2	1.55	0.00	1	0.00	e	e	e
	1985	0.00	1	0.00	0.00 4.9	3	2.1	NA	NA	NA	e	e	e
	1986	c	c	c	c	c	c	c	c	c	IU	IU	<0.51
	1987	c	c	c	c	c	c	c	c	c	<1.1 <1.4	IU	<1.3
	1988	<0.90	IU	<0.90	<0.90	IU	<0.90	<0.90	IU	<0.90	e	e	e
	1989	<0.90 0.95	3	<0.94	<0.90 0.98	3	<0.93	<0.90	2	<0.90	e	e	e
	1990	<0.54 0.69	3	<0.64	<0.61 <0.69	4	<0.65	<0.69 <0.71	2	<0.70	e	e	e

See footnotes at end of table.

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TABLE A-47
(Continued)

[a]Not analyzed.
[b]Not applicable.
[c]Specific locations on river not sampled.
[d]Information unavailable.
[e]Specific locations on river sampled.
[f]Concentration less than stated detection limit.
[g]U-235.
[h]U-236.

TABLE A-48
CHEMICALS IDENTIFIED IN SEDIMENT OF PADDYS RUN ABOVE THE CONFLUENCE WITH THE STORM SEWER OUTFALL DITCH

Constituents	Frequency of Detection	Range of Sample Detection Limits[a] (mg/kg)	Range of Detected Site-Influenced Concentrations (mg/kg)	Average Site-Influenced Concentrations[b] (mg/kg)	Detected Background Levels[c] (mg/kg)
Organics					
2-Butanone	0/3	<0.012 - <0.015	ND	ND	<0.015
Di-n-butylphthalate	2/3	<0.490	.051 - 0.055	0.199	0.039
bis(2-Ethylhexyl)phthalate	2/3	<0.49	0.490 - 0.590	0.527	0.460
2-Hexanone	0/3	<0.012 - <0.015	ND	ND	<0.012
Methylene chloride	2/3	<0.007	0.015 - 0.019	0.014	0.007
2-Propanone	2/3	0.015	0.008 - 0.094	0.039	0.018
Inorganics					
Aluminum	3/3	d	2,080.0 - 5,460.0	3,820.0	1,970.0
Antimony	0/3	<0.1	ND	ND	<0.1
Arsenic	3/3	d	2.7 - 6.5	4.2	7.0
Barium	3/3	d	21.0 - 49.4	33.9	21.0
Beryllium	3/3	d	0.2 - 0.5	0.4	0.5
Cadmium	2/3	<0.2	3.9 - 4.5	2.9	3.7

See footnotes at end of table.

TAB[illegible]A-48
(Continued)

Constituents	Frequency of Detection	Range of Sample Detection Limits[a] (mg/kg)	Range of Detected Site-Influenced Concentrations (mg/kg)	Average Site-Influenced Concentrations[b] (mg/kg)	Detected Background Levels[c] (mg/kg)
Inorganics (cont.)					
Chromium	3/3	d	6.9 - 18.4	14.2	18.3
Cobalt	3/3	d	3.8 - 6.5	5.0	4.9
Copper	3/3	d	9.2 - 14.5	11.8	10.8
Lead	3/3	d	4.6 - 18.4	11.5	9.3
Magnesium	3/3	d	8,580.0 - 26,600.0	17,826.7	18,700.0
Manganese	3/3	d	362.0 - 500.0	425.7	411.0
Mercury	1/3	<0.1	1.70	-[e]	<0.1
Molybdenum	0/3	<2.4 - <5.0	ND	ND	<4.5
Nickel	3/3	d	9.4 - 19.5	15.1	13.7
Selenium	0/3	<0.2 - <5.0	ND	ND	<0.4
Silver	0/3	<0.1	ND	ND	<0.1
Vanadium	3/3	d	8.4 - 14.0	12.0	12.4
Zinc	3/3	d	13.4 - 37.3	25.0	13.5

[a]Calculated from single rounds of sampling at sites ASIT-10, W-10, and W-11. Range of detection limits for the same constituent given when separate sampling rounds and locations are used in the data analysis, (see Figure 3-20 for sampling sites).

[b]When determining average concentrations, nondetects were assumed to be at the detection limit.

[c]Background values from site W-5.

TABLE A-48
(Continued)

[d]Positive hits in all sampling rounds; detection limits were not determined.

[e]Averages were not determined with less than two positive hits.

ND = Not Detected

TABLE A-49

CHEMICALS IDENTIFIED IN SEDIMENTS OF PADDYS RUN BELOW THE CONFLUENCE WITH THE STORM SEWER OUTFALL DITCH

	Frequency of Detection[a]	Sample Detection Limits[a,b] (mg/kg)	Detected Site-Influenced Concentrations[a] (mg/kg)	Detected Background Levels[c] (mg/kg)
Organics				
2-Butanone	1/1	-[b]	0.012	<0.015
Di-n-butylphthlate	0/1	0.390	ND[d]	0.039
bis-(2-Ethylhexyl)phthalate	1/1	-[b]	0.400	0.460
2-Hexanone	1/1	-[b]	0.011	<0.012
Methylene chloride	1/1	-[b]	0.001	0.007
2-Propanone	1/1	-[b]	0.014	0.018
Inorganics				
Aluminum	1/1	-[b]	2,480.0	1,970.0
Antimony	0/1	<0.4	ND	ND
Arsenic	1/1	-[b]	2.6	7.0
Barium	1/1	-[b]	21.2	21.0
Beryllium	1/1	-[b]	0.5	0.5
Cadmium	1/1	-[b]	5.5	3.7
Chromium	1/1	-[b]	16.9	18.3
Cobalt	1/1	-[b]	5.2	4.9
Copper	1/1	-[b]	11.5	10.8
Lead	1/1	-[b]	4.6	9.3

See footnotes at end of table.

TABLE A-49
(Continued)

	Frequency of Detection[a]	Sample Detection Limits[a,b] (mg/kg)	Detected Site-Influenced Concentrations[a] (mg/kg)	Detected Background Levels[c] (mg/kg)
Inorganics (cont.)				
Magnesium	1/1	-[b]	35,900.0	18,700.0
Manganese	1/1	-[b]	273.0	411.0
Mercury	0/1	<0.1	ND	ND
Molybdenum	0/1	<4.4	ND	ND
Nickel	1/1	-[b]	17.9	13.7
Selenium	0/1	<0.5	ND	ND
Silver	0/1	<0.1	ND	ND
Vanadium	1/1	-[b]	15.4	12.4
Zinc	1/1	-[b]	15.3	13.5

[a]Data is from a single round at sampling site W-7. (Refer to Figure 3- 20 for sampling location).

[b]Positive hits were detected in the only sampling round; detection limits were not determined.

[c]Background values from sampling location W-5. (Refer to Figure 3- 20 for sampling location).

[d]ND = Not Detected.

TABLE A-50
CHEMICALS IDENTIFIED IN SEDIMENT AT THE STORM SEWER OUTFALL DITCH

Constituents	Frequency of Detection	Sample Detection Limits[a] (mg/kg)	Detected Site-Influenced Concentrations[a] (mg/kg)	Detected Background Levels[b] (mg/kg)
Organics				
2-Butanone	0/1	<0.012	ND[c]	<0.015
Di-n-butylphthalate	0/1	<0.400	ND	0.039
bis(2-Ethylhexyl)phthalate	0/1	<0.400	ND	0.460
2-Hexanone	0/1	<0.012	ND	<0.012
Methylene chloride	1/1	d	0.016	0.007
2-Propanone	1/1	d	0.055	0.018
Inorganics				
Aluminum	1/1	d	8,830.0	1,970.0
Antimony	0/1	<0.1	ND	<0.1
Arsenic	1/1	d	5.4	7.0
Barium	1/1	d	56.7	21.0
Beryllium	1/1	d	0.4	0.5
Cadmium	0/1	<0.2	ND	3.7
Chromium	1/1	d	12.5	18.3
Cobalt	1/1	d	8.1	4.9
Copper	1/1	d	16.1	10.8

See footnotes at end of table.

TABLE A-50
(Continued)

Constituents	Frequency of Detection	Sample Detection Limits[a] (mg/kg)	Detected Site-Influenced Concentrations[a] (mg/kg)	Detected Background Levels[b] (mg/kg)
Inorganics (cont.)				
Lead	1/1	d	12.0	9.3
Magnesium	1/1	d	21,600.0	18,700.0
Manganese	1/1	d	399.0	411.0
Mercury	1/1	d	1.3	<0.1
Molybdenum	0/1	<0.1	ND	<4.5
Nickel	1/1	d	19.1	13.7
Selenium	0/1	<0.3	ND	<0.4
Silver	0/1	<0.1	ND	<0.1
Vanadium	1/1	d	14.4	12.4
Zinc	1/1	d	47.6	13.5

[a]Calculated from a single round of sampling and testing at sampling site ASIT-7.

[b]Background values are from sampling location W-5.

[c]ND = Not Detected.

[d]Chemical detected in the only sampling round; detection limits not reported.

TABLE A-51
SEDIMENT SUMMARY DATA[a]
RADIONUCLIDES DETECTED
RI/FS SAMPLING

Location	Stats	U-234[b]	U235/236	U-238	U-SUM	Ra-226	Ra-228	Tc-99	Pu-238	Pu-239/240	Th-228	Th-230	Th-232	U-Tot (ug/g)
GMR above	min	<.06	<.06	<.06	0.00	0.4	<0.5	<0.9	<0.6	<0.6	<0.6	<0.6	<0.6	<1.0
effluent	max	1.1	<.06	1.2	2.30	0.6	<0.5	<0.9	<0.6	<0.6	<0.6	1.0	0.8	3.00
GMR below	min	<.06	<.06	<.06	0.00	0.4	<0.5	<0.9	<0.6	<0.6	<0.6	<0.6	<0.6	<1.0
effluent	max	0.7	<.06	0.8	1.50	0.7	<0.5	<0.9	<0.6	<0.6	<0.6	1.9	<0.6	3.0
GMR below	min	<0.6	<0.6	<0.6	0.00	0.4	<0.5	<0.9	<0.6	<0.6	<0.6	<0.6	<0.6	<1.0
CON W/PR	max	0.7	<0.6	0.9	1.60	0.9	<0.5	<0.9	<0.6	<0.6	<0.6	1.0	<0.6	3.0
PR above	min	<.06	<.06	<.06	0.00	0.4	<0.5	<0.9	<0.6	<0.6	<0.6	<0.6	<0.6	1.00
SSOD	max	1.4	<.06	1.1	2.50	10.6	21.7	<0.9	<0.6	<0.6	<0.6	2.5	<0.6	4.00
SSOD	min	2.7	<0.6	1.4	2.70	0.4	<0.5	<0.9	<0.6	<0.6	<0.6	1.9	<0.6	4.53
	max	3.8	0.9	4.6	9.30	1.2	2.8	<0.9	<0.6	<0.6	<0.6	2.5	0.8	51.80
PR below	min	<0.6	<0.6	2.8	5.50	0.5	<0.5	<0.9	<0.6	<0.6	<0.6	1.9	<0.6	1.00
SSOD	max	3.8	0.9	4.6	9.30	2.9	2.8	<0.9	<0.6	<0.6	<0.6	2.6	<0.6	9.00
MH-175	min	126.0	9.6	180.0	315.6	5.5	16.8	365.0	<0.6	<0.6	4.4	<0.6	2.2	595.00
	max	174.0	12.2	244.0	430.10	6.8	24.5	692.0	<0.6	<0.6	32.0	28.2	3.4	614.00

See footnotes at end of table.

TABLE A-51
(Continued)

Location	Stats	U-234[b]	U235/236	U-238	U-SUM	Ra-226	Ra-228	Tc-99	Pu-238	Pu-239/240	Th-228	Th-230	Th-232	U-Tot (ug/g)
misc.	min	1.3	<0.6	1.4	2.70	0.6	<0.5	<0.9	<0.6	<0.6	<0.6	2.5	0.8	4.00
ditches	max	1.3	<0.6	1.4	2.70	10.6	21.7	<0.9	<0.6	<0.6	<0.6	2.5	0.8	230.00

[a]Sediment and surface water (Table A-45) samples were collected from similar locations. Refer to Figure 3-12 for sampling locations. Summary of the laboratory results consist of 142 sediment samples collected in 1988 and 1989.

[b]The results are presented in pCi/l with the exception of U-total (ug/g).

TABLE A-52
RADIONUCLIDE CONCENTRATIONS IN GARDEN PRODUCE AND AGRICULTURAL CROPS

Produce/Crop	Number of Samples	Location	Radionuclide Type and Concentration Range (pCi/g)					Sum of U Activity
			CS-137	SR-90	U-234	U-235, -236	U-238	
Okra	1	Indiana	<0.4[a]	<0.5	<0.6	<0.6	<0.6	-[b]
	3	FEMP vicinity	<0.3-<0.5	<0.5	<0.6-1.4(1)[c]	<0.6	<0.6-0.8(1)	<0.6-2.2
Tomato	3	Indiana	<0.2-<0.4	<0.5	<0.6-2.5(2)	<0.6	<0.6-0.8(1)	<0.6-3.3
	4	FEMP vicinity	<0.2-<0.3	<0.5	<0.6-0.8(1)	<0.6	<0.6	<0.6-0.8
Green pepper	2	Indiana	<0.3	<0.5	<0.6	<0.6	<0.6	-
	3	FEMP vicinity	<0.2	<0.5	<0.6-1.0(1)	<0.6	<0.6	<0.6-1.0
Potato (flesh)	2	Indiana	<0.2	<0.5	<0.6	<0.6	<0.6	-
	1	FEMP vicinity	<0.2	<0.5	<0.6	<0.6	<0.6	-
Potato (peel)	2	Indiana	<0.2-<0.3	<0.5	<0.6-2.7(1)	<0.6-<1.4	<0.6-<1.4	<0.6-2.7
	1	FEMP vicinity	<0.2	<0.5	<0.6	<0.6	<0.6	-
Soybean	2	Indiana	<0.2	<0.5	<0.6	<0.6	<0.6	-
	1	FEMP vicinity	<0.2	<0.5	<0.6	<0.6	<0.6	-
Field corn	2	Indiana	<0.2-0.3(1)	<0.5	<0.6-1.1(1)	<0.6	<0.6-1.0(1)	<0.6-2.1
	2	FEMP vicinity	<0.2	<0.5	<0.6	<0.6	<0.6	-
Alfalfa	1	Indiana	<0.5	0.5(1)	2.4(1)	0.6(1)	1.1(1)	4.1
	1	FEMP vicinity	<0.4	<0.5	1.2(1)	<0.6	<0.6	1.2

See footnotes at end of table.

TABLE A-52
(Continued)

Produce/Crop	Number of Samples	Location	Radionuclide Type and Concentration Range (pCi/g)					Sum of U Activity
			CS-137	SR-90	U-234	U-235, -236	U-238	
Cucumber	1	FEMP vicinity	<1.1	<0.6	3.0(1)	<0.6	1.8(1)	4.8
Squash	1	FEMP vicinity	<0.3	<0.5	<0.6	<0.6	<0.6	-
Cabbage	1	FEMP vicinity	<0.2	<0.5	<0.6	<0.6	<0.6	-
Sweet potato	1	FEMP vicinity	<0.2	<0.5	<0.6	<0.6	<0.6	-
Pumpkin	2	FEMP vicinity	<0.3-<0.4	<0.5	0.9-1.5(2)	<0.6	<0.6-0.8(1)	1.5-1.7

[a]Concentration less than stated detection limit.

[b]All uranium isotopes below detection limit.

[c]Number of samples with detected concentrations.

