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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

VOLUME 1 OF 4

SEPTEMBER 1993

U.S. DEPARTMENT OF ENERGY
FERNALD FIELD OFFICE

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ENGLISH/METRIC AND METRIC/ENGLISH EQUIVALENTS

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In this document, units of measure are presented with the metric equivalent first, followed by the measured English unit in parentheses. In cases where the measurement was originally made in metric units, the values were not converted back to English units; in tables, the data are generally in English or metric units only. The following table lists the appropriate equivalents for English and metric units.

Multiply	By	To Obtain
English/Metric Equivalents		
acres	0.4047	hectares (ha)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
degrees Fahrenheit (°F) -32	0.5555	degrees Celsius (°C)
feet (ft)	0.3048	meters (m)
gallons (gal)	3.785	liters (L)
gallons (gal)	0.003785	cubic meters (m^3)
inches (in)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
pounds (lb)	0.4536	kilograms (kg)
short tons (tons)	907.2	kilograms (kg)
short tons (tons)	0.9072	metric tons (t)
square feet (ft^2)	0.09290	square meters (m^2)
square yards (yd^2)	0.8361	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
yards (yd)	0.9144	meters (m)
Metric/English Equivalents		
centimeters (cm)	0.3937	inches (in)
cubic meters (m^3)	35.31	cubic feet (ft^3)
cubic meters (m^3)	1.308	cubic yards (yd^3)
cubic meters (m^3)	264.2	gallons (gal)
degrees Celsius or Centigrade (°C)	1.8(°C) +32	degrees Fahrenheit (°F)
hectares (ha)	2.471	acres
kilograms (kg)	2.205	pounds (lb)
kilograms (kg)	0.001102	short tons (tons)
kilometers (km)	0.6214	miles (mi)
liters (L)	0.2642	gallons (gal)

ENGLISH/METRIC AND METRIC/ENGLISH EQUIVALENTS
(continued)

Multiply	By	To Obtain
meters (m)	3.281	feet (ft)
meters (m)	1.094	yards (yd)
metric tons (t)	1.102	short tons (tons)
square kilometers (km^2)	0.3861	square miles (mi^2)
square meters (m^2)	10.76	square feet (ft^2)
square meters (m^2)	1.196	square yards (yd^2)

ACRONYM LIST

Ac	actinium
AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
AMS	air monitoring station
ARAR	applicable or relevant and appropriate requirements
ASI	Advanced Sciences, Inc.
AWWT	advanced wastewater treatment
BDAT	best demonstrated available technology
BNI	Bechtel National, Inc.
BRA	Baseline Risk Assessment
Bs	bismuth
CAA	Clean Air Act of 1990
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CI	confidence interval
Ci	Curies
CIS	Characterization Investigation Study
cm	centimeter
CMSA	Cincinnati Metropolitan Statistical Area
COC	constituents of concern
COE	U.S. Army Corps of Engineers
CRARE	Comprehensive Response Action Risk Evaluation
CRDL	contract required detection limit
CRQL	contract required quantitation limit
Cs	cesium
CT	central tendency
D&D	decontamination and decommissioning
DCF	dose conversion factor
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPM	disintegrations per minute
DQO	data quality objectives
EDTA	ethylenediaminetetraacetic acid

EE/CA	Engineering Evaluation/Cost Analysis
EIS	Environmental Impact Statement
EP Tox	Extraction Procedure Toxicity
EPA	U.S. Environmental Protection Agency
ERDA	U.S. Energy Research and Development Administration
ERMC	Environmental Restoration Management Contractor
ESA	Endangered Species Act of 1973
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Company
FFA	Federal Facility Agreement
FFCA	Federal Facility Compliance Agreement
FMPC	Feed Materials Production Center
ft	feet
ft^2	square feet
ft^3	cubic feet
ft^3/sec	cubic feet per second
FR	Federal Register
FS	feasibility study
gal.	gallon
gm/cm^3	grams per cublic centimeter
GPI	glucose phosphate isomerase
gpd	gallons per day
gpm	gallons per minute
GRA	general response action
ha	hectare
HSL	Hazardous Substance List
HEPA	high efficiency particulate air
HDPE	high density polyethylene
HI	hazard index
ILCR	incremental lifetime cancer risk
in.	inch
IRIS	Integrated Risk Information System
IRM	Interim Remedial Measures

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ISA	Initial Screening of Alternatives
IT	International Technologies Corporation, Inc.
kg	kilogram
kg/d	kilograms per day
KCl	potassium chloride
km	kilometers
km^2	square kilometers
kPa	kiloPascals
L	liter
L/day	liters per day
L/min	liters per minute
L/sec	liters per second
LC/DS	leachate collection/detection system
LDR	land disposal restriction
LOOW	Lake Ontario Ordnance Works
LRA	leading remedial alternative
LSA	low specific activity
m	meter
M	million
m^2	square meters
m^3	cubic meter
mi	mile
mi^2	square miles
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MCW	Mallinckrodt Chemical Works
mg/g	milligrams per gram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mrem	millirem
μCi	microcurie
μCi/year	microcuries per year
μA	microAmpere

ACRONYM LIST
(Continued)

μg/g	micrograms per gram
μg/kg	micrograms per kilogram
mg/L	milligrams per liter
μg/L	micrograms per liter
MSL	mean sea level
MTCLP	Modified Toxicity Characteristic Leaching Procedure
mtu	metric tons of uranium
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NLO	National Lead Company of Ohio, Inc.
NOAA	National Oceanic and Atmospheric Administration
NOEL	no observed effect levels
NOI	Notice of Intent
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NTS	Nevada Test Site
O&M	operation and maintenance
OEPA	Ohio Environmental Protection Agency
OHPO	Ohio Historic Preservation Office
Pa	Pascals
Pa	protactinium
PAH	polynuclear aromatic hydrocarbons
Pb	lead
PCB	polychlorinated biphenyl
pCi/g	picoCuries per gram
pCi/L	picoCuries per liter
PCT	product consistency test

ACRONYM LIST
(Continued)

PEIS	Programmatic Environmental Impact Statement
PMCL	proposed maximum contaminant level
Po	polonium
POTW	publicly owned treatment works
PP	Proposed Plan
ppb	parts per billion
PRG	preliminary remediation goal
psi	pounds per square inch
Pu	plutonium
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
Ra	radium
RAO	remedial action objectives
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
RMI	Reactive Metals, Incorporated
RME	reasonable maximum exposure
Rn	radon
ROD	Record of Decision
RSC	relative source contribution
RTS	Radon Treatment System
SARA	Superfund Amendment and Reauthorization Act
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant level
SOWC	Southwestern Ohio Water Company
SQL	sample quantitation limit
Sr	strontium
SWOAPCA	South Western Ohio Air Pollution Control Agency
SWCR	Site-Wide Characterization Report

TBC	to be considered
Tc	technetium
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure
Th	thorium
TIE	Technical Information Exchange
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TON	total organic nitrogen
TOX	total organic halides
TSDF	treatment, storage, and disposal facility
U	uranium
UCL	upper confidence limit
UP	Union Pacific
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTL	upper tolerance limit
UV	ultraviolet
WMCO	Westinghouse Materials Company of Ohio
WEMCO	Westinghouse Environmental Management Company of Ohio
WIPP	Waste Isolation Pilot Plant
yd^3	cubic yards

EXECUTIVE SUMMARY

This report documents the Feasibility Study (FS) phase of the Fernald Environmental Management Project (FEMP) Operable Unit 4 Remedial Investigation/Feasibility Study (RI/FS) Program. The FEMP, formerly known as the Feed Materials Production Center (FEMP), is a U.S. Department of Energy (DOE) facility that operated from 1952 to 1989. The facility's primary function was to provide high purity uranium metal products to support United States defense programs. Production operations were suspended in 1989 to focus on environmental restoration and waste management activities at the facility. The RI/FS, is being conducted pursuant to the terms of a Consent Agreement between DOE and the U.S. Environmental Protection Agency (EPA) under Sections 120 and 106(a) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. The Ohio Environmental Protection Agency (OEPA) is also participating in the RI/FS process at the FEMP through direct involvement in program review meetings and technical review of project documentation. The objective of the RI/FS process is to gather information to support an informed risk management decision regarding which remedy appears to be the most appropriate action for addressing the environmental concerns identified at the FEMP.

To promote a more structured RI/FS and expeditious cleanup of the FEMP property, complex environmental issues associated with the FEMP were divided into five operable units under the Amended Consent Agreement. The term "operable unit" is used to identify a logical grouping of environmental issues that comprise an incremental step toward comprehensively addressing site problems. Separate RI/FS documentation, including Remedial Investigation (RI) and FS Reports, Proposed Plan (PP), and Record of Decision (ROD), are being developed for each of the five operable units at the FEMP. This report documents the FS phase of the RI/FS process for Operable Unit 4, which consists of the following FEMP facilities and associated environmental media:

- Silos 1 and 2 and their contents (also termed K-65 silos)
- Silo 3 and its contents (also termed cold metal oxide silo)
- Silo 4
- K-65 decant sump tank for Silos 1 and 2, its contents, and associated piping
- A radon treatment system (RTS)
- A portion of a concrete pipe trench and other concrete structures
- An earthen berm surrounding Silos 1 and 2

- Soils beneath and immediately surrounding Silos 1, 2, 3, and 4
- Perched groundwater in the vicinity of the silos that may be encountered during the implementation of cleanup activities

The primary objectives of the FS phase of the Operable Unit 4 RI/FS are to develop and evaluate an appropriate range of remedial action alternatives for addressing environmental concerns at Operable Unit 4, perform a screening of the alternatives, and complete a detailed analysis of the feasible alternatives. The alternatives evaluated in the FS were developed during the RI. The results of the FS, when combined with input from support agencies and the general public on the preferred comprehensive alternative and the other remedial alternatives identified in the PP, form the basis for selecting the proposed remedial action. Input from the public and other interested parties will be obtained through receipt of comments on a proposed plan to be issued for public review. The PP for Operable Unit 4 which will be issued to the public at the end of 1993, provides a summary level description of the action proposed for addressing Operable Unit 4 environmental concerns. Subsequently, consistent with the Amended Consent Agreement, selection of a preferred cleanup alternative will be documented in an ROD issued by the EPA following consideration of any comments received from the public and other interested parties.

In October 1990, the EPA approved the Operable Unit 4 Initial Screening of Alternatives (ISA) Report (October 1990) which provided a description of the range of cleanup alternatives being considered for the operable unit. Within the report, the Operable Unit 4 facilities and associated environmental media were grouped into three categories: Silos 1 and 2, Silo 3, and Silo 4 ISA, October 1990). During development of the RI Report, it became apparent that the original waste categories identified in the EPA-approved ISA were defined too broadly to support the necessary detailed evaluation required in the FS Report. The variety of waste media, contaminants, and concentrations encountered within Operable Unit 4, coupled with unique remediation technology requirements, required the use of a "subunit" concept for Operable Unit 4. Designating the following subunits allowed the Operable Unit 4 FS to focus on developing discrete remedial actions that would comprehensively address the entire Operable Unit 4. The subunits employed throughout the FS Report for Operable Unit 4 are as follows:

- Subunit A: Silos 1 and 2 contents, and sludges remaining within the decant sump tank
- Subunit B: Silo 3 contents

- Subunit C: Silo structures (i.e., Silos 1, 2, 3, and 4), berms, surface and subsurface soils, RTS, drum handling building pad, K-65 decant sump tank and associated piping, concrete pipe trench, perched groundwater, and any rubble or debris (i.e., demolition of waste processing facilities) generated consequential to the implementation of remedial actions for all Operable Unit 4 subunits.

Consistent with DOE Order 5400.4, the FEMP is integrating the National Environmental Policy Act (NEPA) requirements into the documentation being prepared to support the RI/FS process. However, DOE's CERCLA/NEPA integration policy is not intended to represent a statement on the legal applicability of NEPA to remedial actions under CERCLA.

On May 15, 1990, a Notice of Intent (NOI) was published in the Federal Register (55 FR 20183-20188) and was amended on June 28, 1990 (to extend the comment period). The NOI stated intent, on the part of DOE, was to prepare an EIS to evaluate the potential impacts associated with proper cleanup activities at the FEMP. The public, interested organizations, and federal, state, and local agencies were invited to provide oral comments at the two scoping meetings held on June 12-13, 1990 and to submit written comments until the close of the EIS scoping period on June 29, 1990. As a result of the scoping meetings, the EIS Implementation Plan was finalized. The EIS Implementation Plan includes: a description of the proposed actions and remedial alternatives; a list of environmental issues to be considered in the EIS (including those identified during public scoping activities); a list of proposed agency consultations; and the timing relationships between the NEPA compliance process and CERCLA project planning and decision-making.

As identified in the NOI, the FS Report and PP for the lead FEMP Operable Unit, in this case Operable Unit 4, will be issued as an FS/PP-EIS. This FS has been written to integrate NEPA requirements at the level of an EIS, in part by summarizing and incorporating by reference other key documents prepared in support of the RI/FS process [RI Report, Site-Wide Characterization Report (SWCR)]. The Operable Unit 4 FS coupled with the PP constitutes the EIS (or FS/PP-EIS). More specifically, in accordance with the "Implementation Plan for the Remedial Investigation/Feasibility Study - Environmental Impact Statement for Remedial Activities at Fernald Environmental Management Project", the FS and the PP have been supplemented to integrate evaluation of the environmental consequences, consistent with NEPA, of implementing the leading remedial alternatives of each of the other FEMP operable units (Appendix I). This discussion of the NEPA impact analysis of the leading remedial alternatives (LRAs) for the five operable units will be updated as appropriate and attached to the CERCLA/NEPA documentation for the remaining operable units.

The RI Report supports the examination of environmental impacts by describing the environment potentially affected by the storage of existing waste within the Operable Unit 4 boundary. The RI Report also assesses the impacts associated with the no-action alternative. The Baseline Risk Assessment (BRA) included in the Operable Unit 4 RI Report evaluates the potential threat to human health and the environment if no remedial actions were undertaken for Operable Unit 4. Based on the BRA, it was determined that remedial action is warranted for Operable Unit 4 to ensure the continued protection of human health and the environment. Additionally, the SWCR (March 1993) evaluated the site-wide no-action alternative by assessing the cumulative, site-wide environmental impacts associated with existing conditions at the FEMP. The RI Report for Operable Unit 4, BRA, and the SWCR are incorporated into the FS/PP-EIS by reference. They are available in the FEMP Administrative Record located on Hamilton-Cleves Highway.

This FS develops and evaluates alternatives for the remediation of Operable Unit 4 by utilizing all the information provided by the RI Report. The NEPA impact analysis of each alternative has been integrated into the Detailed Analysis of Alternatives discussion in this FS Report (Section 4). In addition, this FS provides the NEPA cumulative impact analyses associated with implementing cleanup actions for each of the five operable units (Appendix I). Pursuant to the requirements of 10 CFR 1022, "Floodplain/Wetland Environmental Review Requirements", a wetlands assessment has been prepared for the leading remedial alternative for Operable Unit 4 and is presented in Appendix J. Consistent with the Amended Consent Agreement (September 1991), Section X.F., this FS also presents the results of the initial site-wide Comprehensive Response Action Risk Evaluation (CRARE) in Appendix J. The CRARE provides an analysis of the total cumulative residual human health risk projected to remain after the proposed remediation of the FEMP is complete.

The PP summarizes essential key information from the RI, FS, and CRARE and identifies the preferred comprehensive alternative for remediation of Operable Unit 4. In addition, the PP also presents a summary of the environmental impacts of the preferred alternative. The PP provides key information on the public's important role in the remedy-selection decision-making process. The PP facilitates public participation by providing a document for comment, which details the process by which the preferred alternative for remedial action was selected.

The cleanup decisions made for Operable Unit 4, based on the RI, FS, CRARE, PP, and public comments, will be presented in the ROD for remediation of Operable Unit 4. The ROD will include

a summary of the Operable Unit 4 FS as well as a summary of the, comments received on the final FS/PP-EIS and the manner in which they were addressed.

Source Description

Operable Unit 4 can be defined as the facilities and environmental media within a 2.3-hectare (ha) (5.8-acre) area located in the southwest corner of the Waste Storage Area on the western portion of the FEMP site (see Figure 1-2).

Silos 1 and 2, known as the K-65 silos, contain residues generated from processing high-grade uranium ores; these residues comprise Subunit A. This processing, which was conducted at both the FEMP and the Mallinckrodt Chemical Works (MCW) in St. Louis, Missouri during the early 1950s, was conducted to extract the uranium from the natural ores. The ores, consisting mainly of pitchblende, were shipped to the United States primarily from the Shinkolobwe Mine in the Belgian Congo (now the country of Zaire). Pursuant to the terms of an agreement between the U.S. Atomic Energy Commission (AEC) and the African Metals Corporation (owner of the mine), rights to the uranium in the ores were sold to the United States. The African Metals Corporation retained ownership of the precious metals in the ore including radium, gold, and silver. The K-65 silos were constructed at the FEMP in 1951 to provide interim storage of the residues, pending return of the material to the African Metals Corporation. For more than 30 years, these materials remained in storage at the FEMP under the terms of the original agreement. In 1984, ownership of the residues was transferred to the United States government.

Silo 1 contains 3280 cubic meters (m^3) [115,900 cubic feet (ft^3)] of residues and 360 m^3 (12,600 ft^3) of bentonite clay. Silo 2 contains 2840 m^3 (100,400 ft^3) of residues and 310 m^3 (11,100 ft^3) of bentonite clay. As part of previous studies and as part of the RI, samples were collected from the residues in the silos. These residues are primarily a silty clay with an average moisture content of approximately 40 percent. Analytical results from the residue samples identified significant activity concentrations of radionuclides within the uranium decay series, thus confirming prior process knowledge. The residue volumes within the two silos contain in excess of 3700 Curies (Ci) of radium (Ra)-226, 600 Ci of thorium (Th)-230, and 1900 Ci of radioactive lead (Pb)-210. The residues also contains leachable concentrations of other metals, primarily barium and lead.

Silos 1 and 2 are equipped with a decant sump tank, which was first used to collect decant liquids from residue slurried into the silos. The system also collects silo leachate that entered the Silos 1 and

2 underdrain system. The tank is buried beneath the silo berm, at a depth approximately 0.61 meter (m) [2 feet (ft)] below the base of the silos, between Silos 1 and 2, and is connected to the berm surface via a standpipe. In 1990, site personnel noted 1.2 m (4 ft) of liquid in the standpipe. In 1991, and again in February 1993, the liquid contents of the decant sump tank were emptied and sampled. Analytical results of these liquids indicated the constituents and concentrations were consistent with the contents of Silos 1 and 2.

The significant quantities of liquid in the decant sump tank indicate that the system is collecting leachate from the silo underdrain system, as it was designed to do. Excess quantities of liquid in the decant sump tank, which cause liquid to rise into the standpipe, provide a possible mechanism for leachate from the silos to enter perched groundwater.

Structural evaluations completed on Silos 1 and 2 identified a significant loss of the load-carrying capability at the center portion of the domes on both structures. A protective barrier was placed over the deteriorated central portions of the silo domes in 1986 to minimize potential environmental impacts in the event of a catastrophic dome collapse. The remaining structures, Silos 3 and 4, which are also beyond their original design life, show signs of deterioration from weathering but have required no reinforcement.

As a natural consequence of the decay of the Ra-226 present in the Silos 1 and 2 residues, a radioactive gas, radon (Rn)-222, is formed. Air samples collected in 1987 from the unfilled, upper portion of the Silos 1 and 2 "headspace" showed a maximum concentration of 30,000,000 picoCuries per liter (pCi/L). The average background concentration of Rn-222 in ambient air is approximately 0.5 pCi/L. In late 1991, a layer of bentonite clay slurry was placed over the residues in Silos 1 and 2. This clay layer was installed to reduce the release of radon gas to the atmosphere. Samples collected following emplacement of the bentonite clay showed a 99 percent reduction in the Rn-222 present in the headspace of the silos.

The inventory of radionuclides present in the K-65 residues significantly elevates the direct penetrating radiation field in the vicinity of the silos. Measurements collected from the silo dome surfaces before the bentonite clay layer was installed showed exposure rates in excess of 200 millirem per hour (mrem/hr), or approximately 20,000 times natural background radiation levels. Measurements collected from the surfaces of the domes following bentonite installation showed a greater than 95 percent decrease in the direct radiation fields on the dome surface.

Silo 3 contains 3890 m^3 (137,500 ft^3) of residues, known as cold metal oxides, which were generated at the FEMP during uranium extraction operations in the 1950s. This process involved the previously mentioned Belgian Congo ores and uranium concentrates received from a variety of uranium mills in the United States and abroad; these residues comprise Subunit B. The residues in Silo 3 are substantially different from those in Silos 1 and 2. First, Silo 3 residues have a low moisture content resulting in a powder-like consistency, while residues in Silos 1 and 2 consist of wet slurry from which excess liquids were decanted. Second, while the radiological constituents in Silo 3 are similar to those in Silos 1 and 2, certain radionuclides, such as radium, are present in much lower concentrations. Thus, Silo 3 exhibits a significantly lower direct radiation field and radon emanation rate than Silos 1 and 2.

Residue samples collected from Silo 3 identified the presence of significant activity and concentrations of the radionuclides within the uranium decay series, confirming prior process knowledge. The predominant constituent identified within Silo 3 was Th-230, a radionuclide produced from the natural radioactive decay of U-238. Approximately 450 Ci of Th-230 are distributed within the 3890 m^3 (137,500 ft^3) of waste residues within Silo 3. Tests performed on samples of the Silo 3 residues to determine the leachability of inorganic substances present detected eight metals, of which arsenic, cadmium, chromium, and selenium had the highest concentrations.

Silo 4 is empty and was never used for waste storage; however, rainwater has infiltrated into the silo and has been previously removed by maintenance activities whenever necessary.

Development and Screening of Alternatives

This FS presents information to support the selection of the most appropriate cleanup alternative for each of the three Operable Unit 4 subunits. The alternatives for remediation in this FS were developed in accordance with EPA guidance by following a series of logical steps that involved developing, in succession, more specific definitions of potential remedial alternatives. The steps included the following:

- Development of contaminant- and media-specific remedial action objectives (RAOs) and preliminary remediation goals (PRGs)
- Identification of general response actions (GRAs)
- Identification of volumes and/or areas of waste media to be addressed
- Identification and screening of remedial technologies and process options

- Evaluation and screening of process options within each technology
- As practicable, assemblage of a complete range of remedial alternatives using the selected process options within each remedial technology
- Evaluation of initial screening to determine which most feasible alternatives will be analyzed more fully in the detailed analysis phase of the FS

Detailed/Comparative Analysis of Feasible Alternatives

The detailed analysis of alternatives is performed on those alternatives which are retained through the screening of alternative steps described above. The detailed and comparative analyses consist of the analysis and presentation of the relevant information needed to allow decision makers to select a remedial alternative. The alternatives selected for further evaluation in the detailed analysis of alternatives for each of the three subunits of Operable Unit 4 are listed below.

Subunit A - Silos 1 and 2 Contents

- Alternative 0A - No Action
- Alternative 2A - Removal, Stabilization [by vitrification (Vit); or cementation (Cem)], and On-Property Disposal
- Alternative 3A.1 - Removal, Stabilization [by vitrification (Vit); or cementation Cem)], and Off-Site Disposal at the Nevada Test Site (NTS)

Subunit B - Silo 3 Contents

- Alternative 0B - No Action
- Alternative 2B - Removal, Stabilization (by vitrification [Vit]; or cementation [Cem]), and On-Property Disposal
- Alternative 3B.1 - Removal, Stabilization (by vitrification [Vit]; or cementation [Cem]), and Off-Site Disposal at NTS

Subunit C - Silos 1, 2, 3, 4 Structures, Soils, and Debris

- Alternative 0C - No Action
- Alternative 2C - Demolition, Removal, and On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS

- Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at a Permitted Commercial Disposal Site

As discussed earlier, the phased RI/FS process is intended to better focus the site investigation so that only those data necessary to support the RI/FS and the decision-making process are collected. Data requirements often necessitate the need to conduct treatability studies in order to collect data on remedial technologies identified during the alternative development process to provide additional information for evaluating technologies. Data are analyzed and interpreted on the technology's effectiveness, implementability, and/or cost and anticipated results are compared with actual results. Appendix C provides a summary of the treatability studies conducted in direct support of the Operable Unit 4 RI/FS process. Cement stabilization, chemical separation, and vitrification were leading treatment technologies for which tests were carried out to determine whether the given technologies could achieve the required cleanup goals for Operable Unit 4. The treatability study results were used in the Operable Unit 4 FS to support the detailed analysis of alternatives and to allow selection of the preferred remedial action in the PP for Operable Unit 4 to be made with reasonable certainty of achieving the response objectives.