TABLE A-53
URANIUM CONCENTRATION IN MILK[a]

Year	FEMP Frequency of Concentration	Location[b] Average Concentration	Location[b] Concentration Range	Control Location[c] Frequency of Occurrence	Control Location[c] Average Concentration	Control Location[c] Concentration Range
1983	1/4	0.86 pCi/L[d]	<0.7[e] - 1.35 pCi/L	1/4	0.86 pCi/L	<0.7 - 1.35 pCi/L
1984	0/5	<0.68 pCi/L	-[f]	0/5	<0.68 pCi/L	-
1985	0/3	<0.68 pCi/L	-	0/3	<0.68 pCi/L	-
1986	0/6	<0.68 pCi/L	-	0/6	<0.68 pCi/L	-
1987	NA[g]	<0.7 pCi/L	NA	NA	<0.7 pCi/L	NA
1988	1/12	0.7 pCi/L[d]	<0.7 - 1.0 pCi/L	0/12	<0.7 pCi/L	-
1989	0/11[h]	<0.7 pCi/L	-	0/11	<0.7 pCi/L	-
1990	7/12	1.48 pCi/L	<0.68 - 11 pCi/L	7/12	0.85 pCi/L	<0.015 - 3.7

[a]FEMP Environmental Monitoring Reports 1983 - 1990.

[b]Dairy farm adjacent to the FEMP.

[c]Dairy farm in Kentucky approximately 30 km southeast of the FEMP in 1983 - 1986; dairy farm in Indiana approximately 35 km west of the FEMP in 1987 and 1988. For 1989 and 1990, a dairy farm located 40 km west-southwest of the FEMP.

[d]Average concentration calculated using the detection limit for those samples with uranium concentrations below detectable levels.

[e]Concentration less than stated detection limit.

[f]No detectable quantity of uranium present in samples.

[g]Not available.

[h]For 1989, 12 samples were analyzed (a sample per month). However, the results of the analysis for October's sampling activity proved to be incorrect and, therefore, is not counted as part of this summary.

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TABLE A-54
RADIONUCLIDE CONCENTRATIONS IN VEGETATION AND SOIL ON THE FEMP (RI/FS SAMPLING)

Radionuclide	Parameter	Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots
Total Uranium	Frequency of Detection	28/28	15/30	22/30	12/18	15/18
	Concentration Range (pCi/g)	2.7-35.6	0.7-15.7	0.6-31.9	0.6-6.4	1.5-35.5
	Average Concentration[a]	13.1	3.7	9.9	3.2	11.2
Cesium-137	Frequency of Detection	23/28	1/26	19/27	1/18	3/18
	Concentration Range (pCi/g)	<0.2-1.6	<0.2-0.4	<0.2-1.4	<0.2-0.4	<0.2-0.8
	Average Concentration[b] (pCi/g)	0.7	0.3	0.5	0.3	0.4

See footnotes at end of table.

TABLE A-54
(Continued)

Radionuclide	Parameter	Soil	Grass Leaves	Grass Roots	Forb Leaves	Forb Roots
Total Uranium	Frequency of Detection	28/28	15/30	22/30	12/18	15/18
	Concentration Range (pCi/g)	2.7-35.6	0.7-15.7	0.6-31.9	0.6-6.4	1.5-35.5
	Average Concentration[a]	13.1	3.7	9.9	3.2	11.2
Strontium-90	Frequency of Detection	20/26	1/30	1/31	3/18	2/18
	Concentration Range (pCi/g)	<0.5-2.5	<0.5-0.6	<0.2-0.8	<0.5-0.9	<0.5-0.7
	Average Concentration[c] (pCi/g)	0.9	0.7	0.5	0.6	0.6

[a]Mean of detected concentrations calculated.

[b]Mean calculated using detected concentrations and the stated detection limit for those samples with undetected concentrations.

TABLE A-55
RADIONUCLIDES IN MAMMAL TISSUE FROM THE FEMP (RI/FS SAMPLING)

Sample	Type	Site	Radionuclide Type and Concentration Range (pCi/g)						Sum of U Activity
			CS-137	SR-90	TC-99[a]	U-234,-235	U-236	U-238	
Opossum	Muscle	N. Pine Plantation	<0.2	<0.5	-	<0.2	<0.2	<0.2	-
Opossum	Organs	N. Pine Plantation	<0.2	<0.5	-	<0.6	<0.6	<0.6	-
Opossum	Muscle[b]	-	<0.3	<0.5	<1.0	<0.6	<0.6	<0.6	-
Cottontail	Muscle[b]	-	<0.7	<0.5	<0.9	<0.6	<0.6	<0.6	-
Small mammal[c] (composite)	Carcasses	Waste Pit 5	<0.2	<0.1	-	<0.6	<0.6	<0.6	-
Small mammal[c] (composite)	Organs	Waste Pit 5	<1.1	<2.5	-	8.3	1.1	8.6	18.0
Small mammal[b,c]	Carcasses	-	<0.2	<0.5	ISFA[d]	<0.6	<0.6	<0.6	-
Deer	Kidney[b]	-	<0.2	<0.5	<0.9	<0.6	<0.6	<0.6	-
Deer	Liver[b]	-	<0.2	<0.5	<0.9	<0.6	<0.6	<0.6	-

[a]Technetium-99 analyzed for 1988 samples only.

[b]1988 samples.

[c]Composite small mammal samples of white-footed mouse and short-tailed shrew.

[d]Insufficient sample for analysis.

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TABLE A-56
RADIONUCLIDE CONCENTRATIONS IN WETLAND PLANTS ON THE FEMP (RI/FS SAMPLING)

Sample	Radionuclide Type and Concentration Range (pCi/g)						Sum of U Activity
	Cs-137	Sr-90	Tc-99	U-234	U-235, -236	U-238	
Algae	<0.21[a]	<0.5-0.9	<0.9	<0.6	<0.6	<0.6	-[b]
Cattail leaf	<0.2-<0.6	<0.5-<1.0	NA[c]	<0.6-1.4	<0.6	<0.6-1.9	<0.6-3.3
Cattail root	<0.2-<0.3	<0.5-<0.9	NA	<0.6-2.6	<0.6	<0.6-3.8	<0.6-6.4
Sedge leaf	<0.2	<0.7-<1.3	NA	<0.6	<0.6	<0.6	-
Grass leaf	<0.2-<0.3	<0.5-<0.6	1.9	<0.6	<0.6	<0.6	-
Grass root	<0.2	<0.5	<0.9	0.9-7.7	<0.6-1.3	4.2-22.3	5.1-31.3

[a]Concentration less than stated detection limit.

[b]All uranium isotopes below detection limit.

[c]Not analyzed.

TABLE A-57
RADIONUCLIDES IN AQUATIC FAUNA
(RI/FS SAMPLING)

Sample	Location	Radionuclide Type and Concentration Range (pCi/g)						Sum of U Activity
		CS-137	SR-90	TC-99	U-234	U-235, -236	U-238	
Benthic Macroinvertebrates[a]	Paddys Run	<0.2[b]-<2.0	<0.5-<3.7	<0.9	<0.6-3.6	<0.6-<1.5	<0.6-2.8	<0.6-6.4
Crayfish	Paddys Run	<0.24-<4.00	<1.2-<2.6	NA	1.5-3.6	<0.6-<1.1	<0.6-1.5	1.5-5.1
	Great Miami River	<0.2-<2.1	<1.1-<4.7	<0.9	<0.6-3.4	<0.6-<2.2	<0.6-3.1	<0.6-6.5
Fish								
Minnow	Paddys Run	<0.2-<0.42	<0.5	<0.6-<1.6	<0.6	<0.6	<0.6	c
White sucker	Paddys Run	<0.20-<0.41	<0.5	NA[d]	<0.6-0.6	<0.6	<0.6	<0.6-0.6
Creek chub	Caddys Run	<0.17-<1.90	<0.5-<0.7	NA	<0.6-1.0	<0.6	<0.6-0.7	<0.6-1.7
Bluegill	Paddys Run	<0.19-<1.23	<0.5-<3.32	NA	<0.6-2.4	<0.6-<1.1	<0.6-1.3	<0.6-3.7
Gizzard shad	Great Miami River	<0.2-<0.3	<0.5	NA	<0.6	<0.6	<0.6	c
Channel catfish	Great Miami River	<0.2	<0.5	NA	<0.6	<0.6	<0.6	c
Minnow	Great Miami River	<0.2	<0.5	NA	<0.6	<0.6	<0.6	c
Catfish (fillets)	Great Miami River	<0.3-<0.7	<0.5	NA	<0.6	<0.6	<0.6	c
Catfish (bones and entrails)	Great Miami River	<0.2	<0.5	NA	<0.6	<0.6	<0.6	c
Freshwater drum	Great Miami River	<0.2	<0.5	NA	<0.6	<0.6	<0.6	c
Smallmouth bass	Great Miami River	<0.3	LIA[e]	NA	LIA	LIA	LIA	c
Green sunfish	Great Miami River	<0.3	<0.5	NA	<0.6	<0.6	<0.6	c
Longear sunfish	Great Miami River	<0.3	<0.5	NA	<0.6	<0.6	<0.6	c

See footnotes at end of table.

TAB[illegible]-57
(Continued)

[a]Benthic macroinvertebrates are aquatic organisms, including insects, insect larvae, annelid worms, and snails.

[b]Concentration less than the stated detection limit.

[c]All uranium isotopes below detection limit.

[d]Not analyzed.

[e]Lost in analysis.

APPENDIX B
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

LIST OF TABLES

Table	Title	Page
B-1	Summary List of Potential Applicable or Relevant and Appropriate Requirements and Guidance to be Considered	B-9

The purpose of this appendix is to list potential Applicable or Relevant and Appropriate Requirements (ARAR) and/or their sources.

Potential ARARs for Operable Unit 5

In accordance with current U.S. Environmental Protection Agency (EPA) guidance, ARARs are to be progressively developed and applied on a site-specific basis as the Remedial Investigation/ Feasibility Study (RI/FS) proceeds. The initial step in the process entails the listing of all potential ARARs for the remedial action process at the subject site. A comprehensive listing of potential ARARs for all of the operable units for the Fernald Environmental Management Project (FEMP) was completed as part of the FS Work Plan. The potential ARARs for the FEMP were categorized into the following U.S. EPA-recommended classifications:

- Chemical-Specific ARARs - Usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values for each chemical of concern. These values establish the acceptable amount or concentration of a chemical that may be found in or discharged to the environment.

- Location-Specific ARARs - Restrictions placed on the concentration of a chemical or the conduct of activities solely because they occur in special locations.

- Action-Specific ARARs - Usually technology- or activity-based requirements or limitations on actions taken with respect to waste management and site cleanup.

A brief discussion of each of the primary federal and state of Ohio ARARs, along with pertinent agency-issued criteria, advisories, and guidance is given below. A summary listing of potential ARARs is found in Table B-1.

Federal ARARs

Federal ARARs and other criteria, advisories, or guidelines, are drawn from and include the following:

- Safe Drinking Water Act (42USC300f, et. seq. and 40CFR141 to 149) - Establishes Maximum Contaminant Levels (MCL) which are enforceable standards for chemicals in public drinking water supplies. They not only consider health factors but also the economic and technical feasibility of removing a contaminant from a water supply system. The EPA has recently proposed MCL goals (MCLG) for several organic and inorganic compounds in drinking water. MCLGs are nonenforceable guidelines that do not consider the technical feasibility of contaminant removal. The Safe Drinking Water Act (SDWA) also authorizes the following programs:

- The Underground Injection Control (UIC) Program
- The Sole-Source Aquifer Program
- The Wellhead Protection Program

- Toxic Substances Control Act (15USC2601, et. seq. and 40CFR702 to 799) - Regulates the use and disposal of polychlorinated biphenyls (PCB) and asbestos.

- Resource Conservation and Recovery Act (42USC6901, et. seq. as amended and 40CFR260 to 279) - Establishes the criteria and standards for identification, management, and disposal of hazardous waste.

- Resource Conservation and Recovery Act (40 CFR 240 to 259) - Establishes criteria and standards for the identification, management, and disposal of solid waste.

- Resource Conservation and Recovery Act, Subtitle I (40 CFR 280) - Through the regulation of underground storage tanks (USTs), it provides the technical standards and corrective action requirements for owners and operators of underground storage tanks. This includes the design, construction, installation, general operating requirements, release detection, reporting and response, and closure of UST systems.

- Federal Water Pollution Control Act, as amended by the Clean Water Act (33USC1251, et. seq. and 40CFR104 to 140) - Governs point-source discharges through the National Pollutant Discharge Elimination System (NPDES), dredge and fill activities which may degrade or disturb wetlands or other aquatic habitats, and oil or hazardous substance spills to waters of the United States.

- Ambient Water Quality Criteria - Criteria for 64 chemicals were established in 1980, pursuant to Section 304(a)(1) of the Clean Water Act (CWA). Ambient water quality criteria (AWQC) are available for the protection of human health from exposure to chemicals in drinking water, from ingestion of aquatic biota, and for the protection of fresh water and salt-water aquatic life.

- Regulation of Activities Affecting Waters of the U.S. (33CFR320 to 329) - U.S. Army Corps of Engineers (U.S. ACE) regulations that are applicable to wetlands and navigable waters.

- Occupational Safety and Health Act (29USC651, et. seq. and 29CFR1904, 29CFR1910, and 29CFR1926) - Provides occupational safety and health requirements applicable to workers engaged in on-site field and remediation activities.

- Endangered Species Act of 1978 (16USC1531, et. seq.) - Provides for consideration of the impacts of remedial actions on endangered and threatened species.

- Fish and Wildlife Coordination Act (16USC661, et. seq. and 40CFR 6.302) - Provides for consideration of the impacts on wetlands and protected habitats.

- Fish and Wildlife Improvement Act of 1978 (16USC742a) - Provides for consideration of the impacts on wetlands and protected habitats.

- Clean Air Act (42USC4701, et. seq. and 40CFR61, Subpart H) - Through the National Ambient Air Quality Standards (NAAQS), it identifies primary and secondary standards for six "criteria" pollutants, and through the National Emission Standards for Radionuclides Emissions from U.S. Department of Energy (DOE) facilities (40CFR61), it provides annual exposure limits from air emissions from DOE facilities.

- EPA Regulations for National Emission Standards for Radon Emission from DOE Facilities (40CFR61, Subpart Q) - Applies to design and operation of all storage and disposal facilities for radium-containing material that are owned or operated by DOE that emit Radon-222.

- National Primary and Secondary Ambient Air Quality Standards (40CFR50) - Establishes primary and secondary standards for particulate matter emissions (40CFR50.6) and for lead emissions (40CFR50.12) into ambient air on a per time basis (annually, quarterly, 24-hour, etc.).

- EPA Regulations for Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings (40CFR192) - Applies to the control of residual radioactive material at designated processing or repository sites under Section 108 of the Uranium Mill Tailings Radiation Control Act of 1978 and to restoration of such sites following any use of subsurface minerals under Section 104(h) of the above-referenced act.

- NRC Regulations for Standards for Protection against Radiation (10CFR20) - Establishes standards for protection against radiation hazards arising out of activities under licenses issued by the U.S. Nuclear Regulatory Commission (NRC) and issued pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974.

- NRC Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content (10CFR40, Appendix A) - Establishes technical and long-term site surveillance criteria relating to siting, operation, decontamination, decommissioning, and reclamation of mills and tailings or waste systems and sites at which such mills and systems are located.

- The Atomic Energy Act of 1954 (42USC2011, as amended) - Authorizes the conduct of atomic energy activities.

- Licensing Requirements for Land Disposal of Radioactive Waste (10CFR61) - Establishes procedures and criteria for the land disposal of radioactive wastes.

- Department of Army, Corps of Engineers (33USC401 et seq. and 33 CFR 320.2 (f) - Authorizes the Secretary of the Army to issue permits for the discharge of dredged or fill materials into the waters of the United States at specified disposal sites. In evaluating dredge or fill operations, the U.S. ACE will follow EPA guidelines and requirements found under 40CFR230.

State of Ohio ARARs

State of Ohio ARARs and other criteria, advisories, or guidance include the authority of the Ohio Environmental Protection Agency (OEPA) to manage federal environmental programs. OEPA shares several responsibilities with other Ohio agencies including the Department of Health, the Department of Natural Resources (ODNR), and the Public Utilities Commission:

- Ohio Water Pollution Control Act (ORC Chapter 6111) - The OEPA has the authority to administer all of the federally mandated water discharge programs, including the NPDES programs for all source categories (OAC3745-33-01 through 3745-33-05), and an effective pretreatment program (OAC3745-3). ORC 6111 also prohibits pollution of waters of the state.

- Solid and Hazardous Waste Disposal Law (OAC Chapter 3734) - The OEPA has been developing extensive solid and hazardous waste regulations (OAC3745 Chapters 27-70). These programs are administered by the Solid and Hazardous Waste Division of the OEPA.