For each subunit, the no-action alternative was carried forward into the detailed analysis as a baseline for comparison as required per the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The objectives of the detailed/comparative analysis are: (1) to further define the reasonable alternatives that have been carried forward from the alternative screening phase of the CERCLA process; (2) to individually evaluate each alternative against the evaluation criteria as specified in EPA "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA, 1988); and (3) to compare alternatives with each other to assess the relative performance of each alternative with respect to each evaluation criterion.

Nine evaluation criteria have been developed in the EPA guidance documents to address the CERCLA requirements as stated in the NCP. Assessments against two of the criteria relate directly to evaluation against regulatory requirements and are categorized as threshold criteria. These two criteria are:

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)

The following five criteria are grouped together because they represent the primary balancing criteria upon which the detailed analysis is based:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

The final two criteria will be evaluated following public and agency comments on the FS/PP-EIS and will be addressed in the ROD once a final remedial action decision is made. The modifying criteria are as follows:

- State acceptance
- Community acceptance

The results of the comparative analysis distinguish the relative advantages and disadvantages of each alternative so that the leading remedial action for each subunit can be identified in the PP. Ideally, the leading remedial action alternative identified in the PP for Operable Unit 4 will consist of those alternatives, one from each subunit, which performed best when evaluated against the nine criteria.

The discrete leading remedial alternatives for each subunit may be combined into one comprehensive remedial action strategy that will effectively address the complex nature of Operable Unit 4 cleanup activities in the PP. The PP will be issued for public review and comment with the integrated FS/PP-EIS. The final remedy for Operable Unit 4 will be determined after public consideration of the PP and any significant new information that may become available subsequent to submittal of the FS/PP-EIS. The alternatives selected for implementation will be documented in the Operable Unit 4 ROD.

1.0 INTRODUCTION

This report documents the Feasibility Study (FS) phase of the Remedial Investigation/Feasibility Study (RI/FS) for Operable Unit 4 at the U.S. Department of Energy (DOE) Fernald Environmental Management Project (FEMP). The FEMP, formerly known as the Feed Materials Production Center (FMPC), operated from 1952 until 1989 providing high purity uranium metal products in support of United States defense programs. The FEMP is located in southwestern Ohio about 27 kilometers (km) [17 miles (mi)] northwest of the city of Cincinnati, Ohio (Figure 1-1). Production operations were halted in 1989 to focus available resources on environmental restoration initiatives at the facility. One of these initiatives, the RI/FS, is being conducted pursuant to the terms of an agreement with the U.S. Environmental Protection Agency (EPA) to identify the most plausible cleanup actions to be undertaken at the FEMP to address identified environmental concerns. These concerns have been identified by DOE, EPA, the Ohio Environmental Protection Agency (OEPA), and members of the community living near the facility. These concerns have included: the potential impacts on human health and the environment from past releases of hazardous materials from the FEMP to air, water, and the surrounding soils; continuing releases of hazardous materials from the facility; and the on-site accumulation of a large inventory of uranium process materials and low-level radioactive and hazardous wastes at the site. On the basis of these concerns and an evaluation of existing environmental sampling data, the FEMP was placed on the National Priorities List (NPL) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in November 1989. Inclusion on the NPL reflects the relative importance, placed by the federal government, on ensuring the expedient completion of the RI/FS and any resulting cleanup actions at the FEMP site.

To promote a more structured and expeditious cleanup of the FEMP site, the facility and environmental issues associated with the site are being managed as five operable units. An operable unit is a term employed under federal environmental regulation to identify a logical grouping of environmental issues at a cleanup site. Separate RI/FS documentation is being issued for each of the five operable units at the FEMP. As previously stated, this report documents the FS phase for Operable Unit 4. Operable Unit 4, as depicted in Figure 1-2, consists of the following FEMP facilities and associated environmental media:

- Silos 1 and 2 and their contents (also termed K-65 Silos)
- Silo 3 and its contents (termed cold metal oxide silo)
- Silo 4

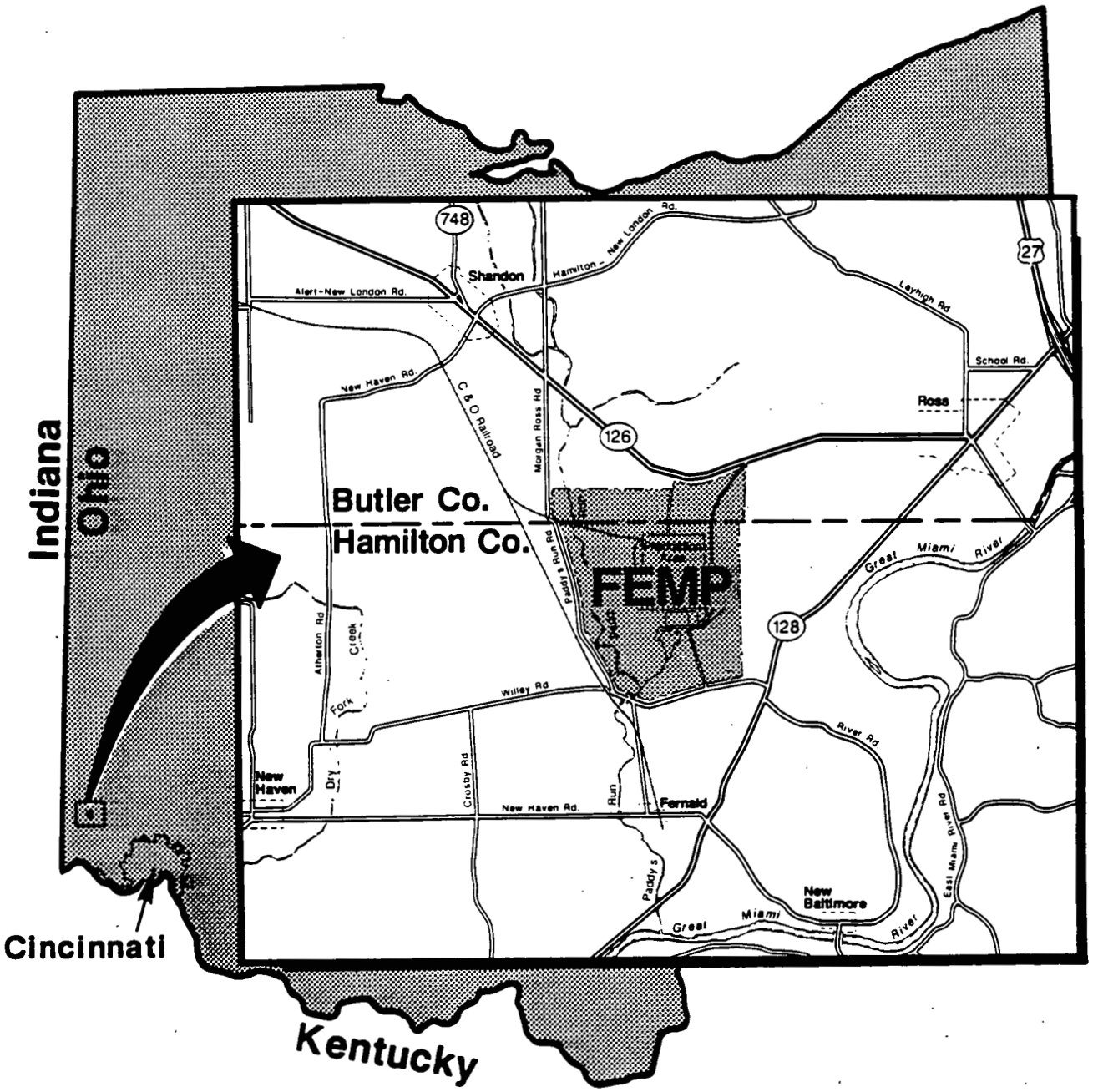

FIGURE 1-1. FEMP FACILITY LOCATION MAP

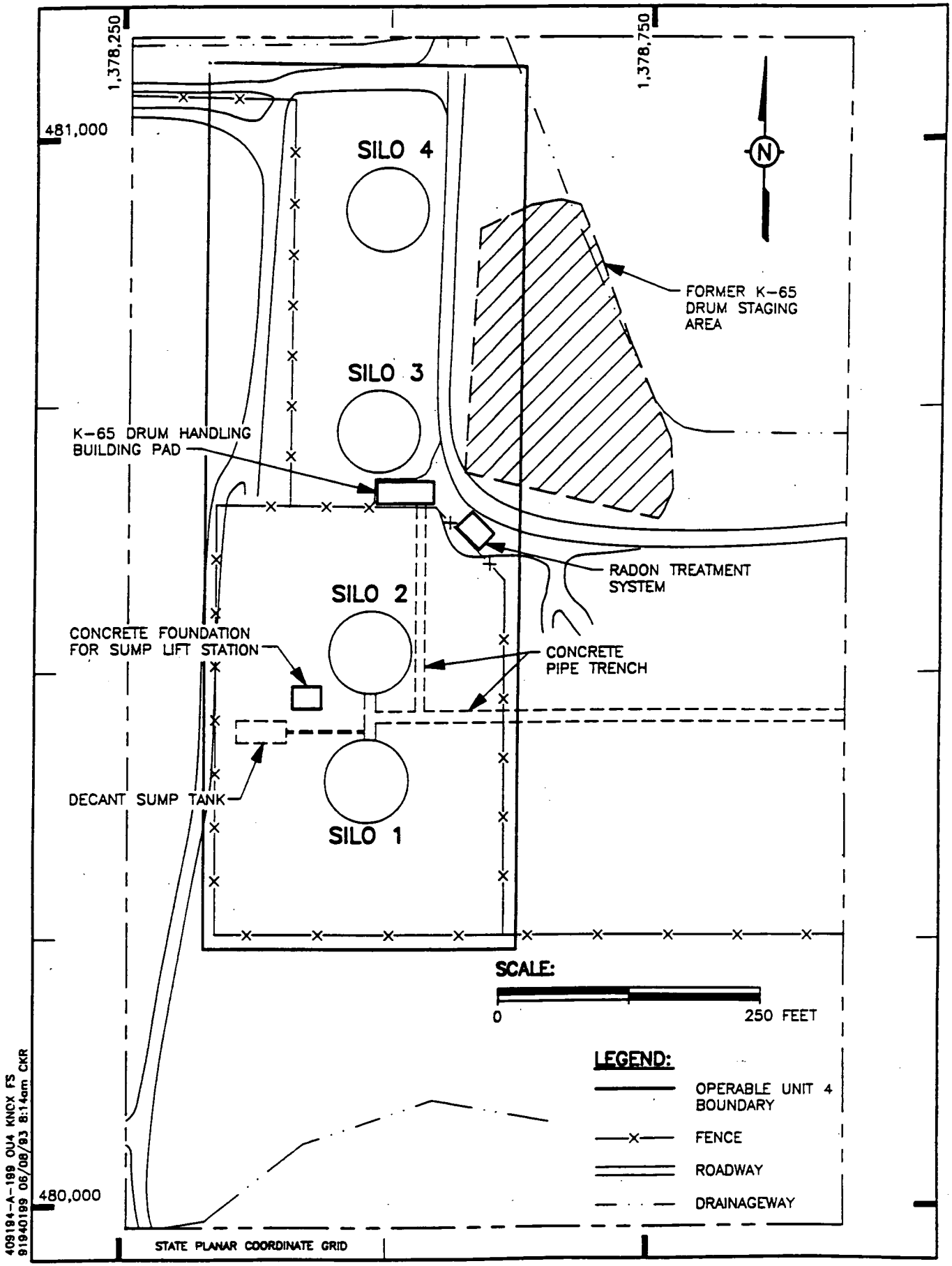

FIGURE 1-2. OPERABLE UNIT 4

- K-65 decant sump tank, its contents, and associated piping
- A radon treatment system (RTS)
- The portion of a concrete pipe trench within the boundaries of Operable Unit 4, and other concrete structures
- An earthen berm surrounding Silos 1 and 2
- Soils beneath and immediately surrounding Silos 1, 2, 3, and 4
- Perched groundwater in the vicinity of the silo that is encountered during the implementation of cleanup activities

Silos 1 and 2, known as the K-65 Silos, contain the residues generated from the processing of high grade uranium ores. This processing was completed to extract the uranium compounds from the natural ores. These ores, termed pitchblende, were shipped to the United States from a mine in the Belgian Congo (now known as Zaire). The K-65 residues contain high activity concentrations of radionuclides, including radium and thorium. These radionuclides contribute to an elevated direct penetrating radiation field in the vicinity of the silos and to the chronic emission of significant quantities of the radioactive gas, radon, to the atmosphere from the silos. The K-65 residues are classified as by-product materials, consistent with Section 11(e)2 of the Atomic Energy Act (AEA), generated consequential to the processing of natural uranium ores.

Silo 3 contains residues, known as cold metal oxides, which were generated at the FEMP site during uranium extraction operations in the 1950s involving the previously mentioned Belgian Congo ores and uranium concentrates received from a variety of uranium mills in the United States and abroad. The residues within Silo 3 also contain significant activity concentrations of radionuclides but exhibit a significantly lower direct radiation field and radon emanation rate than the K-65 residues. The residues within Silo 3 are similarly classified as by-product materials pursuant to Section 11(e)2 of the AEA. Silo 4 was never used for waste storage; however, rain water has infiltrated into the silo and has been previously removed whenever necessary.

The RI/FS for Operable Unit 4 is being conducted in accordance with the Amended Consent Agreement between EPA and DOE. One objective of the RI/FS is to develop a detailed understanding of the nature of the stored waste materials, their impacts on the surrounding environment, and the threat that the Operable Unit 4 facilities pose to human health and the environment. DOE reported the detailed description of the existing conditions in Operable Unit 4 in

the RI Report for Operable Unit 4 issued in August 1993 (DOE 1993a). The purpose of this FS Report for Operable Unit 4 is to evaluate the range of available remedial action alternatives for the permanent disposition of the K-65 residues, cold metal oxides, the silo structures, and associated contaminated environmental media.

For sites undergoing investigations and cleanup under CERCLA, it is DOE policy to integrate the National Environmental Policy Act (NEPA) requirements into the procedural and documentation requirements of the RI/FS process wherever practical. On May 15, 1990, a Notice of Intent (NOI) was published in the *Federal Register* indicating that DOE planned to prepare an integrated FS and Environmental Impact Statement (EIS) consistent with NEPA to evaluate the environmental impacts associated with the implementation of cleanup actions for each of the five FEMP operable units. Consistent with the NOI, this FS Report has been written to integrate elements of an EIS prepared under NEPA. This FS Report, when coupled with the information provided in the Proposed Plan (PP), has been completed in such a manner as to fulfill the requirements of an Operable Unit 4 EIS. The resulting integrated process and documentation package is termed an Feasibility Study/Proposed Plan-Environmental Impact Statement (FS/PP-EIS). Additional details on this integration process can be found in Section 1.3.

The DOE issued a second NOI on October 22, 1990 to prepare a Programmatic EIS (PEIS) on DOE's integrated Environmental Restoration and Waste Management Program. The purpose of DOE's proposed integrated environmental restoration and waste management program is to provide a broad, systematic approach to addressing cleanup activities and waste management practices at sites nationwide. The remedial actions evaluated and selected in the FEMP site's integrated CERCLA/NEPA documentation will be consistent with the approaches developed in this FS/PP-EIS.

1.1 PURPOSE AND NEED FOR DECISION

Facilities and environmental media at the FEMP site contain radioactive and chemical constituents at levels that exceed certain federal and state standards and guidelines for protecting human health and the environment. DOE maintains custody of the site and restricts access with fences and security forces, precluding a member of the public from being exposed to the more heavily contaminated areas on the site. To support the decision as to whether a given waste site warrants the implementation of cleanup actions, EPA has established a formalized risk assessment process. Under this process, several hypothetical scenarios are examined that could expose members of the public to site contamination. One of these scenarios assumes that site access is not controlled and a member of the

public could be exposed to site contaminants. Results of the risk assessment performed for this hypothetical scenario, which assumes a loss of access controls, indicate that if an individual were to enter the site and establish a residence within the Operable Unit 4 Study Area under existing conditions, that individual could incur adverse health effects.

The ongoing RI/FS site characterization and routine environmental monitoring programs at the FEMP site provide information on the nature and extent of contamination, including information for areas off the FEMP property to which contaminants have migrated or could migrate in the future. The routine environmental monitoring program provides environmental data that can be examined over long periods of time (i.e., months, years, and decades) to provide an early indication of any adverse change in site environmental conditions.

While human populations are not presently adversely impacted by Operable Unit 4 contaminants due to access and administrative controls (DOE 1993a), the purpose of DOE's environmental restoration program is to preclude the potential for such impacts in the future by implementing long-term cleanup solutions. DOE is addressing long-term management of the FEMP site through the previously identified integrated environmental decision-making process.

1.2 PURPOSE AND ORGANIZATION OF REPORT

The purpose of this FS Report is to evaluate the range of available remedial action alternatives for addressing the permanent disposition of the stored residues, their storage structures and support facilities, and existing contaminated environmental media within Operable Unit 4 at the FEMP site. This report has been prepared consistent with the requirements of the Amended Consent Agreement, applicable project documentation, and available EPA guidance. The FS Report has been prepared to provide the necessary information, when coupled with regulatory agency and community input, to support an informed decision regarding the appropriate remedy for implementation for Operable Unit 4. The FS Report is organized as follows:

- The remainder of Section 1.0 presents a summary description of the history, environmental setting, and the nature and extent of contamination associated with the FEMP site and Operable Unit 4, emphasizing information from the RI Report for Operable Unit 4. The section further presents a brief discussion of the human health impacts that might occur at the site and Operable Unit 4 in absence of remedial actions, summarizing information from the baseline risk assessment in the RI Report for Operable Unit 4 and the Site-Wide Characterization Report (SWCR DOE 1993b).

- Section 2.0 identifies the scope of the proposed remedial for actions at Operable Unit 4, the volume of waste and contaminated media being addressed, and the goals and

objectives of proposed remedial actions. The section identifies potential technologies and available process options for managing the residues and contaminated media.

- Section 3.0 develops and screens preliminary remedial action alternatives for addressing each waste type and media associated with Operable Unit 4.

- Section 4.0 provides a more detailed description of the remedial action alternatives being considered and performs a detailed analysis of the alternatives employing criteria established by federal regulation. Each detailed analysis has been supplemented to include an impact analysis of the affected environment pursuant to the requirements of NEPA.

- Section 5.0 presents a comparative analysis of the remedial candidates for Operable Unit 4.

Supporting information is contained in Appendices A through K, including more detailed discussions on available process options, costing information, regulatory requirements, and the Comprehensive Response Action Risk Evaluation (CRARE). The CRARE, which is included as Appendix K, presents the results of a risk assessment performed for Operable Unit 4 with the available information from the leading alternatives for the other four FEMP site operable units, to provide an indication of the ability to achieve goals of human health protectiveness from a site-wide perspective.

1.3 OVERVIEW OF FEMP SITE ENVIRONMENTAL RESTORATION PROCESS

This section summarizes the major elements of the FEMP environmental restoration process including the RI/FS and removal actions.

1.3.1 RI/FS Process

The RI/FS is being conducted in accordance with the requirements of the Amended Consent Agreement between DOE and EPA. The Amended Consent Agreement provides that the RI/FS be performed consistent with CERCLA and other applicable EPA regulations and guidance. The RI/FS documents for Operable Unit 4 have been prepared in accordance with the requirements of CERCLA, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and pertinent EPA guidance. A diagram providing an overview of the RI/FS process as it is being implemented at the FEMP site is presented in Figure 1-3. The RI/FS process comprises the following primary components:

- RI - presents information on the existing conditions at the site, defines the nature and extent of contamination, and performs an assessment of the risks to human health and the environment due to existing environmental conditions.

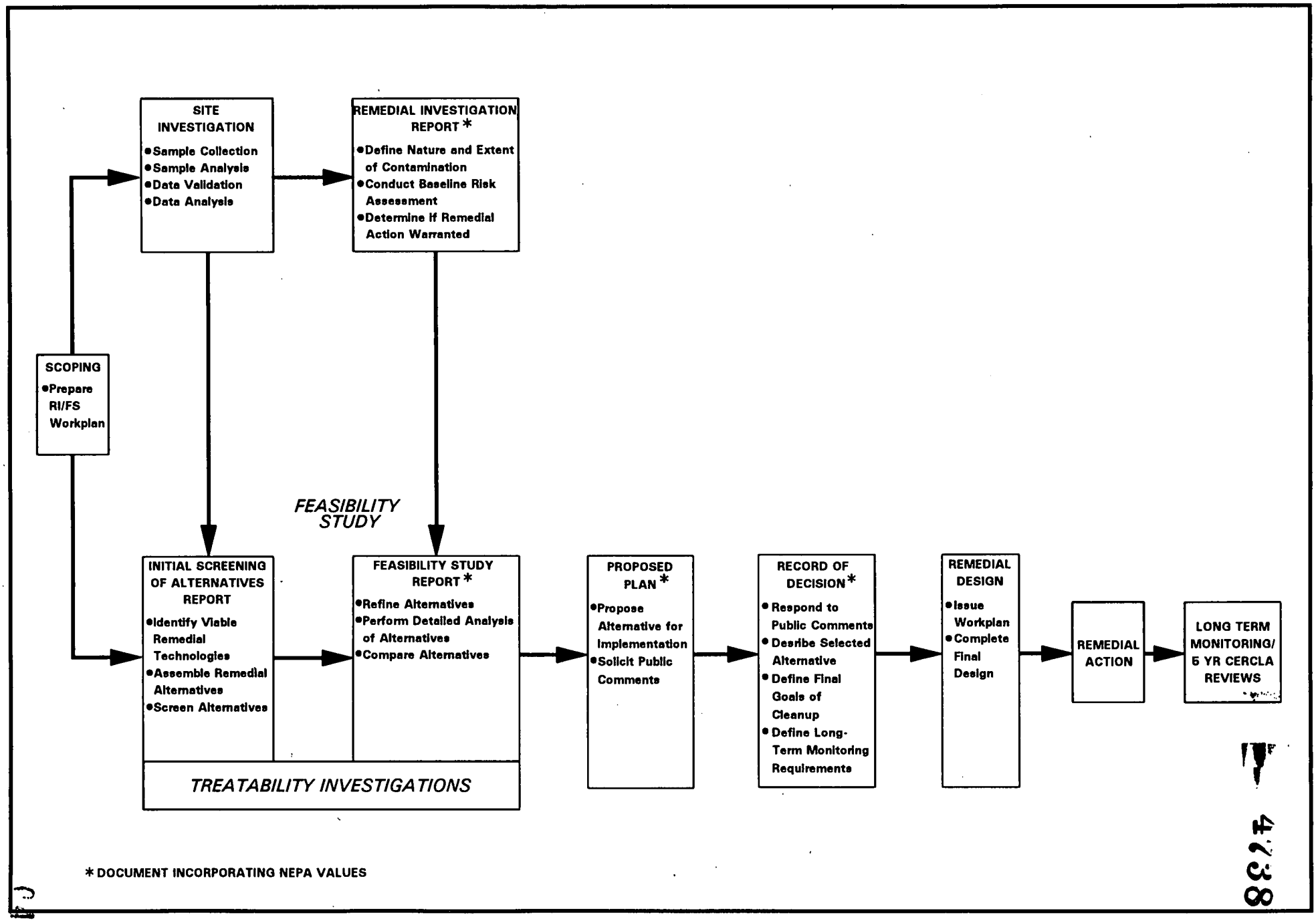

FIGURE 1-3. FEMP ENVIRONMENTAL RESTORATION PROCESS

- FS - develops, screens, and evaluates technologies and alternatives for potential implementation to address identified environmental concerns.