- Ohio Underground Storage Tanks Law (ORC 3737-87 to 99) - The Office of the Fire Marshal, Bureau of Underground Storage Tanks, has the responsibilities and duties for implementation of the Ohio state underground storage tank program and corrective action program for releases from underground petroleum storage tanks.

- Ohio Underground Storage Tank Regulations (OAC 1301:7-9-01 to 1301:7-9-15) - Sets the standards and guidelines that apply to owners and operators of underground storage tanks containing petroleum.

- Water Quality Standards (OAC3745-1) - Ohio has developed water quality standards applicable to state surface water (OAC3745-1-04), an antidegradation policy (OAC3745-1-05), and has designated water use criteria for all major surface water bodies (OAC3745-1-07 to 32).

- Drinking Water Rules - The rules for public drinking water are set forth by OAC3745-81-01 to 55, and includes MCLs. OAC3745-82 sets secondary contaminant standards.

- Water Well Installation - For new wells intended for human consumption, well installation is regulated under OAC3745-9 by the OEPA and ODNR.

- The Underground Injection Well Control Program - Approvals for injection wells are required from the ODNR and OEPA. The requirements for permits to inject fluids via wells are set forth in OAC3745-34.

- Water System - Authority to establish and enforce rules regarding private water systems is granted to the Department of Health under OAC3701. The Department of Health governs plan approvals, procedures, construction, and abandonment for private water systems (OAC3701-38). Community and public water supply systems are governed and approved by the OEPA under OAC3745-83 to 95.

- Radiation Standards - Standards for protection and handling of equipment and materials associated with ionizing radiation are governed by rules set by the Department of Health under OAC3701-38.

- Air Pollution Control (ORC3704, OAC3745-15, OAC3745-17) - Establishes the authority of the OEPA to regulate and control air pollution within the state under ORC 3704.03. Requires person responsible for any air contaminant source to install, employ, maintain, and operate such emissions, ambient air quality, meteorological, or other monitoring devices or methods as director prescribes. Requires the sampling of emissions at such locations, intervals, and in a manner which the director prescribes. Requires the maintenance of records and filing of periodic reports with the director on the location, size, and height of emissions outlets, as well as the rate, duration, and composition of emissions.

- Asbestos Control Standards (OAC 3745-20-05) - Specifies the standards which must be met regarding the handling and disposal of asbestos removed from inactive disposal areas to limit asbestos emissions.

Potential Guidance to be Considered (TBC)

A brief discussion of each of the primary Federal TBC presently being considered is given below.

Federal TBCs

- Health Effects Assessments - "Health Effects Assessment Summary Tables (HEAST)" and/or "Integrated Risk Information System (IRIS)." Presents toxicity data for specific chemicals for use in public health assessments. Also considered applicable are cancer slope factors (CSF) and referenced doses provided in the Human Health Evaluation Manual (EPA 1989c).

- Groundwater Protection Strategy - Documents EPA policy to protect groundwater for its highest present or potential beneficial use. The strategy designates three categories of groundwater:

- Class 1 - Special Groundwaters: Waters that are highly vulnerable to contamination and are either irreplaceable or ecologically vital sources of drinking water.

- Class 2 - Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses: Waters that are currently used or that are potentially available for use.

- Class 3 - Groundwater not a Potential Source of Drinking Water and of Limited Beneficial Use: Class 3 groundwater units are further subdivided into the following two subclasses:

  a. Subclass 3A includes groundwater units that are highly to intermediately interconnected to adjacent groundwater units of a higher class and/or surface waters. They may, as a result, be contributing to the degradation of the adjacent waters. They may be managed at a similar level as Class 2 groundwaters, depending upon the potential for producing adverse effects on the quality of adjacent waters.

  b. Subclass 3B is restricted to groundwater units characterized by a low degree of interconnection to adjacent surface waters or other groundwater units of a higher class within the Classification Review Area. These groundwaters are naturally isolated from sources of drinking water in such a way that there is little potential for producing adverse effects on quality. They have low resource value outside of mining or waste disposal.

- DOE Order for CERCLA Program (5400.4) (October 6, 1989) - Provides direction for DOE to implement a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program.

- DOE Order for General Environmental Protection Program Requirements (5400.1) (April 7, 1988) - Establishes environmental protection program requirements, authorities, and responsibilities for DOE operations.

- DOE Order for Radiation Protection of the Public and the Environment (5400.5) (February 8, 1990) - Establishes standards and requirements with respect to protection of the public and the environment against radiation.

- DOE Order for Radiation Protection for Occupational Workers (5480.11) (December 21, 1988) - Establishes standards and requirements with respect to protection of the occupational worker against radiation.

- DOE Order for Environmental Protection, Safety, and Health Protection Information Reporting Requirements (5484.1) (February 24, 1981) - Establishes the requirements and procedures for reporting and investigating matters of environmental protection, safety, and health protection significant to DOE operations.

- DOE Order for Quality Assurance (5700.6B) (September 23, 1986) - Establishes DOE's quality assurance program.

- DOE Order for Radioactive Waste Management (5820.2A) (September 26, 1988) - Establishes policies and guidelines for the management of radioactive waste and contaminated facilities.

- DOE Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T) (January 1991) - Establishes elements of a radiological effluent monitoring and environmental surveillance program considered acceptable to DOE, in support of DOE Orders 5400.1 and 5400.5.

- DOE Plan for Implementing EPA Standard for UMTRA Sites (UMTRA - DOE/AL-163) (January 1984) - Presents guidance for implementing EPA standards on uranium mill tailings remedial action sites.

- DOE Technical Approach Document - Revision II (UMTRA-DOE/AL 050425.0002) (December 1989) - Presents the technical approach for remediation of uranium mill tailings remedial action sites.

- DOE Remedial Action Planning and Disposal Cell Design (UMTRA-DOE/AL 400503) (January 1989) - Presents guidance for complying with the proposal 40CFR192 for planning and disposal cell design for uranium mill tailings remedial action sites.

- DOE Project Surveillance and Maintenance Plan (UMTRA-DOE/AL 350124) - Presents guidance for surveillance and maintenance of uranium mill tailings remedial action sites.

- Executive Order 11988 - Presents requirements for federal agencies to protect floodplains.

- Executive Order 11990 - Presents requirements for federal agencies to protect wetlands.

- NRC Regulatory Guide for Termination of Operating Licenses for Nuclear Reactors (NRC Regulatory Guide 1.86) (June 1974) - Establishes acceptable surface radioactivity contamination levels for release of equipment and facilities for unrestricted use.

- 40 CFR 141 - Proposed Maximum Contaminant Levels and Maximum Contaminant Level Goals - Nonenforceable levels of protection for contaminants in drinking water.

- 40 CFR 140 - Ambient Water Quality Criteria - Nonenforceable levels for protection of environmental receptors.

A summary listing of TBCs is found in Table B-1.

Summary

The establishment of final federal and state ARARs and TBCs for uranium and other constituents found in the operable unit for the evaluation of remedial action alternatives for Operable Unit 5 at the FEMP will be a progressive, multistep process involving interactive discussions among the DOE, EPA, and OEPA. The critical application of the final ARARs will be performed during the detailed analysis of alternatives. The ARARs, in conjunction with the baseline risk assessment, will assist in the determination of the cleanup levels required to adequately protect public health and the environment at the FEMP.

TABLE B-1

SUMMARY LIST OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND GUIDANCE TO BE CONSIDERED

Chemical-Specific ARARs	
Requirement	**Description**
Resource Conservation and Recovery Act (RCRA), (40CFR260-272)	Set standards applicable to hazardous waste treatment, storage, and disposal
RCRA/Solid Waste (40CFR240-257)	Sets standards applicable to solid waste treatment, storage, and disposal
Safe Drinking Water Act (40CFR141-149) a. Maximum contaminant levels (MCL) b. Maximum contaminant level goals (MCLG)	Remedial actions may provide cleanup to the MCLs considered pursuant to SARA Section 121(d)(2)(A)(ii)
EPA Regulations for Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings (40CFR192)	Establishes cleanup levels for uranium and thorium mill tailings in soil and groundwater
Clean Air Act (42USC7401, et. seq.) a. National Ambient Air Quality Standards (NAAQS) for six criteria pollutants (40CFR61)	Identifies primary and secondary standards for six "criteria pollutants" (i.e., lead, particulates)
b. National Emission Standards for Radionuclides Emissions from DOE Facilities (40CFR61 Subpart H)	Provides annual limits of 10 mrem/yr (whole body) for air emissions (except radon) from DOE facilities
NRC Licensing Requirements for Land Disposal of Radioactive Waste (10CFR61)	Provides for protection of the general population from releases of radioactivity (<25 mrem/yr)
NRC Regulations for Standards for Protection Against Radiation (10CFR20)	Establishes dose limits in unrestricted areas and for waste disposal
Ohio Regulations	
a. Air Pollution	Prevention of air pollution nuisance
OAC3745-15-07	Escape, releases, emissions to open air
OAC3745-17-07	Nondegradation policy
OAC3745-17-05	Particulate emissions to air
OAC3745-17-07	Emissions of organics to air
OAC3745-17-08	Fugitive dust emissions
OAC3745-21-07	Air quality

Chemical-Specific ARARs	
Requirement	Description
b. Water Pollution QAC3745-81	Drinking water rules, sets MCLs for gross alpha, beta and radium-226 and radium-228
OAC3745-31	Set requirements for wastewater treatment facilities
OAC3745-1	Water Quality Standards, 3745-01-4(D) sets the criterion applicable to all waters, 3745-01-05 sets forth the antidegradation policy for state waters, 3745-01-07 presents specific surface water quality criteria for both acute and chronic effects on aquatic organisms, 3745-01-21 describes use designations for the Great Miami River, 3745-1-21(c)(9) set standards for radioactive materials in receiving water of the Ohio River
c. Radiation Protection OAC3701-38	Ohio Radiation Protection Standards provide concentration limits for discharge of radioactive materials into air or water unrestricted areas

TABLE B-1
(Continued)

Location-Specific ARARs	
Requirement	Description
Rivers and Harbors Act of 1899 (33CFR320 to 327)	Requires approval for construction, excavation filling or other alteration affecting navigable waters
Ohio Location Standards (OAC3745-54-18)	Governs the location of hazardous waste treatment, storage, or disposal with respect to floodplains
Regulations of activities affecting waters of the U.S. (33CFR320 to 329)	U.S. ACE regulations apply to both wetlands and navigable (33CFR320-329), and for Ohio (OAC3745-32) waters
Fish and Wildlife Coordination Act (40CFR6.302)	Provides for coordination of the impacts on wetlands and protection habitats

TABLE B-1
(Continued)

Action-Specific ARARs	
Requirement	Description
Resource Conservation and Recovery Act (RCRA) (40CFR260-272)	Set standards applicable to hazardous waste treatment, storage, and disposal
RCRA/Solid Waste (40CFR240-257)	Sets standards applicable to solid waste treatment, storage, and disposal
Resource Conservation and Recovery Act (RCRA) (40CFR280)	Provides technical standards and corrective action requirements for owners and operators of underground storage tanks
Clean Water Act Ambient Water Quality Criteria (40CFR104-140)	Establishes chemical-specific water quality guidelines to maintain surface water quality.
NRC Licensing Requirements for Land Disposal of Radioactive Waste (10CFR61)	Provides criteria for siting, decontamination, decommissioning,and disposition of uranium tailings and wastes (Appendix A)
NRC Regulations for Licensing of Source Materials (10CFR40)	Provides requirements for siting, design operation, closure, and control after closure for radioactive waste disposal facilities
EPA Regulations for Health and Environmental Protection Standards for Uranium and Thorium Mil Tailings (40CFR192)	Provides standards for control or residual radioactive materials from inactive uranium processing sites
Department of Army Corps of Engineers - Responsibility of Dredge and Fill Operations (33CFR320.2[f])	Authorizes the issuance of permits for dredge or fill materials into a United States Waterway - U.S. ACE will follow EPA guidelines and requirements
Ohio General Radiation Protection Standards (OAC3701 to 70)	Applies to all facilities that receive, possess, use store, transfer, etc., any source of radiation
Ohio Radiation Protection Standards (OAC3702-38)	Applies to all facilities that receive, possess, use, store, transfer, etc., and source of radiation
Hazardous Waste Transport (OAC3745-53-11)	Remedial alternatives may include off-site transport
Air Pollution Nuisances Prohibited (OAC3745-15-07)	Prohibits air which could be constituted as a public nuisance

Action-Specific ARARs	
Requirement	Description
Control of Asbestos Emissions (OAC3745-2005)	Specifies standards for the handling and disposal of asbestos to limit asbestos air emissions from inactive waste disposal areas
Nuisance Prevention (ORC 3767)	Prohibits noxious exhalation or smells, obstructions or pollution of water courses, other nuisances
Water Pollution Prevention (ORC6111)	Prohibits pollution of waters of the state
Ohio Underground Storage Tanks Law (ORC 3737-87 to 99)	Authorizes the Fire Marshall, Bureau of Underground Storage Tanks, to implement the underground storage tank program and corrective action program for releases from underground petroleum storage tanks in the state of Ohio
Ohio Underground Storage Tank Regulations (OAC 1301:7-9-01 to 1301:7-9-15)	Sets rules that apply to owners and operators of underground storage tanks containing petroleum

TBCs	
Requirement	Description
Executive Order 11988 Floodplain Management	Provides considerations for management of floodplain areas
Executive Order 11990 Protection of the Wetlands	Provides considerations for protection of wetlands
Radioactive Waste Management (DOE Order 5820.2A)	Sets requirements for management of radioactive wastes at DOE facilities
DOE Order for General Environmental Protection Program Requirements (5400.1) (April 17, 1988)	Establishes environmental protection program requirements, authorities and responsibilities for DOE operations
CERCLA Program (DOE Order 5400.4)	Provides direction for DOE to implement a CERCLA program
DOE Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T) (January 1991)	Establishes elements of a radiological effluent monitoring and environmental surveillance program considered acceptable to DOE, in support of DOE Order 5400.1 and 5400.5
Plan for Implementing EPA Standards for UMTRA Sites (UMTRA-DOE/AL-163)	Presents guidance for implementing EPA standards on uranium mill tailings remedial action sites
Technical Approach Document (UMTRA-DOE/AL 050425)	Presents the technical approach used by DOE for remediation of uranium mill tailings remedial action sites
Remedial Action Planning and Disposal Cell Design (UMTRA-DOE/AL 400503)	Presents guidance for complying with 40CFR192 for planning and disposal cell design for uranium mill tailings remedial action sites
Project Surveillance and Maintenance Plan (UMTRA-DOE/AL 350134)	Presents guidance for surveillance and maintenance of uranium mill tailings remedial action sites
Minimum Technology Guidance for Final Covers on Hazardous Waste Landfills and Surface Impoundments (EPA)	Presents guidance for final cover of hazardous waste landfills and surface impoundments

APPENDIX C
ESTIMATED COSTS OF ALTERNATIVES

TABLE C-1
GROUNDWATER ALTERNATIVE GW-2:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
REVERSE OSMOSIS AND SURFACE WATER DISCHARGE (OPTION 1: GREAT MIAMI RIVER)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Reverse Osmosis System)	LS	1	$34,604,000	$34,604,000
14	NPDES Discharge Pipeline	LS	1	$20,000	$20,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$36,702,300	$3,670,230
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$36,627,300	$1,831,365
20	Contingency (20 % Of Items 1 To 19)	%	20	$42,203,895	$8,440,779
				TOTAL =	$50,644,674