- PP - summarizes the proposed remedial alternative for implementation at a specific operable unit based on information collected and assessed in the FS/PP-EIS so as to facilitate input from the public and other interested parties in the decision-making process.

- Record of Decision (ROD) - responds to public comments on the PP, documents the selected alternative, and defines final cleanup goals and long-term monitoring requirements.

As previously stated, it is DOE policy to integrate the NEPA requirements into the procedural and documentation requirements of CERCLA wherever practicable. In accordance with this policy, the RI/FS documents prepared to support the Operable Unit 4 decision process have been written to place added emphasis on the evaluation elements and criteria employed in the development of an EIS under NEPA. This includes an impact on analysis of each of the alternatives presented in section 4.0 and consideration of these impacts in the comparative analysis section 5.0. Figure 1-3 indicates the RI/FS documents supplemented to provide added emphasis to NEPA requirements.

The five operable units for which RI/FS documents are being compiled are defined as:

- Operable Unit 1: Waste Pit Area. Waste Pits 1 through 6, Clearwell, Burn Pit, berms, liners and soil within the operable unit boundary as approved in the RI/FS Work Plan Addendum.

- Operable Unit 2: Other Waste Units. Flyash piles, other South Field disposal areas, lime sludge ponds, solid waste landfill, berms, liners, and soil within the operable unit boundary as approved in the RI/FS Work Plan Addendum.

- Operable Unit 3: Former Production Area. Former Production Area and production-associated facilities and equipment (includes all above- and below-grade improvements) including, <u>but</u> not limited to, all structures, equipment, utilities, drums, tanks, solid waste, waste, product, thorium, effluent lines, a portion of the K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feedstocks, and coal pile.

- Operable Unit 4: Silos 1 through 4. Silos 1, 2, 3, and 4, berms, decant sump tank system, and soil within the operable unit boundary as approved in the RI/FS Work Plan Addendum.

- Operable Unit 5: Environmental Media. Groundwater, surface water, soil not included in the definitions of Operable Units 1 through 4, sediment, flora, and fauna.

Separate RI/FS documentation including RI Reports, Initial Screening of Alternatives (ISA) Reports, FS Reports, PPs, and RODs are being issued on varied time schedules for each of the five operable units as established by the Amended Consent Agreement. The lead operable unit (i.e., chronologically, the first operable unit issuing RI/FS documents) for the FEMP site is Operable Unit 4.

The RI reports for each operable unit will contain characterization data for the specific operable unit and nearby environmental media and will function as the description of the affected environment for NEPA purposes. The SWCR, issued in March 1993 (DOE 1993b), includes detailed technical appendices reporting FEMP-wide studies of wetlands, threatened and endangered species, and cultural resources. The SWCR also presents the CERCLA preliminary site-wide baseline risk assessment. The preliminary site-wide baseline risk assessment evaluates the present and future risks posed by the site should no further action be taken; as such, it serves as a mechanism to support the decision, on the part of EPA and DOE as the lead agency, that remedial action is warranted at the FEMP site to protect human health and the environment. Furthermore, it provides input to the NEPA impact analysis of the consequences of implementing no remedial actions. The FS documents prepared for each operable unit will incorporate NEPA requirements in that they will contain the impact analysis of each FEMP alternative for the specific operable unit.

The Operable Unit 4 FS/PP-EIS functions as the lead CERCLA/NEPA integrated document and addresses the cumulative impacts of the LRAs for each operable unit. Specifically, Appendix I of this document contains the NEPA Cumulative Impact Analysis of Leading Remedial Alternatives. Appendix I also contains a list of contributors and a list of agencies contacted pursuant to NEPA requirements. Appendix J contains a Wetlands Assessment pursuant to the requirements of 10 CFR 1022. The CERCLA/NEPA integrated documents prepared subsequent to Operable Unit 4 will be derived from or be fully encompassed by the impact analysis presented in the Operable Unit 4 FS/PP-EIS. If the LRAS for any of the operable units change, additional NEPA review will be performed and documented as appropriate to evaluate the impacts to human health and the environment. This additional analysis will be presented in the integrated CERCLA/NEPA documents for the remaining operable units where appropriate.

In accordance with both CERCLA and NEPA processes, these documents are made available to the public for comment. Public involvement is an important factor in the decision-making process for site remediation. Public comments will be considered in the selection of remedy for each operable unit,

which will be presented in a ROD. Applying the integrated approach for CERCLA and NEPA, DOE plans to prepare and issue a single ROD to be signed by both DOE and EPA. The contents of the documents prepared for the remedial actions at the FEMP are not intended to represent a statement on the legal applicability of NEPA to remedial actions conducted under CERCLA.

While the operable unit concept provides a management strategy to expedite the cleanup process at a site, the concept does not obviate the statutory requirement to ensure protection of human health and the environment from a site-wide perspective. To ensure site-wide protectiveness, the FEMP Amended Consent Agreement provides for a CRARE within each operable unit FS Report and a follow-up Comprehensive Site-Wide Operable Unit.

As identified in Figure 1-4, each FEMP operable unit FS Report incorporates a CRARE. The purpose of this risk evaluation is to provide an indication of the contribution to the residual risk projected to be remaining following completion of remedial activities of the other four FEMP operable units not the subject of the particular FS Report. This residual risk contribution is then examined in context with the contribution of residual risk attributable to a representative alternative for the particular operable unit of issue in the FS Report. The intent of this process is to provide decision makers with relevant information of potential cumulative site-wide residual risk across all operable units, so as to provide an indication of the ability of the available alternatives to effectively contribute to the overall goal of site-wide protection of human health and the environment. To accommodate such a process for Operable Unit 4, the LRA for each of the other four FEMP operable units has been employed to estimate the residual risk contribution from these operable units.

The leading remedial alternatives for Operable Units 1, 2, 3, and 5 being employed in this risk evaluation process were previously identified in the SWCR. The leading remedial alternatives represent the remedial option which, on the basis of available data, is the most likely to be implemented for a particular operable unit. The leading remedial alternatives should in no way be considered a preselection of alternatives for implementation in advance of the formal RI/FS process. The leading remedial candidates have been identified and employed solely to support the progressive evaluation of site-wide protectiveness in the CRARE in each operable unit FS Report.

The residual risk projected to remain following implementation of these leading alternatives has been examined in context with a representative alternative for Operable Unit 4. As the FEMP site proceeds through the RI/FS process for the other operable units, each FS Report CRARE will adopt

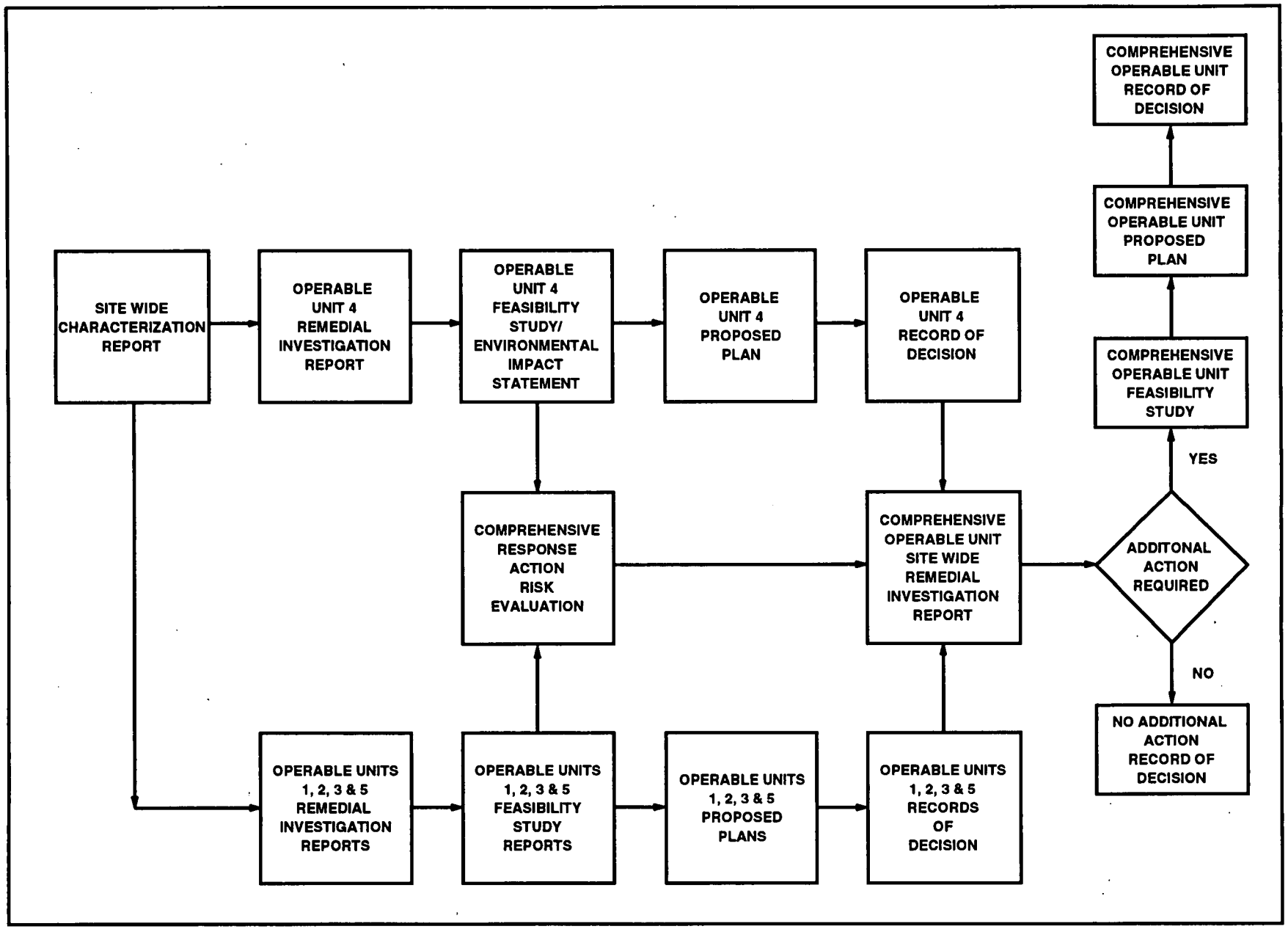

FIGURE 1-4. FEMP OPERABLE UNIT INTEGRATION STRATEGY

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the leading remedial alternatives or the previously selected alternatives for the other four operable units to provide a progressive analysis of cumulative site-wide residual risks to human health and the environment. The CRARE is provided in Appendix K.

Following issuance of the ROD for the last of the five operable units, the Amended Consent Agreement provides for a Comprehensive Site-Wide Operable Unit. The Comprehensive Site-Wide Operable Unit will involve the completion of a risk assessment to evaluate the residual risk projected to be remaining following the implementation of each of the remedies selected for the five operable units in the RODs. The intent of this risk assessment is to provide a final examination of site-wide residual risks to ensure protection of human health and the environment from a site-wide perspective. If the risk evaluation deems that the residual risks from the five remedies is sufficiently protective, a no-action ROD will be issued for the Comprehensive Site-Wide Operable Unit. Should the risk evaluation deem the projected residual risks for the five selected remedies to not be sufficiently protective, a Comprehensive Site-Wide Operable Unit FS will be conducted. The focus of the FS will be to determine what, if any, supplemental actions must be undertaken by one or more of the five operable units to reduce overall site risks to acceptable levels.

All necessary site investigations have been completed for Operable Unit 4 and the RI Report for Operable Unit 4 was issued in August 1993 (DOE 1993a). The results of the RI Report for Operable Unit 4 are summarized within Sections 1.5.2 and 1.6.3. Remedy selection-based treatability studies have also been completed with the results of these studies summarized in Appendix C.

On October 29, 1990, DOE received approval of the Operable Unit 4 ISA Report. The ISA Report summarizes viable remedial technologies potentially applicable to Operable Unit 4. Viable technologies were assembled into remedial alternatives and screened to remove inappropriate alternatives. The results of the initial screening process and changes since the approved ISA Report are discussed in Section 3.0.