TABLE C-1B
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-2
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	50,644,700 (5)	0	50,644,700
2	10,100,000 (1)	100,000 (2)	100,000 (2)	50,000 (2)	147,000 (3)	10,497,000	1.05	0.91	0	10,019,864	10,019,864
3	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.10	0.83	0	9,564,415	9,564,415
4	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.16	0.75	0	9,129,669	9,129,669
5	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.22	0.68	0	8,714,684	8,714,684
6	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.28	0.62	0	8,318,562	8,318,562
7	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.34	0.56	0	7,940,446	7,940,446
8	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.41	0.51	0	7,579,516	7,579,516
9	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.48	0.47	0	7,234,993	7,234,993
10	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.55	0.42	0	6,906,130	6,906,130
11	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.63	0.39	0	6,592,215	6,592,215
12	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.71	0.35	0	6,292,568	6,292,568
13	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.80	0.32	0	6,006,543	6,006,543
14	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.89	0.29	0	5,733,518	5,733,518
15	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.98	0.26	0	5,472,904	5,472,904
16	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.08	0.24	0	5,224,135	5,224,135
17	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.18	0.22	0	4,986,674	4,986,674
18	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.29	0.20	0	4,760,007	4,760,007
19	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.41	0.18	0	4,543,643	4,543,643
20	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.53	0.16	0	4,337,114	4,337,114
21	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.65	0.15	0	4,139,973	4,139,973
22	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.79	0.14	0	3,951,792	3,951,792
23	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.93	0.12	0	3,772,165	3,772,165
24	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.07	0.11	0	3,600,703	3,600,703
25	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.23	0.10	0	3,437,035	3,437,035
26	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.39	0.09	0	3,280,806	3,280,806
27	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.56	0.08	0	3,131,678	3,131,678
28	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.73	0.08	0	2,989,329	2,989,329
29	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.92	0.07	0	2,853,451	2,853,451
30	10,100,000	100,000	100,000	50,000	147,000	10,497,000	4.12	0.06	0	2,723,748	2,723,748
31	10,100,000	100,000	100,000	50,000	147,000	10,497,000	4.32	0.06	0	2,599,942	2,599,942
	303,000,000	3,000,000	3,000,000	1,500,000	4,410,000	314,910,000			50,644,700	165,838,224	216,482,924

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-1

(6) J=F*G*H

(7) K=I+J

TABLE C-1a
GROUNDWATER ALTERNATIVE GW-2a:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
REVERSE OSMOSIS; AND SURFACE WATER DISCHARGE (OPTION 2: PADDYS RUN)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Reverse Osmosis System)	LS	1	$34,604,000	$34,604,000
14	NPDES Discharge Pipeline (to Paddys Run)	LS	1	$5,000	$5,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$36,687,300	$3,668,730
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$36,612,300	$1,830,615
20	Contingency (20 % Of Items 1 To 19)	%	20	$42,186,645	$8,437,329
				TOTAL =	$50,623,974

TABLE C-1aB
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-2a
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	50,624,000 (5)	0	50,624,000
2	10,100,000 (1)	100,000 (2)	100,000 (2)	50,000 (2)	147,000 (3)	10,497,000	1.05	0.91	0	10,019,864	10,019,864
3	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.10	0.83	0	9,564,415	9,564,415
4	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.16	0.75	0	9,129,669	9,129,669
5	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.22	0.68	0	8,714,684	8,714,684
6	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.28	0.62	0	8,318,562	8,318,562
7	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.34	0.56	0	7,940,446	7,940,446
8	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.41	0.51	0	7,579,516	7,579,516
9	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.48	0.47	0	7,234,993	7,234,993
10	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.55	0.42	0	6,906,130	6,906,130
11	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.63	0.39	0	6,592,215	6,592,215
12	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.71	0.35	0	6,292,568	6,292,568
13	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.80	0.32	0	6,006,543	6,006,543
14	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.89	0.29	0	5,733,518	5,733,518
15	10,100,000	100,000	100,000	50,000	147,000	10,497,000	1.98	0.26	0	5,472,904	5,472,904
16	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.08	0.24	0	5,224,135	5,224,135
17	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.18	0.22	0	4,986,674	4,986,674
18	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.29	0.20	0	4,760,007	4,760,007
19	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.41	0.18	0	4,543,643	4,543,643
20	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.53	0.16	0	4,337,114	4,337,114
21	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.65	0.15	0	4,139,973	4,139,973
22	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.79	0.14	0	3,951,792	3,951,792
23	10,100,000	100,000	100,000	50,000	147,000	10,497,000	2.93	0.12	0	3,772,165	3,772,165
24	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.07	0.11	0	3,600,703	3,600,703
25	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.23	0.10	0	3,437,035	3,437,035
26	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.39	0.09	0	3,280,806	3,280,806
27	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.56	0.08	0	3,131,678	3,131,678
28	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.73	0.08	0	2,989,329	2,989,329
29	10,100,000	100,000	100,000	50,000	147,000	10,497,000	3.92	0.07	0	2,853,451	2,853,451
30	10,100,000	100,000	100,000	50,000	147,000	10,497,000	4.12	0.06	0	2,723,748	2,723,748
31	10,100,000	100,000	100,000	50,000	147,000	10,497,000	4.32	0.06	0	2,599,942	2,599,942
	303,000,000	3,000,000	3,000,000	1,500,000	4,410,000	314,910,000			50,624,000	165,838,224	216,462,224

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-1a

(6) J=F*G*H

(7) K=I+J

TABLE C-2
GROUNDWATER ALTERNATIVE GW-3:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
ION EXCHANGE; AND SURFACE WATER DISCHARGE (OPTION 1: GREAT MIAMI RIVER)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Ion Exchange System)	LS	1	$18,264,000	$18,264,000
14	NPDES Discharge Pipeline	LS	1	$20,000	$20,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$20,362,300	$2,036,230
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$20,287,300	$1,014,365
20	Contingency (20 % Of Items 1 To 19)	%	20	$23,412,895	$4,682,579
				TOTAL =	$28,095,474

TABLE C-2B
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-3
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	28,095,500 (5)	0	28,095,500
2	8,060,000 (1)	100,000 (2)	100,000 (2)	50,000 (2)	147,000 (3)	8,457,000	1.05	0.91	0	8,072,591	8,072,591
3	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.10	0.83	0	7,705,655	7,705,655
4	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.16	0.75	0	7,355,398	7,355,398
5	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.22	0.68	0	7,021,062	7,021,062
6	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.28	0.62	0	6,701,922	6,701,922
7	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.34	0.56	0	6,397,290	6,397,290
8	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.41	0.51	0	6,106,504	6,106,504
9	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.48	0.47	0	5,828,935	5,828,935
10	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.55	0.42	0	5,563,984	5,563,984
11	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.63	0.39	0	5,311,075	5,311,075
12	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.71	0.35	0	5,069,663	5,069,663
13	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.80	0.32	0	4,839,224	4,839,224
14	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.89	0.29	0	4,619,259	4,619,259
15	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.98	0.26	0	4,409,293	4,409,293
16	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.08	0.24	0	4,208,870	4,208,870
17	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.18	0.22	0	4,017,558	4,017,558
18	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.29	0.20	0	3,834,942	3,834,942
19	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.41	0.18	0	3,660,626	3,660,626
20	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.53	0.16	0	3,494,234	3,494,234
21	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.65	0.15	0	3,335,405	3,335,405
22	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.79	0.14	0	3,183,796	3,183,796
23	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.93	0.12	0	3,039,078	3,039,078
24	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.07	0.11	0	2,900,938	2,900,938
25	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.23	0.10	0	2,769,077	2,769,077
26	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.39	0.09	0	2,643,210	2,643,210
27	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.56	0.08	0	2,523,064	2,523,064
28	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.73	0.08	0	2,408,379	2,408,379
29	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.92	0.07	0	2,298,908	2,298,908
30	8,060,000	100,000	100,000	50,000	147,000	8,457,000	4.12	0.06	0	2,194,412	2,194,412
31	8,060,000	100,000	100,000	50,000	147,000	8,457,000	4.32	0.06	0	2,094,666	2,094,666
	241,800,000	3,000,000	3,000,000	1,500,000	4,410,000	253,710,000			28,095,500	133,609,018	161,704,518

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-2

(6) J=F*G*H

(7) K=I+J

TABLE C-2a
GROUNDWATER ALTERNATIVE GW-3a:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
ION EXCHANGE; AND SURFACE WATER DISCHARGE (OPTION 2: PADDYS RUN)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Ion Exchange System)	LS	1	$18,264,000	$18,264,000
14	NPDES Discharge Pipeline (to Paddys Run)	LS	1	$5,000	$5,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$20,347,300	$2,034,730
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$20,272,300	$1,013,615
20	Contingency (20 % Of Items 1 To 19)	%	20	$23,395,645	$4,679,129
				TOTAL =	$28,074,774

TABLE C-2aB
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-3a
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	28,074,800 (5)	0	28,074,800
2	8,060,000 (1)	100,000 (2)	100,000 (2)	50,000 (2)	147,000 (3)	8,457,000	1.05	0.91	0	8,072,591	8,072,591
3	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.10	0.83	0	7,705,655	7,705,655
4	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.16	0.75	0	7,355,398	7,355,398
5	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.22	0.68	0	7,021,062	7,021,062
6	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.28	0.62	0	6,701,922	6,701,922
7	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.34	0.56	0	6,397,290	6,397,290
8	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.41	0.51	0	6,106,504	6,106,504
9	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.48	0.47	0	5,828,935	5,828,935
10	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.55	0.42	0	5,563,984	5,563,984
11	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.63	0.39	0	5,311,075	5,311,075
12	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.71	0.35	0	5,069,663	5,069,663
13	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.80	0.32	0	4,839,224	4,839,224
14	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.89	0.29	0	4,619,259	4,619,259
15	8,060,000	100,000	100,000	50,000	147,000	8,457,000	1.98	0.26	0	4,409,293	4,409,293
16	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.08	0.24	0	4,208,870	4,208,870
17	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.18	0.22	0	4,017,558	4,017,558
18	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.29	0.20	0	3,834,942	3,834,942
19	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.41	0.18	0	3,660,626	3,660,626
20	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.53	0.16	0	3,494,234	3,494,234
21	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.65	0.15	0	3,335,405	3,335,405
22	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.79	0.14	0	3,183,796	3,183,796
23	8,060,000	100,000	100,000	50,000	147,000	8,457,000	2.93	0.12	0	3,039,078	3,039,078
24	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.07	0.11	0	2,900,938	2,900,938
25	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.23	0.10	0	2,769,077	2,769,077
26	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.39	0.09	0	2,643,210	2,643,210
27	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.56	0.08	0	2,523,064	2,523,064
28	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.73	0.08	0	2,408,379	2,408,379
29	8,060,000	100,000	100,000	50,000	147,000	8,457,000	3.92	0.07	0	2,298,908	2,298,908
30	8,060,000	100,000	100,000	50,000	147,000	8,457,000	4.12	0.06	0	2,194,412	2,194,412
31	8,060,000	100,000	100,000	50,000	147,000	8,457,000	4.32	0.06	0	2,094,666	2,094,666
	241,800,000	3,000,000	3,000,000	1,500,000	4,410,000	253,710,000			28,074,800	133,609,018	161,683,818

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-2a

(6) J=F*G*H

(7) K=I+J

TABLE C-3
GROUNDWATER ALTERNATIVE GW-4:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
REVERSE OSMOSIS; AND REINJECTION WELL DISCHARGE
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Reverse Osmosis System)	LS	1	$34,604,000	$34,604,000
14	Reinjection Wells	EA	12	$12,500	$150,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$36,832,300	$3,683,230
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$36,757,300	$1,837,865
20	Contingency (20 % Of Items 1 To 19)	%	20	$42,353,395	$8,470,679
				TOTAL =	$50,824,074

TABLE C-3B
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-4
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	50,824,100 (5)	0	50,824,100
2	10,100,000 (1)	100,000 (2)	100,000 (2)	90,000 (2)	147,000 (3)	10,537,000	1.05	0.91	0	10,058,045	10,058,045
3	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.10	0.83	0	9,600,862	9,600,862
4	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.16	0.75	0	9,164,459	9,164,459
5	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.22	0.68	0	8,747,892	8,747,892
6	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.28	0.62	0	8,350,261	8,350,261
7	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.34	0.56	0	7,970,704	7,970,704
8	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.41	0.51	0	7,608,399	7,608,399
9	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.48	0.47	0	7,262,563	7,262,563
10	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.55	0.42	0	6,932,446	6,932,446
11	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.63	0.39	0	6,617,335	6,617,335
12	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.71	0.35	0	6,316,547	6,316,547
13	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.80	0.32	0	6,029,431	6,029,431
14	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.89	0.29	0	5,755,366	5,755,366
15	10,100,000	100,000	100,000	90,000	147,000	10,537,000	1.98	0.26	0	5,493,759	5,493,759
16	10,100,000	100,000	100,000	90,000	147,000	10,537,000	2.08	0.24	0	5,244,042	5,244,042
17	10,100,000	100,000	100,000	90,000	147,000	10,537,000	2.18	0.22	0	5,005,677	5,005,677
18	10,100,000	100,000	100,000	90,000	147,000	10,537,000	2.29	0.20	0	4,778,146	4,778,146
19	10,100,000	100,000	100,000	90,000	147,000	10,537,000	2.41	0.18	0	4,560,958	4,560,958
20	10,100,000	100,000	100,000	90,000	147,000	10,537,000	2.53	0.16	0	4,353,641	4,353,641
21	10,100,000	100,000	100,000	90,000	147,000	10,537,000	2.65	0.15	0	4,155,749	4,155,749
22	10,100,000	100,000	100,000	90,000	147,000	10,537,000	2.79	0.14	0	3,966,851	3,966,851
23	10,100,000	100,000	100,000	90,000	147,000	10,537,000	2.93	0.12	0	3,786,539	3,786,539
24	10,100,000	100,000	100,000	90,000	147,000	10,537,000	3.07	0.11	0	3,614,424	3,614,424
25	10,100,000	100,000	100,000	90,000	147,000	10,537,000	3.23	0.10	0	3,450,132	3,450,132
26	10,100,000	100,000	100,000	90,000	147,000	10,537,000	3.39	0.09	0	3,293,308	3,293,308
27	10,100,000	100,000	100,000	90,000	147,000	10,537,000	3.56	0.08	0	3,143,612	3,143,612
28	10,100,000	100,000	100,000	90,000	147,000	10,537,000	3.73	0.08	0	3,000,721	3,000,721
29	10,100,000	100,000	100,000	90,000	147,000	10,537,000	3.92	0.07	0	2,864,324	2,864,324
30	10,100,000	100,000	100,000	90,000	147,000	10,537,000	4.12	0.06	0	2,734,128	2,734,128
31	10,100,000	100,000	100,000	90,000	147,000	10,537,000	4.32	0.06	0	2,609,849	2,609,849
	303,000,000	3,000,000	3,000,000	2,700,000	4,410,000	316,110,000			50,824,100	166,470,169	217,294,269

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-3

(6) J=F*G*H

(7) K=I+J

TABLE C-4
GROUNDWATER ALTERNATIVE GW-5:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
ION EXCHANGE; AND REINJECTION WELL DISCHARGE
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Ion Exchange System)	LS	1	$18,264,000	$18,264,000
14	Reinjection Wells	EA	12	$12,500	$150,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$20,492,300	$2,049,230
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$20,417,300	$1,020,865
20	Contingency (20 % Of Items 1 To 19)	%	20	$23,562,395	$4,712,479
				TOTAL =	$28,274,874