1.3.2 Removal Actions

A removal action is a cleanup action undertaken pursuant to CERCLA to address a near term environmental concern at a site, while the typically more lengthy RI/FS process continues to completion. Removal actions typically contribute to the efficient performance of final remedial actions.

Under the terms of the Amended Consent Agreement and in accordance with authorities granted to DOE under Section 106 of CERCLA by Executive Order 12580, the FEMP site is in the process of conducting or has completed 31 removal actions. These removal actions are part of each of the five operable units. Removal actions associated with Operable Unit 4 were previously discussed in Section 1.0 of the RI Report for Operable Unit 4.

1.4 BACKGROUND INFORMATION

This section provides a brief summary description and history of the affected sites and Operable Unit 4. The RI Report for Operable Unit 4, Baseline Risk Assessment, and the SWCR are incorporated herein by reference. They are available in the FEMP Administrative Record located at 10845 Hamilton-Cleves Road, Harrison, Ohio, 45030.

1.4.1 Description of Affected Sites

The following provides a description of the sites potentially involved in the Operable Unit 4 Remedial Action. The FEMP will be the primary site where the remedial activities will be conducted. Therefore, the most in depth discussion has been devoted to the FEMP site. Remedial activities may also involve the Nevada Test Site (NTS) and the permitted commercial disposal site. Summary information on the Nevada Test Site and a brief description of the permitted commercial disposal site have been provided in Appendix B.

1.4.1.1 Description of the FEMP Site

The FEMP is a 425-hectare (ha) (1050-acre), government-owned, contractor-operated facility located in southwestern Ohio, about 27 km (17 mi) northwest of downtown Cincinnati, Ohio. The facility is located just north of Fernald, Ohio, a small farming community, and lies on the boundary between Hamilton and Butler counties (Figure 1-1). Of the total site area, 345 ha (850 acres) are in Morgan and Crosby townships of Hamilton County, and 80 ha (200 acres) are in Ross Township of Butler County.

Production operations at the FEMP site were limited to a fenced in, 55-ha (136-acre) tract of land known as the former Production Area, located near the center of the site. Large quantities of liquid and solid wastes were generated by the various operations at the FEMP site. Prior to 1984, solid and slurried wastes from FEMP processes were stored or disposed in the on-site Waste Storage Area. This area, located west of the production facilities, includes six low-level radioactive waste storage pits; two earthen-bermed concrete silos containing K-65 residues; one concrete silo containing metal

oxides; one unused concrete silo; two lime sludge ponds; a burn pit; a clearwell; and a solid waste landfill. The Waste Storage Area, shown graphically in Figure 1-5, is addressed under Operable Units 1, 2, and 4. The remaining FEMP site areas consist of forest and pasturelands, a portion on which a nearby dairy farmer is leased to graze livestock.

The following is a brief presentation of the characteristics of the FEMP site and its surrounding environment. Included is a description of the physical, environmental, and demographic settings of the FEMP area. Topics discussed include air quality, climate, topography, seismology, surface water hydrology, geology, groundwater hydrology, soils, land use, population, vegetation, and wildlife. Additional detailed discussion on each of these subjects are available in the RI Report for Operable Unit 4 and the SWCR.

Air Quality

National Ambient Air Quality Standards (NAAQS) are health-protective standards that apply to the six pollutants regulated under the Clean Air Act (CAA) of 1990: inhalable (PM 10) particulates, carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and lead. Extensive monitoring has been performed by the Southwestern Ohio Air Pollution Control Agency (SWOAPCA) in urban locations where the highest concentrations within its four-county jurisdiction (Hamilton, Butler, Warren, and Clermont) are found. With the exception of ozone, pollutant concentrations at the FEMP site meet the NAAQS. Ozone is a widespread problem requiring regional control and abatement measures mandated by the CAA of 1990. Air quality standards for toxic compounds not regulated under the CAA are defined by individual states. The State of Ohio, acting through the SWOAPCA, has established standards for chemically toxic compounds including ammonia, hydrogen fluoride, and nitric acid, all of which have been released from the FEMP site in small amounts. Estimates of the impacts to air quality resulting from releases from the FEMP site have been developed using air dispersion modeling. The results of this modeling, which are supported by site monitoring results, appear to indicate that concentrations of air contaminants attributable to FEMP site operations have been well within limits set by the State of Ohio in recent years.

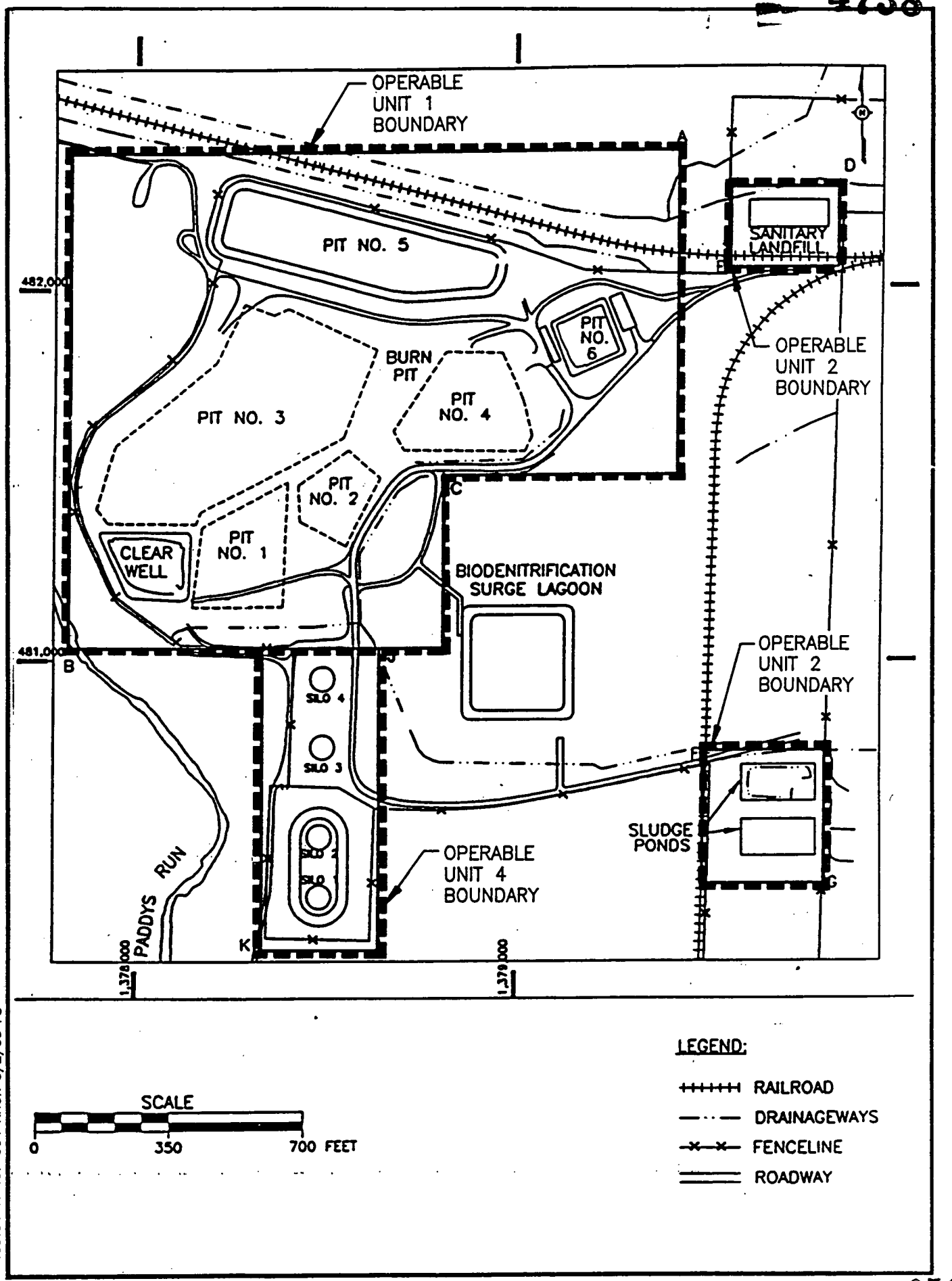

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FIGURE 1-5. WASTE STORAGE AREA

Meteorology

The FEMP has installed and maintains a site meteorological system providing site-specific data for wind speed and direction, ambient air temperature, lapse rate, dew point, temperature, relative humidity, barometric pressure, and precipitation. The system was used by the National Oceanic and Atmospheric Administration (NOAA) to examine the complexity of the local wind field at the FEMP site.

Prevailing winds are generally from the southwest and west-southwest. Compiled wind rose information from the FEMP meteorological tower for the years 1987 through 1992 is available within the RI Report for Operable Unit 4.

As part of the probabilistic risk assessment performed for the FEMP (DOE 1989), an annual probability was assessed for a tornado occurring per square mile within Ohio. Based on data accumulated from Ohio during the years 1978 through 1990, the probability was calculated to be 1.248×10^{-4}.

The average annual precipitation for the Cincinnati area for the period of 1960 through 1989 was 103 centimeters (cm) [40.56 inches (in.)] and ranged from 71.1 cm (27.99 in.) in 1963 to 134 cm (52.76 in.) 1979. The highest precipitation occurs during the spring and early summer. The maximum 24-hour rainfall event of record occurred in March 1964 when 13.2 cm (5.21 in.) fell. Precipitation is typically lowest in late summer and fall.

The average annual snowfall for the 1960 to 1989 period was 59.7 cm (23.5 in.), with the heaviest snowfall usually occurring in January. The maximum monthly snowfall of 80 cm (31.5 in.) occurred in January 1978.

The regional climate is defined as continental, with temperatures ranging from a monthly average of -1.57°C (29.2°F) in January to 24.5°C (75.7°F) in July. The highest temperature recorded from 1960 through 1989 was 39.8°C (103°F) in July 1988, and the lowest was -32°C (-25°F) in January 1977. Average ambient air temperatures measured at the FEMP meteorological station for the years 1987 through 1992 ranged from 10.5°C (50.7°F) to 13.1°C (55.4°F), with the highest annual average daily maximum temperature of 18.5°C (65.1°F) and the lowest annual average daily minimum temperature of 5°C (41°F).

The average number of days per year with a minimum temperature of 0°C (32°F) or less is 109 days, and the average number of days per year with a maximum temperature of 32°C (90°F) or greater is 20 days. Frost depth ranges from 76.2 to 91.4 cm (30 to 36 in.).