TABLE C-4B
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-5
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	28,274,900 (5)	0	28,274,900
2	8,060,000 (1)	100,000 (2)	100,000 (2)	90,000 (2)	147,000 (3)	8,497,000	1.05	0.91	0	10,029,409	10,029,409
3	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.10	0.83	0	9,573,527	9,573,527
4	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.16	0.75	0	9,138,367	9,138,367
5	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.22	0.68	0	8,722,986	8,722,986
6	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.28	0.62	0	8,326,487	8,326,487
7	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.34	0.56	0	7,948,010	7,948,010
8	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.41	0.51	0	7,586,737	7,586,737
9	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.48	0.47	0	7,241,885	7,241,885
10	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.55	0.42	0	6,912,709	6,912,709
11	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.63	0.39	0	6,598,495	6,598,495
12	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.71	0.35	0	6,298,563	6,298,563
13	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.80	0.32	0	6,012,265	6,012,265
14	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.89	0.29	0	5,738,980	5,738,980
15	8,060,000	100,000	100,000	90,000	147,000	8,497,000	1.98	0.26	0	5,478,117	5,478,117
16	8,060,000	100,000	100,000	90,000	147,000	8,497,000	2.08	0.24	0	5,229,112	5,229,112
17	8,060,000	100,000	100,000	90,000	147,000	8,497,000	2.18	0.22	0	4,991,425	4,991,425
18	8,060,000	100,000	100,000	90,000	147,000	8,497,000	2.29	0.20	0	4,764,542	4,764,542
19	8,060,000	100,000	100,000	90,000	147,000	8,497,000	2.41	0.18	0	4,547,972	4,547,972
20	8,060,000	100,000	100,000	90,000	147,000	8,497,000	2.53	0.16	0	4,341,246	4,341,246
21	8,060,000	100,000	100,000	90,000	147,000	8,497,000	2.65	0.15	0	4,143,917	4,143,917
22	8,060,000	100,000	100,000	90,000	147,000	8,497,000	2.79	0.14	0	3,955,557	3,955,557
23	8,060,000	100,000	100,000	90,000	147,000	8,497,000	2.93	0.12	0	3,775,759	3,775,759
24	8,060,000	100,000	100,000	90,000	147,000	8,497,000	3.07	0.11	0	3,604,133	3,604,133
25	8,060,000	100,000	100,000	90,000	147,000	8,497,000	3.23	0.10	0	3,440,309	3,440,309
26	8,060,000	100,000	100,000	90,000	147,000	8,497,000	3.39	0.09	0	3,283,931	3,283,931
27	8,060,000	100,000	100,000	90,000	147,000	8,497,000	3.56	0.08	0	3,134,662	3,134,662
28	8,060,000	100,000	100,000	90,000	147,000	8,497,000	3.73	0.08	0	2,992,177	2,992,177
29	8,060,000	100,000	100,000	90,000	147,000	8,497,000	3.92	0.07	0	2,856,169	2,856,169
30	8,060,000	100,000	100,000	90,000	147,000	8,497,000	4.12	0.06	0	2,726,343	2,726,343
31	8,060,000	100,000	100,000	90,000	147,000	8,497,000	4.32	0.06	0	2,602,419	2,602,419
	241,800,000	3,000,000	3,000,000	2,700,000	4,410,000	254,910,000			28,274,900	165,996,210	194,271,110

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-4

(6) J=F*G*H

(7) K=I+J

TABLE C-5
GROUNDWATER ALTERNATIVE GW-6:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
CHEMICAL PRECIPITATION AND SURFACE WATER DISCHARGE (OPTION 1: GREAT MIAMI AQUIFER)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Chemical Precipitation System)	LS	1	$13,089,766	$13,089,766
14	NPDES Discharge Pipeline	LS	1	$20,000	$20,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$15,188,066	$1,518,807
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$15,113,066	$755,653
20	Contingency (20 % Of Items 1 To 19)	%	20	$17,462,526	$3,492,505
				TOTAL =	$20,955,031

TABLE C-5B
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-6
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	20,955,000 (5)	0	20,955,000
2	113,492,500 (1)	100,000 (2)	100,000 (2)	50,000 (2)	147,000 (3)	113,889,500	1.05	0.91	0	108,712,705	108,712,705
3	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.10	0.83	0	103,771,218	103,771,218
4	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.16	0.75	0	99,054,344	99,054,344
5	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.22	0.68	0	94,551,874	94,551,874
6	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.28	0.62	0	90,254,062	90,254,062
7	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.34	0.56	0	86,151,604	86,151,604
8	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.41	0.51	0	82,235,622	82,235,622
9	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.48	0.47	0	78,497,640	78,497,640
10	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.55	0.42	0	74,929,565	74,929,565
11	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.63	0.39	0	71,523,676	71,523,676
12	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.71	0.35	0	68,272,600	68,272,600
13	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.80	0.32	0	65,169,300	65,169,300
14	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.89	0.29	0	62,207,059	62,207,059
15	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.98	0.26	0	59,379,465	59,379,465
16	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.08	0.24	0	56,680,399	56,680,399
17	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.18	0.22	0	54,104,017	54,104,017
18	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.29	0.20	0	51,644,743	51,644,743
19	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.41	0.18	0	49,297,255	49,297,255
20	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.53	0.16	0	47,056,471	47,056,471
21	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.65	0.15	0	44,917,540	44,917,540
22	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.79	0.14	0	42,875,834	42,875,834
23	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.93	0.12	0	40,926,932	40,926,932
24	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.07	0.11	0	39,066,617	39,066,617
25	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.23	0.10	0	37,290,862	37,290,862
26	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.39	0.09	0	35,595,823	35,595,823
27	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.56	0.08	0	33,977,831	33,977,831
28	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.73	0.08	0	32,433,384	32,433,384
29	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.92	0.07	0	30,959,139	30,959,139
30	113,492,500	100,000	100,000	50,000	147,000	113,889,500	4.12	0.06	0	29,551,906	29,551,906
31	113,492,500	100,000	100,000	50,000	147,000	113,889,500	4.32	0.06	0	28,208,637	28,208,637
	3,404,775,000	3,000,000	3,000,000	1,500,000	4,410,000	3,416,685,000			20,955,000	1,799,298,121	1,820,253,121

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-5

(6) J=F*G*H

(7) K=I+J

TABLE C-5a
GROUNDWATER ALTERNATIVE GW-6a:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
CHEMICAL PRECIPITATION AND SURFACE WATER DISCHARGE (OPTION 2: PADDYS RUN)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Chemical Precipitation System)	LS	1	$13,089,766	$13,089,766
14	NPDES Discharge Pipeline (to Paddys Run)	LS	1	$5,000	$5,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$15,173,066	$1,517,307
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$15,098,066	$754,903
20	Contingency (20 % Of Items 1 To 19)	%	20	$17,445,276	$3,489,055
				TOTAL =	$20,934,331

TABLE C-5aB
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-6a
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	20,934,300 (5)	0	20,934,300
2	113,492,500 (1)	100,000 (2)	100,000 (2)	50,000 (2)	147,000 (3)	113,889,500	1.05	0.91	0	108,712,705	108,712,705
3	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.10	0.83	0	103,771,218	103,771,218
4	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.16	0.75	0	99,054,344	99,054,344
5	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.22	0.68	0	94,551,874	94,551,874
6	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.28	0.62	0	90,254,062	90,254,062
7	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.34	0.56	0	86,151,604	86,151,604
8	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.41	0.51	0	82,235,622	82,235,622
9	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.48	0.47	0	78,497,640	78,497,640
10	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.55	0.42	0	74,929,565	74,929,565
11	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.63	0.39	0	71,523,676	71,523,676
12	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.71	0.35	0	68,272,600	68,272,600
13	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.80	0.32	0	65,169,300	65,169,300
14	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.89	0.29	0	62,207,059	62,207,059
15	113,492,500	100,000	100,000	50,000	147,000	113,889,500	1.98	0.26	0	59,379,465	59,379,465
16	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.08	0.24	0	56,680,399	56,680,399
17	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.18	0.22	0	54,104,017	54,104,017
18	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.29	0.20	0	51,644,743	51,644,743
19	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.41	0.18	0	49,297,255	49,297,255
20	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.53	0.16	0	47,056,471	47,056,471
21	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.65	0.15	0	44,917,540	44,917,540
22	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.79	0.14	0	42,875,834	42,875,834
23	113,492,500	100,000	100,000	50,000	147,000	113,889,500	2.93	0.12	0	40,926,932	40,926,932
24	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.07	0.11	0	39,066,617	39,066,617
25	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.23	0.10	0	37,290,862	37,290,862
26	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.39	0.09	0	35,595,823	35,595,823
27	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.56	0.08	0	33,977,831	33,977,831
28	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.73	0.08	0	32,433,384	32,433,384
29	113,492,500	100,000	100,000	50,000	147,000	113,889,500	3.92	0.07	0	30,959,139	30,959,139
30	113,492,500	100,000	100,000	50,000	147,000	113,889,500	4.12	0.06	0	29,551,906	29,551,906
31	113,492,500	100,000	100,000	50,000	147,000	113,889,500	4.32	0.06	0	28,208,637	28,208,637
	3,404,775,000	3,000,000	3,000,000	1,500,000	4,410,000	3,416,685,000			20,934,300	1,799,298,121	1,820,232,421

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-5a

(6) J=F*G*H

(7) K=I+J

TABLE C-6
GROUNDWATER ALTERNATIVE GW-7:
INSTITUTIONAL ACTIONS; EXTRACTION/INJECTION WELLS;
EXTRACTION WELLS AND WELL POINT SYSTEM; AIR STRIPPING AND ADSORPTION;
CHEMICAL PRECIPITATION AND REINJECTION WELL DISCHARGE
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Extraction And Injection Wells (For Hydraulic Containment System)	EA	18	$5,000	$90,000
2	Pumps (No pumps For injection wells; Includes 4 Spares)	EA	13	$10,000	$130,000
3	Piping (for Hydraulic Containment System)	LS	1	$200,000	$200,000
4	Wellpoints At 15 To 25 Ft (Perched GW Collection)	EA	84	$1,000	$84,000
5	Wellpoint Pump (1 Pump/42 Wellpoints; 2 gpm Each; 1 Spare)	EA	3	$5,000	$15,000
6	Piping (for wellpoint system)	LS	1	$25,000	$25,000
7	French Drains	LF	2,500	$60	$150,000
8	Extraction Wells (Regional Aquifer; 100 To 120 Ft)	EA	10	$14,500	$145,000
9	Groundwater Extraction Pumps (500 gpm; 2 Spares)	EA	12	$10,000	$120,000
10	Perched Groundwater Extraction Wells (2 gpm each)	EA	15	$8,500	$127,500
11	Perched Groundwater Extraction Pumps (2 gpm; 2 Spares)	EA	17	$5,000	$85,000
12	Groundwater Pretreatment Plant (For Organics)	LS	1	$571,800	$571,800
13	Groundwater Treatment Plant (Chemical Precipitation System)	LS	1	$13,089,766	$13,089,766
14	Reinjection Wells	EA	12	$12,500	$150,000
15	Permitting	LS	1	$50,000	$50,000
16	Institutional Actions	LS	1	$210,000	$210,000
17	Treatability Studies	LS	1	$75,000	$75,000
18	Engineering (@ 10% Of Items 1 Thru 17)	%	10	$15,318,066	$1,531,807
19	Construction Administration (@ 5% Of Items 1 Thru 16)	%	5	$15,243,066	$762,153
20	Contingency (20 % Of Items 1 To 19)	%	20	$17,612,026	$3,522,405
				TOTAL =	$21,134,431

TABLE C-6B
COST SUMMARY
GROUNDWATER ALTERNATIVE GW-7
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Treatment Plant A	Monitoring B	Reevaluation C	Maintenance D	Hydraulic Containment E	Annual(4) Operating Cost, $ F	Inflation @ 5% G	Present Worth Factor @ 10% H	Capital Cost $ I	Present Worth Of Operating Cost(6), $ J	Total Cost(7), $ K
1	0	0	0	0	0	0	1	1	21,134,400 (5)	0	21,134,400
2	113,492,500 (1)	100,000 (2)	100,000 (2)	90,000 (2)	147,000 (3)	113,929,500	1.05	0.91	0	108,750,886	108,750,886
3	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.10	0.83	0	103,807,664	103,807,664
4	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.16	0.75	0	99,089,134	99,089,134
5	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.22	0.68	0	94,585,083	94,585,083
6	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.28	0.62	0	90,285,761	90,285,761
7	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.34	0.56	0	86,181,862	86,181,862
8	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.41	0.51	0	82,264,505	82,264,505
9	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.48	0.47	0	78,525,209	78,525,209
10	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.55	0.42	0	74,955,882	74,955,882
11	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.63	0.39	0	71,548,796	71,548,796
12	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.71	0.35	0	68,296,578	68,296,578
13	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.80	0.32	0	65,192,188	65,192,188
14	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.89	0.29	0	62,228,907	62,228,907
15	113,492,500	100,000	100,000	90,000	147,000	113,929,500	1.98	0.26	0	59,400,320	59,400,320
16	113,492,500	100,000	100,000	90,000	147,000	113,929,500	2.08	0.24	0	56,700,306	56,700,306
17	113,492,500	100,000	100,000	90,000	147,000	113,929,500	2.18	0.22	0	54,123,019	54,123,019
18	113,492,500	100,000	100,000	90,000	147,000	113,929,500	2.29	0.20	0	51,662,882	51,662,882
19	113,492,500	100,000	100,000	90,000	147,000	113,929,500	2.41	0.18	0	49,314,569	49,314,569
20	113,492,500	100,000	100,000	90,000	147,000	113,929,500	2.53	0.16	0	47,072,998	47,072,998
21	113,492,500	100,000	100,000	90,000	147,000	113,929,500	2.65	0.15	0	44,933,316	44,933,316
22	113,492,500	100,000	100,000	90,000	147,000	113,929,500	2.79	0.14	0	42,890,893	42,890,893
23	113,492,500	100,000	100,000	90,000	147,000	113,929,500	2.93	0.12	0	40,941,306	40,941,306
24	113,492,500	100,000	100,000	90,000	147,000	113,929,500	3.07	0.11	0	39,080,338	39,080,338
25	113,492,500	100,000	100,000	90,000	147,000	113,929,500	3.23	0.10	0	37,303,959	37,303,959
26	113,492,500	100,000	100,000	90,000	147,000	113,929,500	3.39	0.09	0	35,608,325	35,608,325
27	113,492,500	100,000	100,000	90,000	147,000	113,929,500	3.56	0.08	0	33,989,764	33,989,764
28	113,492,500	100,000	100,000	90,000	147,000	113,929,500	3.73	0.08	0	32,444,775	32,444,775
29	113,492,500	100,000	100,000	90,000	147,000	113,929,500	3.92	0.07	0	30,970,013	30,970,013
30	113,492,500	100,000	100,000	90,000	147,000	113,929,500	4.12	0.06	0	29,562,285	29,562,285
31	113,492,500	100,000	100,000	90,000	147,000	113,929,500	4.32	0.06	0	28,218,544	28,218,544
	3,404,775,000	3,000,000	3,000,000	2,700,000	4,410,000	3,417,885,000			21,134,400	1,799,930,066	1,821,064,466

(1) Annual Cost For G.W. Treatment At 5,500 Gpm

(2) Estimated Cost

(3) (20 Hp)*(0.746 Kw-Hr/Hp)/(80% Motor Eff)*(10C/Kw-Hr)*(24 Hr/Day)*(365 Day/Yr)*(9 Pumps)=$147,000/Yr

(4) F=A+B+C+D+E

(5) See Table C-6

(6) J=F*G*H

(7) K=I+J

TABLE C-7
SOIL/SEDIMENT ALTERNATIVE SS-2:
INSTITUTIONAL ACTIONS; EXCAVATION; INTERMEDIATE STORAGE
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	320,500	$8	$2,564,000
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	On-Site Intermediate Storage (Includes Transportation)	CY	320,500	$135	$43,267,500
6	Institutional Actions	LS	1	$300,000	$300,000
7	Engineering (@ 10% Of Items 1 Thru 6)	%	10	$55,731,500	$5,573,150
8	Construction Administration (@ 5% Of Items 1 Thru 6)	%	5	$55,731,500	$2,786,575
9	Contingency (20 % Of Items 1 To 8)	%	20	$64,091,225	$12,818,245
				TOTAL =	$76,909,470