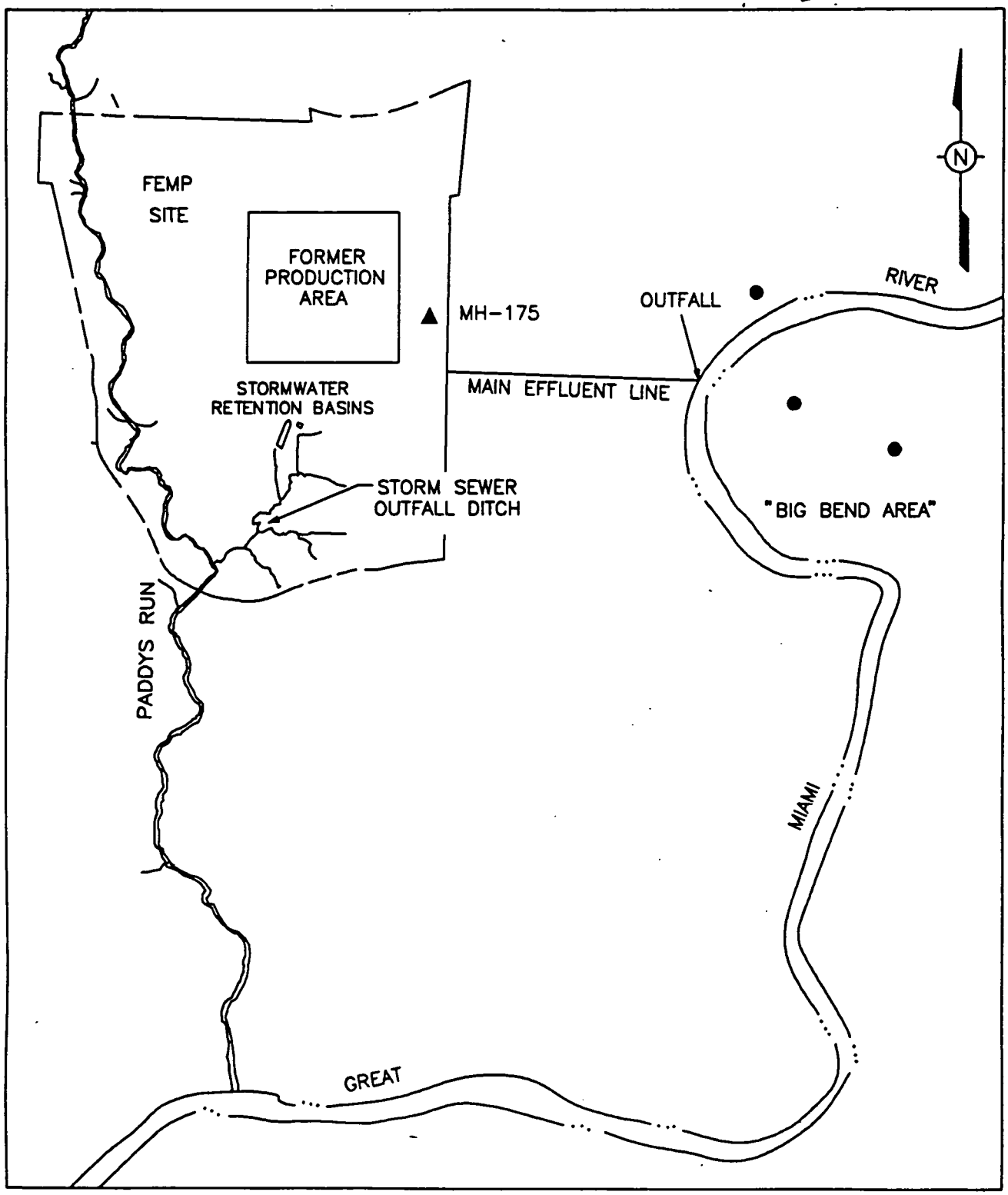
Topography and Surface Water

Maximum elevation along the northern boundary of the FEMP property is a little more than 213 meters (m) [700 feet (ft)] above mean sea level (MSL). The former Production Area and Waste Storage Area rest on a relatively level plain at about 177 m (580 ft) above MSL. The plain slopes from 183 m (600 ft) above MSL along the eastern boundary of the FEMP site to 174 m (570 ft) above MSL at the K-65 Silos, and then drops off toward Paddys Run at an elevation of 168 m (550 ft) above MSL. All drainage, including surface water, on the FEMP site is generally from east to west into Paddys Run, with the exception of the extreme northeast corner, which drains east toward the Great Miami River (Figure 1-6).

Surface waters on and adjacent to the FEMP site are the Storm Sewer Outfall Ditch, Paddys Run, and the Great Miami River. The Storm Sewer Outfall Ditch originates within the FEMP site and flows toward the southwest where it enters Paddys Run, which flows southward along the western boundary of the facility. Paddys Run, in turn, is a tributary of the Great Miami River. The Great Miami River flows generally toward the southwest; however, locally it flows to the east and south of the FEMP site.

Paddys Run originates north of the FEMP site, flows southward along the western boundary of the facility, and enters the Great Miami River approximately 2.4 km (1.5 mi) south of the southwest corner of the FEMP property. The stream is approximately 14 km (8.8 mi) long and drains an area of approximately 40.9 square kilometers (km^2) [15.8 square miles (mi^2)]. Due to the highly permeable channel bottom, the stream loses water to the underlying Great Miami Aquifer. In addition, the stream is intermittent and is generally dry during the summer months.

Paddys Run is a steep-sided stream, and its banks erode severely during high flow periods. In 1961 and 1962, the course of the stream was altered to prevent it from eroding into the Operable Unit 1 Study Area [Westinghouse Materials Company of Ohio (WMCO) 1987]. In 1970, a reach of the stream south of the K-65 Silos was straightened to prevent erosion of Paddys Run Road. The stream is ungauged, but typical flows from January through May and range from 0.2 to 4.0 cubic feet per second (ft^3/s) [5.7 to 113 liters/second (L/s)]. Channel overflow resulting from 25-year, 24-hour and



LEGEND:

● SOUTHWESTERN OHIO WATER COMPANY WELL FIELD

▲ MANHOLE

SCALE

0 1000 2000 FEET

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FIGURE 1-6. SURFACE WATER HYDROLOGY

100-year, 24-hour storm events is possible, but peak flows occurring during storm events have not been measured.

The Great Miami River is the main surface water feature in the vicinity of the FEMP site and is the receiving water from a National Pollutant Discharge Elimination System (NPDES)-permitted discharge from the FEMP site. The river flows generally to the southwest and has a drainage area of approximately 8702 km^2 (3360 mi^2) at the Hamilton gauge, which is located about 16.1 km (10 mi) upstream from the FEMP site discharge outfall.

The river exhibits meandering patterns that result in sharp directional changes over distances of less than 900 m (3000 ft). Directly east of the FEMP site and within the site-wide RI/FS Study Area, the river passes through a 180-degree curve known as the Big Bend. A 90-degree bend in the river also occurs near New Baltimore, approximately 3.2 km (2 mi) downstream from the FEMP site discharge outfall.

Soils and Seismology

The Butler County and Hamilton County Soil Surveys [U.S. Department of Agriculture (USDA) 1980, 1982] have 15 specific soil series or types mapped within FEMP site boundaries. The major series are Fincastle and Xenia silt loams, which also cover large areas west of the FEMP. These soils are moderately high in productivity when properly managed. Moisture-supplying capacity is moderate, as is fertility and organic content.

The Fincastle series consists of deep, nearly level, somewhat poorly drained soils on broad flats. Permeability is low and the available water capacity is high. These soils are associated with the former Production Area and with the pastures to the east and west of the facility. The Xenia soil series is a deep, nearly level, moderately well-drained soil located on till plains. Permeability is moderately low, available water capacity is high, and the runoff potential is low.

A seismic risk zone of two (on a scale of less-than-one to four), a measurement of earthquake intensity, has been assigned to the region of the FEMP site.

Geology and Groundwater

The following discussion provides a summary of the physiography, geologic history, and hydrogeological setting of the area surrounding the FEMP site.

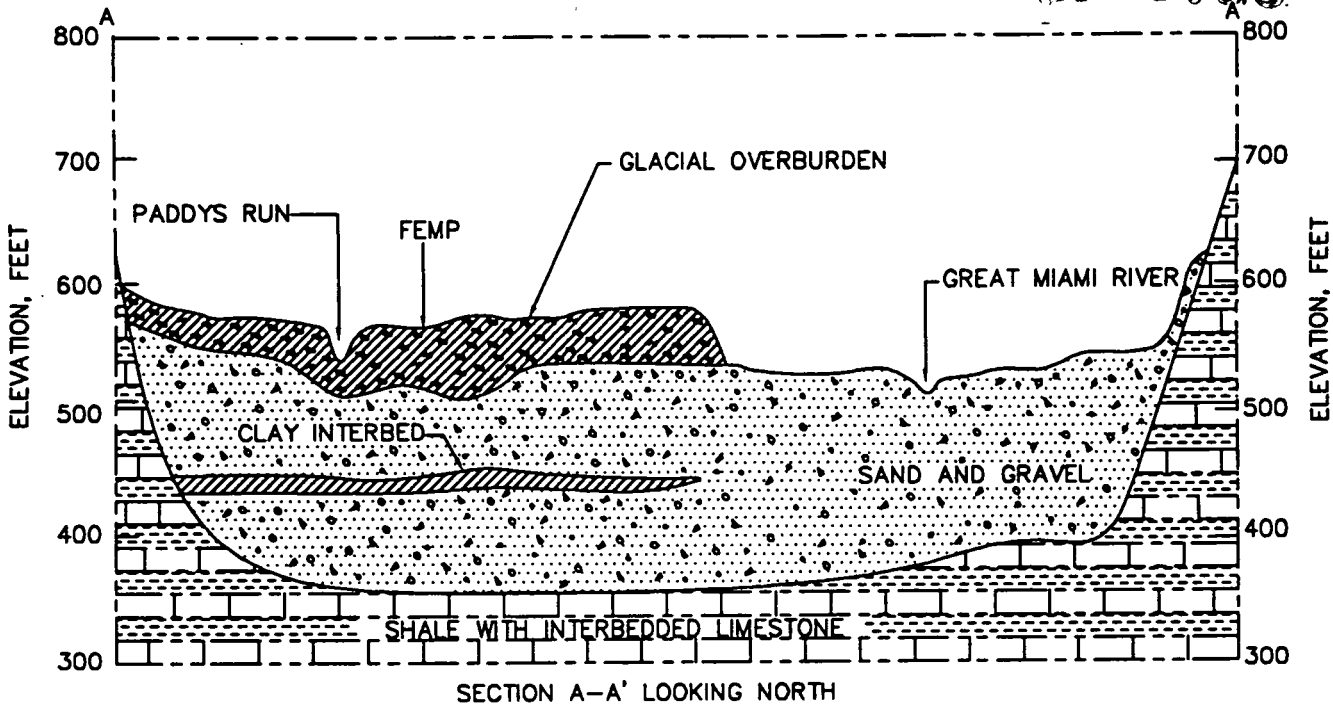
Physiography. The FEMP site lies in the Till Plains section of the Central Lowland physiographic province, characterized by structural and sedimentary basins and domes. The main physiographic features in the area are gently rolling uplands, steep hillsides along the major streams, and the Great Miami River Valley. This valley is a relatively broad, flat-bottomed valley flanked on either side by bluffs that rise to a maximum of 90 m (300 ft) above the general level of the valley floor.

Geologic History. In summary, the FEMP overlies a 3.2- to 5.6-km (2- to 3-mi) wide buried Pleistocene valley known as the New Haven Trough. This valley was formed (eroded) by the ancestral Ohio River during the Pleistocene period and was subsequently filled with glacial outwash materials that were in turn covered by glacial overburden as glaciers advanced across the area. The outwash deposits under the FEMP are a part of the Great Miami Aquifer, which is a widely distributed buried valley aquifer. In addition to surface water, the valley fill aquifer system is the major source of drinking water in the southwestern Ohio area.

Since the last retreat of continental glaciers, the streams in the area have removed much of the glacial overburden and lacustrine strata left by the ice sheets. The Great Miami River has eroded through the glacial overburden and is now in direct contact with the glaciofluvial outwash deposits that comprise the Great Miami Aquifer. Paddys Run is also in contact with these deposits in its lower reaches. The FEMP site is located on a dissected glacial overburden plain left by the Wisconsin Glaciation.

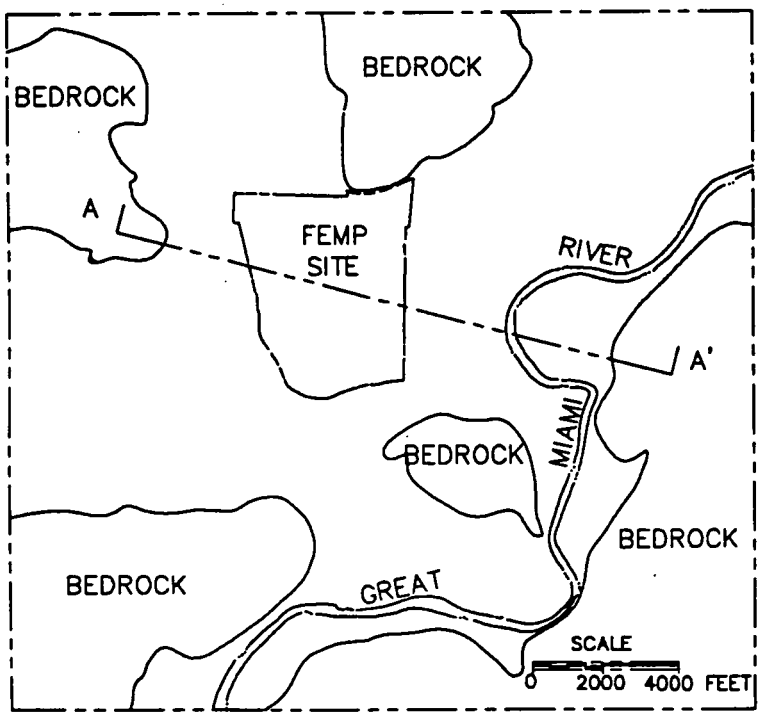
Site-Wide Hydrogeology. The Great Miami Aquifer is the principal aquifer within the FEMP Study Area and has been designated a sole source aquifer under the provisions of the Safe Drinking Water Act (SDWA). The buried valley in which it occurs varies in width from about 0.8 km (0.5 mi) to more than 3.2 km (2 mi), having a U-shaped cross section with a broad, relatively flat bottom, and steep valley walls (Figure 1-7). This valley is filled with extensive deposits of sand and gravel that range in thickness from 36 to 60 m (120 to 200 ft) in the valley to only several feet along the valley walls, along the scattered silt and clay deposits.