TABLE C-7B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-2
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	76,909,500 (3)	0	76,909,500
2	50,000 (1)	100,000 (1)	30,000 (1)	180,000	1.05	0.91	0	171,818	171,818
3	50,000	100,000	30,000	180,000	1.10	0.83	0	164,008	164,008
4	50,000	100,000	30,000	180,000	1.16	0.75	0	156,553	156,553
5	50,000	100,000	30,000	180,000	1.22	0.68	0	149,437	149,437
6	50,000	100,000	30,000	180,000	1.28	0.62	0	142,645	142,645
7	50,000	100,000	30,000	180,000	1.34	0.56	0	136,161	136,161
8	50,000	100,000	30,000	180,000	1.41	0.51	0	129,972	129,972
9	50,000	100,000	30,000	180,000	1.48	0.47	0	124,064	124,064
10	50,000	100,000	30,000	180,000	1.55	0.42	0	118,425	118,425
11	50,000	100,000	30,000	180,000	1.63	0.39	0	113,042	113,042
12	50,000	100,000	0	150,000	1.71	0.35	0	89,920	89,920
13	50,000	100,000	0	150,000	1.80	0.32	0	85,832	85,832
14	50,000	100,000	0	150,000	1.89	0.29	0	81,931	81,931
15	50,000	100,000	0	150,000	1.98	0.26	0	78,207	78,207
16	50,000	100,000	0	150,000	2.08	0.24	0	74,652	74,652
17	50,000	100,000	0	150,000	2.18	0.22	0	71,259	71,259
18	50,000	100,000	0	150,000	2.29	0.20	0	68,020	68,020
19	50,000	100,000	0	150,000	2.41	0.18	0	64,928	64,928
20	50,000	100,000	0	150,000	2.53	0.16	0	61,976	61,976
21	50,000	100,000	0	150,000	2.65	0.15	0	59,159	59,159
22	50,000	100,000	0	150,000	2.79	0.14	0	56,470	56,470
23	50,000	100,000	0	150,000	2.93	0.12	0	53,903	53,903
24	50,000	100,000	0	150,000	3.07	0.11	0	51,453	51,453
25	50,000	100,000	0	150,000	3.23	0.10	0	49,115	49,115
26	50,000	100,000	0	150,000	3.39	0.09	0	46,882	46,882
27	50,000	100,000	0	150,000	3.56	0.08	0	44,751	44,751
28	50,000	100,000	0	150,000	3.73	0.08	0	42,717	42,717
29	50,000	100,000	0	150,000	3.92	0.07	0	40,775	40,775
30	50,000	100,000	0	150,000	4.12	0.06	0	38,922	38,922
31	50,000	100,000	0	150,000	4.32	0.06	0	37,153	37,153
	1,500,000	3,000,000	300,000	4,800,000			76,909,500	2,604,149	79,513,649

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-7
(4) H=D*E*F
(5) I=G+H

TABLE C-8
SOIL/SEDIMENT ALTERNATIVE SS-3:
INSTITUTIONAL ACTIONS; EXCAVATION;
DISPOSAL (OPTION 1: ON-SITE)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	320,500	$8	$2,564,000
4	Backfill And Compact	CY	365,600	$10	$3,656,000
8	On-Site Disposal (includes transportation)	CY	320,500	$195	$62,497,500
9	Institutional Actions	LS	1	$300,000	$300,000
10	Engineering (@ 10% Of Items 1 Thru 9)	%	10	$74,961,500	$7,496,150
11	Construction Administration (@ 5% Of Items 1 Thru 9)	%	5	$74,961,500	$3,748,075
12	Contingency (20 % Of Items 1 To 11)	%	20	$86,205,725	$17,241,145
				TOTAL =	$103,446,870

TABLE C-8B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-3
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	103,446,900 (3)	0	103,446,900
2	100,000 (1)	20,000 (1)	100,000 (1)	220,000	1.05	0.91	0	210,000	210,000
3	100,000	20,000	100,000	220,000	1.10	0.83	0	200,455	200,455
4	100,000	20,000	100,000	220,000	1.16	0.75	0	191,343	191,343
5	100,000	20,000	100,000	220,000	1.22	0.68	0	182,646	182,646
6	100,000	20,000	100,000	220,000	1.28	0.62	0	174,343	174,343
7	100,000	20,000	100,000	220,000	1.34	0.56	0	166,419	166,419
8	100,000	20,000	100,000	220,000	1.41	0.51	0	158,854	158,854
9	100,000	20,000	100,000	220,000	1.48	0.47	0	151,634	151,634
10	100,000	20,000	100,000	220,000	1.55	0.42	0	144,741	144,741
11	100,000	20,000	100,000	220,000	1.63	0.39	0	138,162	138,162
12	100,000	20,000	100,000	220,000	1.71	0.35	0	131,882	131,882
13	100,000	20,000	100,000	220,000	1.80	0.32	0	125,887	125,887
14	100,000	20,000	100,000	220,000	1.89	0.29	0	120,165	120,165
15	100,000	20,000	100,000	220,000	1.98	0.26	0	114,703	114,703
16	100,000	20,000	100,000	220,000	2.08	0.24	0	109,489	109,489
17	100,000	20,000	100,000	220,000	2.18	0.22	0	104,513	104,513
18	100,000	20,000	100,000	220,000	2.29	0.20	0	99,762	99,762
19	100,000	20,000	100,000	220,000	2.41	0.18	0	95,227	95,227
20	100,000	20,000	100,000	220,000	2.53	0.16	0	90,899	90,899
21	100,000	20,000	100,000	220,000	2.65	0.15	0	86,767	86,767
22	100,000	20,000	100,000	220,000	2.79	0.14	0	82,823	82,823
23	100,000	20,000	100,000	220,000	2.93	0.12	0	79,058	79,058
24	100,000	20,000	100,000	220,000	3.07	0.11	0	75,465	75,465
25	100,000	20,000	100,000	220,000	3.23	0.10	0	72,035	72,035
26	100,000	20,000	100,000	220,000	3.39	0.09	0	68,760	68,760
27	100,000	20,000	100,000	220,000	3.56	0.08	0	65,635	65,635
28	100,000	20,000	100,000	220,000	3.73	0.08	0	62,651	62,651
29	100,000	20,000	100,000	220,000	3.92	0.07	0	59,804	59,804
30	100,000	20,000	100,000	220,000	4.12	0.06	0	57,085	57,085
31	100,000	20,000	100,000	220,000	4.32	0.06	0	54,491	54,491
	3,000,000	600,000	3,000,000	6,600,000			103,446,900	3,475,699	106,922,599

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-8
(4) H=D*E*F
(5) I=G+H

TABLE C-9
SOIL/SEDIMENT ALTERNATIVE SS-3:
INSTITUTIONAL ACTIONS; EXCAVATION;
DISPOSAL (OPTION 2: OFF-SITE)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	320,500	$8	$2,564,000
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	96 CF Box For Packaging	EA	90,200	$600	$54,120,000
6	Rail Spur Construction (Las Vegas - NTS)	LS	1	$35,500,000	$35,500,000
7	Railroad Transportation	TON	433,800	$92	$39,909,600
8	Off-Site Disposal	CY	320,500	$10	$3,205,000
9	Institutional Actions	LS	1	$300,000	$300,000
10	Engineering (@ 10% Of Items 1 Thru 9)	%	10	$145,198,600	$14,519,860
11	Construction Administration (@ 5% Of Items 1 Thru 9)	%	5	$145,198,600	$7,259,930
12	Contingency (20 % Of Items 1 To 11)	%	20	$166,978,390	$33,395,678
				TOTAL =	$200,374,068

If a commercial off-site disposal facility (such as Envirocare) is used at $300/CY the total capital cost would be $328,638,168.

TABLE C-9B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-3
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	200,374,100 (3)	0	200,374,100
2	0 (1)	0 (1)	0 (1)	0	1.05	0.91	0	0	0
3	0	0	0	0	1.10	0.83	0	0	0
4	0	0	0	0	1.16	0.75	0	0	0
5	0	0	0	0	1.22	0.68	0	0	0
6	0	0	0	0	1.28	0.62	0	0	0
7	0	0	0	0	1.34	0.56	0	0	0
8	0	0	0	0	1.41	0.51	0	0	0
9	0	0	0	0	1.48	0.47	0	0	0
10	0	0	0	0	1.55	0.42	0	0	0
11	0	0	0	0	1.63	0.39	0	0	0
12	0	0	0	0	1.71	0.35	0	0	0
13	0	0	0	0	1.80	0.32	0	0	0
14	0	0	0	0	1.89	0.29	0	0	0
15	0	0	0	0	1.98	0.26	0	0	0
16	0	0	0	0	2.08	0.24	0	0	0
17	0	0	0	0	2.18	0.22	0	0	0
18	0	0	0	0	2.29	0.20	0	0	0
19	0	0	0	0	2.41	0.18	0	0	0
20	0	0	0	0	2.53	0.16	0	0	0
21	0	0	0	0	2.65	0.15	0	0	0
22	0	0	0	0	2.79	0.14	0	0	0
23	0	0	0	0	2.93	0.12	0	0	0
24	0	0	0	0	3.07	0.11	0	0	0
25	0	0	0	0	3.23	0.10	0	0	0
26	0	0	0	0	3.39	0.09	0	0	0
27	0	0	0	0	3.56	0.08	0	0	0
28	0	0	0	0	3.73	0.08	0	0	0
29	0	0	0	0	3.92	0.07	0	0	0
30	0	0	0	0	4.12	0.06	0	0	0
31	0	0	0	0	4.32	0.06	0	0	0
	0	0	0	0			200,374,100	0	200,374,100

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-9
(4) H=D*E*F
(5) I=G+H

TABLE C-10
SOIL/SEDIMENT ALTERNATIVE SS-4:
INSTITUTIONAL ACTIONS; EXCAVATION OF SEDIMENTS;
MULTILAYER CAPPING FOR SOILS/SEDIMENTS
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation and placement of Paddys Run And Storm Outfall contaminated Sediments	SY	2,333	$10	$23,330
2	Construction of Multi-Layer Cap	SY	275,100	$48	$13,204,800
3	Top Soil/Revegetation	SY	275,100	$1	$220,080
4	Permitting From U.S. Army Corps Of Engineers	LS	1	$30,000	$30,000
5	Institutional Actions	LS	1	$300,000	$300,000
6	Engineering (@ 10% Of Items 1 Thru 5)	%	10	$13,778,210	$1,377,821
7	Construction Administration (@ 5% Of Items 1 Thru 5)	%	5	$13,778,210	$688,911
8	Contingency (20 % Of Items 1 To 7)	%	20	$15,844,942	$3,168,988
				TOTAL =	$19,013,930

TABLE C-10B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-4
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	19,013,900 (3)	0	19,013,900
2	100,000 (1)	100,000 (1)	40,000 (1)	240,000	1.05	0.91	0	229,091	229,091
3	100,000	100,000	40,000	240,000	1.10	0.83	0	218,678	218,678
4	100,000	100,000	40,000	240,000	1.16	0.75	0	208,738	208,738
5	100,000	100,000	40,000	240,000	1.22	0.68	0	199,250	199,250
6	100,000	100,000	40,000	240,000	1.28	0.62	0	190,193	190,193
7	100,000	100,000	40,000	240,000	1.34	0.56	0	181,548	181,548
8	100,000	100,000	40,000	240,000	1.41	0.51	0	173,296	173,296
9	100,000	100,000	40,000	240,000	1.48	0.47	0	165,419	165,419
10	100,000	100,000	40,000	240,000	1.55	0.42	0	157,900	157,900
11	100,000	100,000	40,000	240,000	1.63	0.39	0	150,722	150,722
12	100,000	100,000	40,000	240,000	1.71	0.35	0	143,871	143,871
13	100,000	100,000	40,000	240,000	1.80	0.32	0	137,332	137,332
14	100,000	100,000	40,000	240,000	1.89	0.29	0	131,089	131,089
15	100,000	100,000	40,000	240,000	1.98	0.26	0	125,131	125,131
16	100,000	100,000	40,000	240,000	2.08	0.24	0	119,443	119,443
17	100,000	100,000	40,000	240,000	2.18	0.22	0	114,014	114,014
18	100,000	100,000	40,000	240,000	2.29	0.20	0	108,831	108,831
19	100,000	100,000	40,000	240,000	2.41	0.18	0	103,884	103,884
20	100,000	100,000	40,000	240,000	2.53	0.16	0	99,162	99,162
21	100,000	100,000	40,000	240,000	2.65	0.15	0	94,655	94,655
22	100,000	100,000	40,000	240,000	2.79	0.14	0	90,352	90,352
23	100,000	100,000	40,000	240,000	2.93	0.12	0	86,246	86,246
24	100,000	100,000	40,000	240,000	3.07	0.11	0	82,325	82,325
25	100,000	100,000	40,000	240,000	3.23	0.10	0	78,583	78,583
26	100,000	100,000	40,000	240,000	3.39	0.09	0	75,011	75,011
27	100,000	100,000	40,000	240,000	3.56	0.08	0	71,602	71,602
28	100,000	100,000	40,000	240,000	3.73	0.08	0	68,347	68,347
29	100,000	100,000	40,000	240,000	3.92	0.07	0	65,240	65,240
30	100,000	100,000	40,000	240,000	4.12	0.06	0	62,275	62,275
31	100,000	100,000	40,000	240,000	4.32	0.06	0	59,444	59,444
	3,000,000	3,000,000	1,200,000	7,200,000			19,013,900	3,791,671	22,805,571

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-10
(4) H=D*E*F
(5) I=G+H

TABLE C-11
SOIL/SEDIMENT ALTERNATIVE SS-5:
INSTITUTIONAL ACTIONS; EXCAVATION; SOIL WASHING;
INTERMEDIATE STORAGE OF RESIDUALS
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	32,100	$8	$256,800
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Soil Washing	CY	320,500	$250	$80,125,000
6	On-Site Intermediate Storage (Includes Transportation)	CY	32,100	$135	$4,333,500
7	Institutional Actions	LS	1	$300,000	$300,000
8	Engineering (@ 10% Of Items 1 Thru 7)	%	10	$94,615,300	$9,461,530
9	Construction Administration (@ 5% Of Items 1 Thru 7)	%	5	$94,615,300	$4,730,765
10	Contingency (20% Of Items 1 To 9)	%	20	$108,807,595	$21,761,519
				TOTAL =	$130,569,114

TABLE C-11B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-5
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	130,569,100 (3)	0	130,569,100
2	20,000 (1)	100,000 (1)	50,000 (1)	170,000	1.05	0.91	0	162,273	162,273
3	20,000	100,000	50,000	170,000	1.10	0.83	0	154,897	154,897
4	20,000	100,000	50,000	170,000	1.16	0.75	0	147,856	147,856
5	20,000	100,000	50,000	170,000	1.22	0.68	0	141,135	141,135
6	20,000	100,000	50,000	170,000	1.28	0.62	0	134,720	134,720
7	20,000	100,000	50,000	170,000	1.34	0.56	0	128,596	128,596
8	20,000	100,000	50,000	170,000	1.41	0.51	0	122,751	122,751
9	20,000	100,000	50,000	170,000	1.48	0.47	0	117,171	117,171
10	20,000	100,000	50,000	170,000	1.55	0.42	0	111,845	111,845
11	20,000	100,000	50,000	170,000	1.63	0.39	0	106,762	106,762
12				0	1.71	0.35	0	0	0
13				0	1.80	0.32	0	0	0
14				0	1.89	0.29	0	0	0
15				0	1.98	0.26	0	0	0
16				0	2.08	0.24	0	0	0
17				0	2.18	0.22	0	0	0
18				0	2.29	0.20	0	0	0
19				0	2.41	0.18	0	0	0
20				0	2.53	0.16	0	0	0
21				0	2.65	0.15	0	0	0
22				0	2.79	0.14	0	0	0
23				0	2.93	0.12	0	0	0
24				0	3.07	0.11	0	0	0
25				0	3.23	0.10	0	0	0
26				0	3.39	0.09	0	0	0
27				0	3.56	0.08	0	0	0
28				0	3.73	0.08	0	0	0
29				0	3.92	0.07	0	0	0
30				0	4.12	0.06	0	0	0
31				0	4.32	0.06	0	0	0
	200,000	1,000,000	500,000	1,700,000			130,569,100	1,328,006	131,897,106

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-11
(4) H=D*E*F
(5) I=G+H

TABLE C-12
SOIL/SEDIMENT ALTERNATIVE SS-6:
INSTITUTIONAL ACTIONS; EXCAVATION; SOIL WASHING;
DISPOSAL OF RESIDUALS (OPTION 1: ON-SITE)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	32,100	$8	$256,800
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Soil Washing	CY	320,500	$250	$80,125,000
6	On-Site Disposal	CY	32,100	$195	$6,259,500
7	Institutional Actions	LS	1	$300,000	$300,000
8	Engineering (@ 10% Of Items 1 Thru 7)	%	10	$96,541,300	$9,654,130
9	Construction Administration (@ 5% Of Items 1 Thru 7)	%	5	$96,541,300	$4,827,065
10	Contingency (20 % Of Items 1 To 9)	%	20	$111,022,495	$22,204,499
				TOTAL =	$133,226,994

TABLE C-12B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-6
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	133,227,000 (3)	0	133,227,000
2	20,000 (1)	100,000 (1)	50,000 (1)	170,000	1.05	0.91	0	162,273	162,273
3	20,000	100,000	50,000	170,000	1.10	0.83	0	154,897	154,897
4	20,000	100,000	50,000	170,000	1.16	0.75	0	147,856	147,856
5	20,000	100,000	50,000	170,000	1.22	0.68	0	141,135	141,135
6	20,000	100,000	50,000	170,000	1.28	0.62	0	134,720	134,720
7	20,000	100,000	50,000	170,000	1.34	0.56	0	128,596	128,596
8	20,000	100,000	50,000	170,000	1.41	0.51	0	122,751	122,751
9	20,000	100,000	50,000	170,000	1.48	0.47	0	117,171	117,171
10	20,000	100,000	50,000	170,000	1.55	0.42	0	111,845	111,845
11	20,000	100,000	50,000	170,000	1.63	0.39	0	106,762	106,762
12	20,000	100,000	50,000	170,000	1.71	0.35	0	101,909	101,909
13	20,000	100,000	50,000	170,000	1.80	0.32	0	97,277	97,277
14	20,000	100,000	50,000	170,000	1.89	0.29	0	92,855	92,855
15	20,000	100,000	50,000	170,000	1.98	0.26	0	88,634	88,634
16	20,000	100,000	50,000	170,000	2.08	0.24	0	84,605	84,605
17	20,000	100,000	50,000	170,000	2.18	0.22	0	80,760	80,760
18	20,000	100,000	50,000	170,000	2.29	0.20	0	77,089	77,089
19	20,000	100,000	50,000	170,000	2.41	0.18	0	73,585	73,585
20	20,000	100,000	50,000	170,000	2.53	0.16	0	70,240	70,240
21	20,000	100,000	50,000	170,000	2.65	0.15	0	67,047	67,047
22	20,000	100,000	50,000	170,000	2.79	0.14	0	64,000	64,000
23	20,000	100,000	50,000	170,000	2.93	0.12	0	61,091	61,091
24	20,000	100,000	50,000	170,000	3.07	0.11	0	58,314	58,314
25	20,000	100,000	50,000	170,000	3.23	0.10	0	55,663	55,663
26	20,000	100,000	50,000	170,000	3.39	0.09	0	53,133	53,133
27	20,000	100,000	50,000	170,000	3.56	0.08	0	50,718	50,718
28	20,000	100,000	50,000	170,000	3.73	0.08	0	48,412	48,412
29	20,000	100,000	50,000	170,000	3.92	0.07	0	46,212	46,212
30	20,000	100,000	50,000	170,000	4.12	0.06	0	44,111	44,111
31	20,000	100,000	50,000	170,000	4.32	0.06	0	42,106	42,106
	600,000	3,000,000	1,500,000	5,100,000			133,227,000	2,685,767	135,912,767

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-12
(4) H=D*E*F
(5) I=G+H

TABLE C-13
SOIL/SEDIMENT ALTERNATIVE SS-6:
INSTITUTIONAL ACTIONS; EXCAVATION; SOIL WASHING;
DISPOSAL OF RESIDUALS (OPTION 2: OFF-SITE)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	32,100	$8	$256,800
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Soil Washing	CY	320,500	$200	$64,100,000
6	96 CF Box For Packaging	EA	9,100	$600	$5,460,000
7	Rail Spur Construction (Las Vegas - NTS)	LS	1	$35,500,000	$35,500,000
8	Railroad Transportation	TON	43,300	$92	$3,983,600
9	Off-Site Disposal	CY	32,100	$10	$321,000
10	Institutional Actions	LS	1	$300,000	$300,000
11	Engineering (@ 10% Of Items 1 Thru 10)	%	10	$119,521,400	$11,952,140
12	Construction Administration (@ 5% Of Items 1 Thru 10)	%	5	$119,521,400	$5,976,070
13	Contingency (20 % Of Items 1 To 12)	%	20	$137,449,610	$27,489,922
				TOTAL =	$164,939,532

If a commercial off-site disposal facility (such as Envirocare) is used at $300/CY the total capital cost would be $177,785,952.

TABLE C-13B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-6
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	164,939,500 (3)	0	164,939,500
2	0 (1)	0 (1)	0 (1)	0	1.05	0.91	0	0	0
3	0	0	0	0	1.10	0.83	0	0	0
4	0	0	0	0	1.16	0.75	0	0	0
5	0	0	0	0	1.22	0.68	0	0	0
6	0	0	0	0	1.28	0.62	0	0	0
7	0	0	0	0	1.34	0.56	0	0	0
8	0	0	0	0	1.41	0.51	0	0	0
9	0	0	0	0	1.48	0.47	0	0	0
10	0	0	0	0	1.55	0.42	0	0	0
11	0	0	0	0	1.63	0.39	0	0	0
12	0	0	0	0	1.71	0.35	0	0	0
13	0	0	0	0	1.80	0.32	0	0	0
14	0	0	0	0	1.89	0.29	0	0	0
15	0	0	0	0	1.98	0.26	0	0	0
16	0	0	0	0	2.08	0.24	0	0	0
17	0	0	0	0	2.18	0.22	0	0	0
18	0	0	0	0	2.29	0.20	0	0	0
19	0	0	0	0	2.41	0.18	0	0	0
20	0	0	0	0	2.53	0.16	0	0	0
21	0	0	0	0	2.65	0.15	0	0	0
22	0	0	0	0	2.79	0.14	0	0	0
23	0	0	0	0	2.93	0.12	0	0	0
24	0	0	0	0	3.07	0.11	0	0	0
25	0	0	0	0	3.23	0.10	0	0	0
26	0	0	0	0	3.39	0.09	0	0	0
27	0	0	0	0	3.56	0.08	0	0	0
28	0	0	0	0	3.73	0.08	0	0	0
29	0	0	0	0	3.92	0.07	0	0	0
30	0	0	0	0	4.12	0.06	0	0	0
31	0	0	0	0	4.32	0.06	0	0	0
	0	0	0	0			164,939,500	0	164,939,500

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-13
(4) H=D*E*F
(5) I=G+H

TABLE C-14
SOIL/SEDIMENT ALTERNATIVE SS-7:
INSTITUTIONAL ACTIONS; EXCAVATION; BATCH VITRIFICATION;
BACKFILLING OF VITRIFIED RESIDUALS
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	128,200	$8	$1,025,600
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Batch Vitrification	CY	320,500	$400	$128,200,000
6	Institutional Actions	LS	1	$300,000	$300,000
7	Engineering (@ 10% Of Items 1 Thru 6)	%	10	$139,125,600	$13,912,560
8	Construction Administration (@ 5% Of Items 1 Thru 6)	%	5	$139,125,600	$6,956,280
9	Contingency (20 % Of Items 1 To 8)	%	20	$159,994,440	$31,998,888
				TOTAL =	$191,993,328

TABLE C-14B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-7
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	191,993,300 (3)	0	191,993,300
2	20,000 (1)	100,000 (1)	10,000 (1)	130,000	1.05	0.91	0	124,091	124,091
3	20,000	100,000	10,000	130,000	1.10	0.83	0	118,450	118,450
4	20,000	100,000	10,000	130,000	1.16	0.75	0	113,066	113,066
5	20,000	100,000	10,000	130,000	1.22	0.68	0	107,927	107,927
6	20,000	100,000	10,000	130,000	1.28	0.62	0	103,021	103,021
7	20,000	100,000	10,000	130,000	1.34	0.56	0	98,338	98,338
8	20,000	100,000	10,000	130,000	1.41	0.51	0	93,868	93,868
9	20,000	100,000	10,000	130,000	1.48	0.47	0	89,602	89,602
10	20,000	100,000	10,000	130,000	1.55	0.42	0	85,529	85,529
11	20,000	100,000	10,000	130,000	1.63	0.39	0	81,641	81,641
12	20,000	100,000	10,000	130,000	1.71	0.35	0	77,930	77,930
13	20,000	100,000	10,000	130,000	1.80	0.32	0	74,388	74,388
14	20,000	100,000	10,000	130,000	1.89	0.29	0	71,007	71,007
15	20,000	100,000	10,000	130,000	1.98	0.26	0	67,779	67,779
16	20,000	100,000	10,000	130,000	2.08	0.24	0	64,698	64,698
17	20,000	100,000	10,000	130,000	2.18	0.22	0	61,757	61,757
18	20,000	100,000	10,000	130,000	2.29	0.20	0	58,950	58,950
19	20,000	100,000	10,000	130,000	2.41	0.18	0	56,271	56,271
20	20,000	100,000	10,000	130,000	2.53	0.16	0	53,713	53,713
21	20,000	100,000	10,000	130,000	2.65	0.15	0	51,271	51,271
22	20,000	100,000	10,000	130,000	2.79	0.14	0	48,941	48,941
23	20,000	100,000	10,000	130,000	2.93	0.12	0	46,716	46,716
24	20,000	100,000	10,000	130,000	3.07	0.11	0	44,593	44,593
25	20,000	100,000	10,000	130,000	3.23	0.10	0	42,566	42,566
26	20,000	100,000	10,000	130,000	3.39	0.09	0	40,631	40,631
27	20,000	100,000	10,000	130,000	3.56	0.08	0	38,784	38,784
28	20,000	100,000	10,000	130,000	3.73	0.08	0	37,021	37,021
29	20,000	100,000	10,000	130,000	3.92	0.07	0	35,339	35,339
30	20,000	100,000	10,000	130,000	4.12	0.06	0	33,732	33,732
31	20,000	100,000	10,000	130,000	4.32	0.06	0	32,199	32,199
	600,000	3,000,000	300,000	3,900,000			191,993,300	2,053,822	194,047,122

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-14
(4) H=D*E*F
(5) I=G+H

TABLE C-15
SOIL/SEDIMENT ALTERNATIVE SS-8:
INSTITUTIONAL ACTIONS; EXCAVATION, BATCH VITRIFICATION;
DISPOSAL OF RESIDUALS (OPTION 1: ON-SITE)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	320,500	$8	$2,564,000
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Batch Vitrification	CY	320,500	$400	$128,200,000
9	On-Site Disposal (includes transportation)	CY	192,300	$195	$37,498,500
10	Institutional Actions	LS	1	$300,000	$300,000
11	Engineering (@ 10% Of Items 1 Thru 10)	%	10	$178,162,500	$17,816,250
12	Construction Administration (@ 5% Of Items 1 Thru 10)	%	5	$178,162,500	$8,908,125
13	Contingency (20 % Of Items 1 To 12)	%	20	$204,886,875	$40,977,375
				TOTAL =	$245,864,250

TABLE C-15B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-8
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	245,864,200 (3)	0	245,864,200
2	20,000 (1)	100,000 (1)	50,000 (1)	170,000	1.05	0.91	0	162,273	162,273
3	20,000	100,000	50,000	170,000	1.10	0.83	0	154,897	154,897
4	20,000	100,000	50,000	170,000	1.16	0.75	0	147,856	147,856
5	20,000	100,000	50,000	170,000	1.22	0.68	0	141,135	141,135
6	20,000	100,000	50,000	170,000	1.28	0.62	0	134,720	134,720
7	20,000	100,000	50,000	170,000	1.34	0.56	0	128,596	128,596
8	20,000	100,000	50,000	170,000	1.41	0.51	0	122,751	122,751
9	20,000	100,000	50,000	170,000	1.48	0.47	0	117,171	117,171
10	20,000	100,000	50,000	170,000	1.55	0.42	0	111,845	111,845
11	20,000	100,000	50,000	170,000	1.63	0.39	0	106,762	106,762
12	20,000	100,000	50,000	170,000	1.71	0.35	0	101,909	101,909
13	20,000	100,000	50,000	170,000	1.80	0.32	0	97,277	97,277
14	20,000	100,000	50,000	170,000	1.89	0.29	0	92,855	92,855
15	20,000	100,000	50,000	170,000	1.98	0.26	0	88,634	88,634
16	20,000	100,000	50,000	170,000	2.08	0.24	0	84,605	84,605
17	20,000	100,000	50,000	170,000	2.18	0.22	0	80,760	80,760
18	20,000	100,000	50,000	170,000	2.29	0.20	0	77,089	77,089
19	20,000	100,000	50,000	170,000	2.41	0.18	0	73,585	73,585
20	20,000	100,000	50,000	170,000	2.53	0.16	0	70,240	70,240
21	20,000	100,000	50,000	170,000	2.65	0.15	0	67,047	67,047
22	20,000	100,000	50,000	170,000	2.79	0.14	0	64,000	64,000
23	20,000	100,000	50,000	170,000	2.93	0.12	0	61,091	61,091
24	20,000	100,000	50,000	170,000	3.07	0.11	0	58,314	58,314
25	20,000	100,000	50,000	170,000	3.23	0.10	0	55,663	55,663
26	20,000	100,000	50,000	170,000	3.39	0.09	0	53,133	53,133
27	20,000	100,000	50,000	170,000	3.56	0.08	0	50,718	50,718
28	20,000	100,000	50,000	170,000	3.73	0.08	0	48,412	48,412
29	20,000	100,000	50,000	170,000	3.92	0.07	0	46,212	46,212
30	20,000	100,000	50,000	170,000	4.12	0.06	0	44,111	44,111
31	20,000	100,000	50,000	170,000	4.32	0.06	0	42,106	42,106
	600,000	3,000,000	1,500,000	5,100,000			245,864,200	2,685,767	248,549,967

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-15
(4) H=D*E*F
(5) I=G+H

TABLE C-16
SOIL/SEDIMENT ALTERNATIVE SS-8:
INSTITUTIONAL ACTIONS; EXCAVATION, BATCH VITRIFICATION;
DISPOSAL OF RESIDUALS (OPTION 2: OFF-SITE)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	320,500	$8	$2,564,000
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Batch Vitrification	CY	320,500	$400	$128,200,000
6	96 CF Box For Packaging	EA	54,100	$600	$32,460,000
7	Rail Spur Construction (Las Vegas - NTS)	LS	1	$35,500,000	$35,500,000
8	Railroad Transportation	TON	384,600	$92	$35,383,200
9	Off-Site Disposal	CY	192,300	$10	$1,923,000
10	Institutional Actions	LS	1	$300,000	$300,000
11	Engineering (@ 10% Of Items 1 Thru 10)	%	10	$245,930,200	$24,593,020
12	Construction Administration (@ 5% Of Items 1 Thru 10)	%	5	$245,930,200	$12,296,510
13	Contingency (20 % Of Items 1 To 12)	%	20	$282,819,730	$56,563,946
				TOTAL =	$339,383,676

If a commercial off-site disposal facility (such as Envirocare) is used at $300/CY the total capital cost would be $416,342,136.

TABLE C-16B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-8
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	339,383,700 (3)	0	339,383,700
2	0 (1)	0 (1)	0 (1)	0	1.05	0.91	0	0	0
3	0	0	0	0	1.10	0.83	0	0	0
4	0	0	0	0	1.16	0.75	0	0	0
5	0	0	0	0	1.22	0.68	0	0	0
6	0	0	0	0	1.28	0.62	0	0	0
7	0	0	0	0	1.34	0.56	0	0	0
8	0	0	0	0	1.41	0.51	0	0	0
9	0	0	0	0	1.48	0.47	0	0	0
10	0	0	0	0	1.55	0.42	0	0	0
11	0	0	0	0	1.63	0.39	0	0	0
12	0	0	0	0	1.71	0.35	0	0	0
13	0	0	0	0	1.80	0.32	0	0	0
14	0	0	0	0	1.89	0.29	0	0	0
15	0	0	0	0	1.98	0.26	0	0	0
16	0	0	0	0	2.08	0.24	0	0	0
17	0	0	0	0	2.18	0.22	0	0	0
18	0	0	0	0	2.29	0.20	0	0	0
19	0	0	0	0	2.41	0.18	0	0	0
20	0	0	0	0	2.53	0.16	0	0	0
21	0	0	0	0	2.65	0.15	0	0	0
22	0	0	0	0	2.79	0.14	0	0	0
23	0	0	0	0	2.93	0.12	0	0	0
24	0	0	0	0	3.07	0.11	0	0	0
25	0	0	0	0	3.23	0.10	0	0	0
26	0	0	0	0	3.39	0.09	0	0	0
27	0	0	0	0	3.56	0.08	0	0	0
28	0	0	0	0	3.73	0.08	0	0	0
29	0	0	0	0	3.92	0.07	0	0	0
30	0	0	0	0	4.12	0.06	0	0	0
31	0	0	0	0	4.32	0.06	0	0	0
	0	0	0	0			339,383,700	0	339,383,700

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-16
(4) H=D*E*F
(5) I=G+H

TABLE C-17
SOIL/SEDIMENT ALTERNATIVE SS-9
INSTITUTIONAL ACTIONS; EXCAVATION; SOIL WASHING;
BATCH VITRIFICATION OF RESIDUALS; BACKFILLING OF VITRIFIED RESIDUALS
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	12,800	$8	$102,400
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Soil Washing	CY	320,500	$250	$80,125,000
6	Batch Vitrification of residuals	CY	32,100	$400	$12,840,000
7	Backfilling of vitrified residuals	CY	19,300	$135	$2,605,500
8	Institutional Actions	LS	1	$300,000	$300,000
9	Engineering (@ 10% Of Items 1 Thru 8)	%	10	$105,572,900	$10,557,290
10	Construction Administration (@ 5% Of Items 1 Thru 8)	%	5	$105,572,900	$5,278,645
11	Contingency (20% Of Items 1 To 10)	%	20	$121,408,835	$24,281,767
				TOTAL =	$145,690,602

TABLE C-17B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-9
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	145,690,600 (3)	0	145,690,600
2	50,000 (1)	100,000 (1)	30,000 (1)	180,000	1.05	0.91	0	171,818	171,818
3	50,000	100,000	30,000	180,000	1.10	0.83	0	164,008	164,008
4	50,000	100,000	30,000	180,000	1.16	0.75	0	156,553	156,553
5	50,000	100,000	30,000	180,000	1.22	0.68	0	149,437	149,437
6	50,000	100,000	30,000	180,000	1.28	0.62	0	142,645	142,645
7	50,000	100,000	30,000	180,000	1.34	0.56	0	136,161	136,161
8	50,000	100,000	30,000	180,000	1.41	0.51	0	129,972	129,972
9	50,000	100,000	30,000	180,000	1.48	0.47	0	124,064	124,064
10	50,000	100,000	30,000	180,000	1.55	0.42	0	118,425	118,425
11	50,000	100,000	30,000	180,000	1.63	0.39	0	113,042	113,042
12	50,000	100,000	30,000	180,000	1.71	0.35	0	107,903	107,903
13	50,000	100,000	30,000	180,000	1.80	0.32	0	102,999	102,999
14	50,000	100,000	30,000	180,000	1.89	0.29	0	98,317	98,317
15	50,000	100,000	30,000	180,000	1.98	0.26	0	93,848	93,848
16	50,000	100,000	30,000	180,000	2.08	0.24	0	89,582	89,582
17	50,000	100,000	30,000	180,000	2.18	0.22	0	85,510	85,510
18	50,000	100,000	30,000	180,000	2.29	0.20	0	81,623	81,623
19	50,000	100,000	30,000	180,000	2.41	0.18	0	77,913	77,913
20	50,000	100,000	30,000	180,000	2.53	0.16	0	74,372	74,372
21	50,000	100,000	30,000	180,000	2.65	0.15	0	70,991	70,991
22	50,000	100,000	30,000	180,000	2.79	0.14	0	67,764	67,764
23	50,000	100,000	30,000	180,000	2.93	0.12	0	64,684	64,684
24	50,000	100,000	30,000	180,000	3.07	0.11	0	61,744	61,744
25	50,000	100,000	30,000	180,000	3.23	0.10	0	58,937	58,937
26	50,000	100,000	30,000	180,000	3.39	0.09	0	56,258	56,258
27	50,000	100,000	30,000	180,000	3.56	0.08	0	53,701	53,701
28	50,000	100,000	30,000	180,000	3.73	0.08	0	51,260	51,260
29	50,000	100,000	30,000	180,000	3.92	0.07	0	48,930	48,930
30	50,000	100,000	30,000	180,000	4.12	0.06	0	46,706	46,706
31	50,000	100,000	30,000	180,000	4.32	0.06	0	44,583	44,583
	1,500,000	3,000,000	900,000	5,400,000			145,690,600	2,843,753	148,534,353

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-17
(4) H=D*E*F
(5) I=G+H

TABLE C-18
SOIL/SEDIMENT ALTERNATIVE SS-10:
INSTITUTIONAL ACTIONS; EXCAVATION; SOIL WASHING;
BATCH VITRIFICATION AND DISPOSAL OF RESIDUALS (OPTION 1: ON-SITE)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	32,100	$8	$256,800
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Soil Washing	CY	320,500	$250	$80,125,000
6	Batch Vitrification of residuals	CY	32,100	$400	$12,840,000
7	On-Site Disposal	CY	19,300	$195	$3,763,500
8	Institutional Actions	LS	1	$300,000	$300,000
9	Engineering (@ 10% Of Items 1 Thru 8)	%	10	$106,885,300	$10,688,530
10	Construction Administration (@ 5% Of Items 1 Thru 8)	%	5	$106,885,300	$5,344,265
11	Contingency (20 % Of Items 1 To 10)	%	20	$122,918,095	$24,583,619
				TOTAL =	$147,501,714

TABLE C-18B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-10
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	147,501,700 (3)	0	147,501,700
2	100,000 (1)	20,000 (1)	100,000 (1)	220,000	1.05	0.91	0	210,000	210,000
3	100,000	20,000	100,000	220,000	1.10	0.83	0	200,455	200,455
4	100,000	20,000	100,000	220,000	1.16	0.75	0	191,343	191,343
5	100,000	20,000	100,000	220,000	1.22	0.68	0	182,646	182,646
6	100,000	20,000	100,000	220,000	1.28	0.62	0	174,343	174,343
7	100,000	20,000	100,000	220,000	1.34	0.56	0	166,419	166,419
8	100,000	20,000	100,000	220,000	1.41	0.51	0	158,854	158,854
9	100,000	20,000	100,000	220,000	1.48	0.47	0	151,634	151,634
10	100,000	20,000	100,000	220,000	1.55	0.42	0	144,741	144,741
11	100,000	20,000	100,000	220,000	1.63	0.39	0	138,162	138,162
12	100,000	20,000	100,000	220,000	1.71	0.35	0	131,882	131,882
13	100,000	20,000	100,000	220,000	1.80	0.32	0	125,887	125,887
14	100,000	20,000	100,000	220,000	1.89	0.29	0	120,165	120,165
15	100,000	20,000	100,000	220,000	1.98	0.26	0	114,703	114,703
16	100,000	20,000	100,000	220,000	2.08	0.24	0	109,489	109,489
17	100,000	20,000	100,000	220,000	2.18	0.22	0	104,513	104,513
18	100,000	20,000	100,000	220,000	2.29	0.20	0	99,762	99,762
19	100,000	20,000	100,000	220,000	2.41	0.18	0	95,227	95,227
20	100,000	20,000	100,000	220,000	2.53	0.16	0	90,899	90,899
21	100,000	20,000	100,000	220,000	2.65	0.15	0	86,767	86,767
22	100,000	20,000	100,000	220,000	2.79	0.14	0	82,823	82,823
23	100,000	20,000	100,000	220,000	2.93	0.12	0	79,058	79,058
24	100,000	20,000	100,000	220,000	3.07	0.11	0	75,465	75,465
25	100,000	20,000	100,000	220,000	3.23	0.10	0	72,035	72,035
26	100,000	20,000	100,000	220,000	3.39	0.09	0	68,760	68,760
27	100,000	20,000	100,000	220,000	3.56	0.08	0	65,635	65,635
28	100,000	20,000	100,000	220,000	3.73	0.08	0	62,651	62,651
29	100,000	20,000	100,000	220,000	3.92	0.07	0	59,804	59,804
30	100,000	20,000	100,000	220,000	4.12	0.06	0	57,085	57,085
31	100,000	20,000	100,000	220,000	4.32	0.06	0	54,491	54,491
	3,000,000	600,000	3,000,000	6,600,000			147,501,700	3,475,699	150,977,399

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-18
(4) H=D*E*F
(5) I=G+H

TABLE C-19
SOIL/SEDIMENT ALTERNATIVE SS-10:
INSTITUTIONAL ACTIONS; EXCAVATION; SOIL WASHING;
BATCH VITRIFICATION AND DISPOSAL OF RESIDUALS (OPTION 2: OFF-SITE)
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	Excavation (Accessable Areas)	CY	273,600	$15	$4,104,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Borrow	CY	32,100	$8	$256,800
4	Backfill And Compact	CY	365,600	$10	$3,656,000
5	Soil Washing	CY	320,500	$250	$80,125,000
6	Batch Vitrification of residuals	CY	32,100	$400	$12,840,000
7	96 CF Box For Packaging	EA	5,500	$600	$3,300,000
8	Rail Spur Construction (Las Vegas - NTS)	LS	1	$35,500,000	$35,500,000
9	Railroad Transportation	TON	38,600	$92	$3,551,200
10	Off-Site Disposal	CY	19,300	$10	$193,000
11	Institutional Actions	LS	1	$300,000	$300,000
12	Engineering (@ 10% Of Items 1 Thru 11)	%	10	$145,666,000	$14,566,600
13	Construction Administration (@ 5% Of Items 1 Thru 11)	%	5	$145,666,000	$7,283,300
14	Contingency (20 % Of Items 1 To 13)	%	20	$167,515,900	$33,503,180
				TOTAL =	$201,019,080

If a commercial off-site disposal facility (such as Envirocare) is used at $300/CY the total capital cost would be $208,742,940.

TABLE C-19B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-10
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	201,019,100 (3)	0	201,019,100
2	0 (1)	0 (1)	0 (1)	0	1.05	0.91	0	0	0
3	0	0	0	0	1.10	0.83	0	0	0
4	0	0	0	0	1.16	0.75	0	0	0
5	0	0	0	0	1.22	0.68	0	0	0
6	0	0	0	0	1.28	0.62	0	0	0
7	0	0	0	0	1.34	0.56	0	0	0
8	0	0	0	0	1.41	0.51	0	0	0
9	0	0	0	0	1.48	0.47	0	0	0
10	0	0	0	0	1.55	0.42	0	0	0
11	0	0	0	0	1.63	0.39	0	0	0
12	0	0	0	0	1.71	0.35	0	0	0
13	0	0	0	0	1.80	0.32	0	0	0
14	0	0	0	0	1.89	0.29	0	0	0
15	0	0	0	0	1.98	0.26	0	0	0
16	0	0	0	0	2.08	0.24	0	0	0
17	0	0	0	0	2.18	0.22	0	0	0
18	0	0	0	0	2.29	0.20	0	0	0
19	0	0	0	0	2.41	0.18	0	0	0
20	0	0	0	0	2.53	0.16	0	0	0
21	0	0	0	0	2.65	0.15	0	0	0
22	0	0	0	0	2.79	0.14	0	0	0
23	0	0	0	0	2.93	0.12	0	0	0
24	0	0	0	0	3.07	0.11	0	0	0
25	0	0	0	0	3.23	0.10	0	0	0
26	0	0	0	0	3.39	0.09	0	0	0
27	0	0	0	0	3.56	0.08	0	0	0
28	0	0	0	0	3.73	0.08	0	0	0
29	0	0	0	0	3.92	0.07	0	0	0
30	0	0	0	0	4.12	0.06	0	0	0
31	0	0	0	0	4.32	0.06	0	0	0
	0	0	0	0			201,019,100	0	201,019,100

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-19
(4) H=D*E*F
(5) I=G+H

TABLE C-20
SOIL/SEDIMENT ALTERNATIVE SS-11
INSTITUTIONAL ACTIONS; EXCAVATION;
POZZOLANIC-BASED/CEMENT-BASED STABILIZATION/SOLIDIFICATION
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

Item No.	Description	Unit	Quantity	Unit Cost	Total Cost
1	In-situ Stabilization/Solidification	CY	273,600	$150	$41,040,000
2	Excavation (Limited Access And Inside Building Areas)	CY	92,000	$20	$1,840,000
3	Ex-situ Stabilization/Solidification	CY	92,000	$200	$18,400,000
4	Borrow	CY	0	$8	$0
5	Backfill And Compact	CY	92,000	$10	$920,000
6	Institutional Actions	LS	1	$300,000	$300,000
7	Engineering (@ 10% Of Items 1 Thru 6)	%	10	$62,500,000	$6,250,000
8	Construction Administration (@ 5% Of Items 1 Thru 6)	%	5	$62,500,000	$3,125,000
9	Contingency (20 % Of Items 1 To 8)	%	20	$71,875,000	$14,375,000
				TOTAL =	$86,250,000

TABLE C-20B
COST SUMMARY
SOIL/SEDIMENT ALTERNATIVE SS-11
OPERABLE UNIT 5
FEMP, FERNALD, OHIO

YEAR	Operating Cost, $ Monitoring A	Reevaluation B	Maintenance C	Annual(2) Operating Cost, $ D	Inflation @ 5% E	Present Worth Factor @ 10% F	Capital Cost $ G	Present Worth of Operating Cost(4) H	Total Cost(5), $ I
1	0	0	0	0	1	1	86,250,000 (3)	0	86,250,000
2	100,000 (1)	20,000 (1)	80,000 (1)	200,000	1.05	0.91	0	190,909	190,909
3	100,000	20,000	80,000	200,000	1.10	0.83	0	182,231	182,231
4	100,000	20,000	80,000	200,000	1.16	0.75	0	173,948	173,948
5	100,000	20,000	80,000	200,000	1.22	0.68	0	166,041	166,041
6	100,000	20,000	80,000	200,000	1.28	0.62	0	158,494	158,494
7	100,000	20,000	80,000	200,000	1.34	0.56	0	151,290	151,290
8	100,000	20,000	80,000	200,000	1.41	0.51	0	144,413	144,413
9	100,000	20,000	80,000	200,000	1.48	0.47	0	137,849	137,849
10	100,000	20,000	80,000	200,000	1.55	0.42	0	131,583	131,583
11	100,000	20,000	80,000	200,000	1.63	0.39	0	125,602	125,602
12	100,000	20,000	80,000	200,000	1.71	0.35	0	119,893	119,893
13	100,000	20,000	80,000	200,000	1.80	0.32	0	114,443	114,443
14	100,000	20,000	80,000	200,000	1.89	0.29	0	109,241	109,241
15	100,000	20,000	80,000	200,000	1.98	0.26	0	104,276	104,276
16	100,000	20,000	80,000	200,000	2.08	0.24	0	99,536	99,536
17	100,000	20,000	80,000	200,000	2.18	0.22	0	95,011	95,011
18	100,000	20,000	80,000	200,000	2.29	0.20	0	90,693	90,693
19	100,000	20,000	80,000	200,000	2.41	0.18	0	86,570	86,570
20	100,000	20,000	80,000	200,000	2.53	0.16	0	82,635	82,635
21	100,000	20,000	80,000	200,000	2.65	0.15	0	78,879	78,879
22	100,000	20,000	80,000	200,000	2.79	0.14	0	75,294	75,294
23	100,000	20,000	80,000	200,000	2.93	0.12	0	71,871	71,871
24	100,000	20,000	80,000	200,000	3.07	0.11	0	68,604	68,604
25	100,000	20,000	80,000	200,000	3.23	0.10	0	65,486	65,486
26	100,000	20,000	80,000	200,000	3.39	0.09	0	62,509	62,509
27	100,000	20,000	80,000	200,000	3.56	0.08	0	59,668	59,668
28	100,000	20,000	80,000	200,000	3.73	0.08	0	56,956	56,956
29	100,000	20,000	80,000	200,000	3.92	0.07	0	54,367	54,367
30	100,000	20,000	80,000	200,000	4.12	0.06	0	51,896	51,896
31	100,000	20,000	80,000	200,000	4.32	0.06	0	49,537	49,537
	3,000,000	600,000	2,400,000	6,000,000			86,250,000	3,159,726	89,409,726

(1) Estimated Cost
(2) D=A+B+C
(3) See Table C-20
(4) H=D*E*F
(5) I=G+H