Contained within the sand and gravel that underlies much of the FEMP property is a relatively continuous, low-permeability clay interbed ranging from about 1.5 to 4.5 m (5 to 15 ft) in thickness. The clay interbed occurs at an approximate elevation of 140 m (460 ft), and where present, divides the aquifer into upper and lower sand and gravel units, referred to as the Upper Great Miami Aquifer and the Lower Great Miami Aquifer.



NOTES:

HORIZONTAL SCALE IS APPROXIMATELY 1" = 2500'



LOCATION OF CROSS SECTION

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FIGURE 1–7. SCHEMATIC CROSS SECTION OF BURIED CHANNEL AQUIFER

Large groundwater supplies occur in the sand and gravel deposits, allowing the aquifer to yield a considerable amount of water. In areas where the aquifer is 45 to 60 m (150 to 200 ft) thick or more and induced stream infiltration is available, water supply wells in the Great Miami Aquifer are the most productive; individual wells can yield 11,355 liters per minute (L/min) [3000 gallons per minute (gpm)] or more in these areas (Spieker 1968). In areas where the aquifer is capped by glacial till, subdivided by the clay interlayer, and induced stream recharge is not available, wells generally yield 379 to 1893 L/min (100 to 500 gpm), though wells of 3785 L/min (1000 gpm) are not uncommon. The bedrock outside the buried valleys has a lower hydraulic conductivity, and bedrock well yields are generally less than 38 L/min (10 gpm) (Spieker 1968).

Hydrogeology of the Glacial Overburden. Overlying the Great Miami Aquifer throughout most of the FEMP property are a series of glacial overburden deposits. The glacial overburden is composed primarily of till, a dense, silty clay that contains discontinuous and isolated lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt. Lacustrine deposits lie upon till in working places. The lacustrine deposits have at least one, and possibly more, laterally extensive permeable sand/silt strata. The glacial overburden exposed at the surface has relatively low permeability, so most of the precipitation that falls on it is lost to evaporation and surface water runoff. Limited infiltration occurs along the upper weathered portion of the overburden and in isolated areas where more permeable deposits of silt, sand, and gravel are the primary overburden constituents. The thickness of the glacial overburden ranges from 1.5 to 15 m (5 to 50 ft) within the FEMP Study Area, but most commonly averages between 6 and 9 m (20 and 30 ft). Except for some scattered deposits, this overburden does not exist along the floodplain of the Great Miami River to the east and south of the FEMP site. The only on-property areas that lack overburden are certain reaches of Paddys Run and the Storm Sewer Outfall Ditch where this material has been eroded away. These streams are in direct contact with the upper portion of the Great Miami Aquifer along these reaches, allowing surface water leakage directly to the aquifer.

Erratically distributed pockets of silty sand and gravel within the glacial overburden contain zones of perched groundwater. Perched groundwater is separated from the underlying aquifer by the surrounding relatively impermeable clay and silt components of the overburden. These low-permeability units behave as an aquitard that can store groundwater but transmit it slowly downward from one more porous saturated zone to another. Depth to perched groundwater at the FEMP site ranges from 0.3 to 4.5 m (1 to 15 ft) below the land surface. This measurement can fluctuate

seasonally by up to 3 m (10 ft) at a single location, with the highest water levels occurring during the early spring and the lowest during the late fall.

In the K-65 Silos area, sand and gravel outwash deposits of the buried valley are overlain by 1.5 to 3 m (5 to 10 ft) of till that is in turn overlain by 4.5 to 6 m (15 to 20 ft) of lacustrine sediments. The till is an unsorted mixture of clay, silt, sand and pebble to cobble size material with 70 to 80 percent of the material falling in the clay and silt size range. The till contains sparse, thin, and discontinuous lenses of sand and gravel.

The lacustrine strata consists of a 5- to 10-foot thick coarse-grain stratum that is overlain by clay and silt. The coarse grain stratum is part of a widespread glacial outwash unit that is found at the base of lacustrine strata throughout the northern half of the filled lacustrine basin. The coarse grain unit was deposited by streams and debris flows that entered the basin from the north. The unit comprises clayey silt, silt, sands with appreciable fine fractions, and clean sands with silty/clayey sand being the dominant lithology. Strata that overlie the outwash unit were deposited by lower energy depositional lacustrine processes. The low-energy lacustrine sediment consists of clay, silty clay, clayey silt, silt and fine sand with silty clay the dominant lithology. A loess cap probably overlies the lacustrine strata; however, it cannot be readily distinguished from the low-energy lacustrine deposits using the USC soil description/classification methods used during the RI/FS. Elsewhere on the site, where the loess cap can be distinguished, loess is a clayey silt approximately 3 feet think.

The conceptual model for groundwater flow in the glacial overburden is that the lacustrine strata has good, but slow, hydraulic communication and that the till that underlies the lacustrine strata acts as an aquitard. Groundwater within the approximately 6 m (20 ft) of lacustrine strata is predicted to flow at a lateral rate that is significantly greater than its downward rate. Therefore, groundwater is likely discharging westward to the bank of Paddys Run and southward in the east-west drainageway immediately south of Silo 1.

Hydrogeology of the Great Miami Aquifer. The principal sources of aquifer recharge in the FEMP Study Area are direct precipitation and stream infiltration. Infiltration of rainfall and snowmelt is the dominant regional source of groundwater recharge, providing approximately 2,157,450 liters per day (L/day) per km^2 [570,000 gallons per day (gpd) per mi^2], or roughly 30.5 centimeters (cm) (12 in. per year) to the water table of the aquifer (Dove 1961). Much of the precipitation that runs off the glacial overburden on the FEMP property enters Paddys Run and the Storm Sewer Outfall Ditch, both

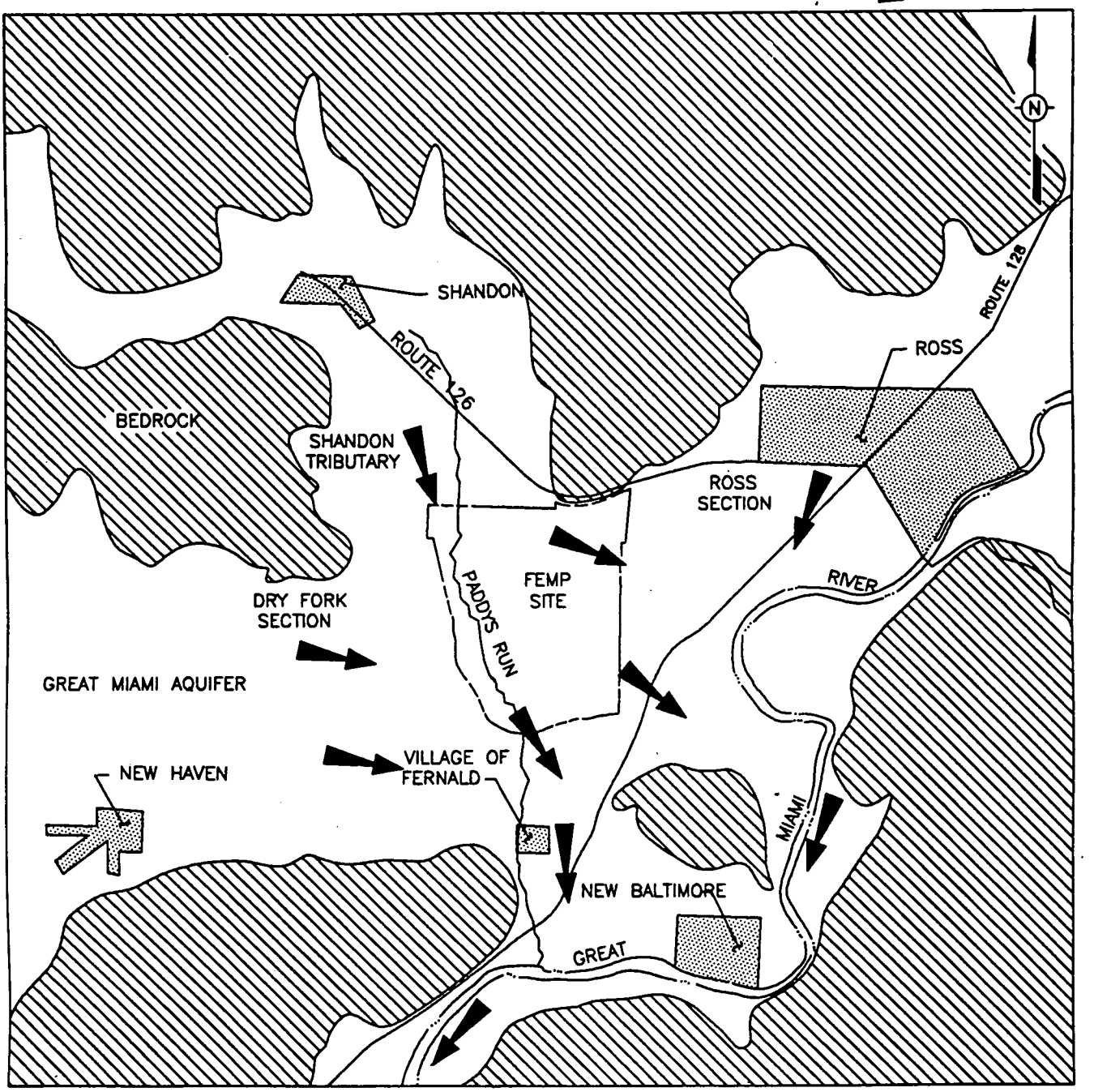
of which are subject to leakage directly to the aquifer along portions of their length. These streams are intermittent and provide recharge on a seasonal basis. The pumping of the Southwestern Ohio Water Company (SOWC) supply wells, located at the Big Bend meander of the Great Miami River east of the FEMP site, causes a portion of the surface water to infiltrate through the bed of the river and recharge the aquifer. In areas of the river not influenced by the pumping wells, groundwater 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 from groundwater occurring in bedrock is limited due to its low permeability. However, erratically distributed joints and cracks allow small amounts of water to seep into the aquifer.

The generalized groundwater flow in the Great Miami Aquifer is shown in Figure 1-8. Groundwater enters the FEMP Study Area from three separate flow systems: the Dry Fork Section of the New Haven Trough to the west, the Shandon Tributary to the north, and the Ross Section of the New Haven Trough to the northeast. Natural gradients cause the groundwater to exit the FEMP Study Area either by flowing east to the Great Miami River, upstream from New Baltimore, or south through the branch of the bedrock channel west of New Baltimore. The Great Miami River is the ultimate receptor of all groundwater in the FEMP Study Area.

Population and Land Use

The land adjacent to the FEMP is primarily devoted to open land use such as agriculture and recreation. Commercial activity is generally restricted to the village of Ross, approximately 4.8 km (3 mi) northeast of the facility, and along State Route 128 just south of the village. More than 160 ha (400 acres) of the open land on the FEMP site are leased to a nearby dairy farmer who allows livestock to graze on the property. Pine plantations are located to the northeast and southwest of the former Production Area. A considerable amount of the soils within the boundaries of the FEMP site are designated by the USDA as prime agricultural land (USDA 1980, 1982). Because the area had been intensively used for agricultural purposes prior to the establishment of the FEMP site, there is no land on or in the vicinity of the FEMP site where a predevelopment natural environment remains intact. The land closest to the description is the recreated prairie lands on the Miami Whitewater Forest property, located several miles south of the FEMP site.

The area surrounding the FEMP site has a large and diverse archaeological and historical resource base. According to records kept by the Miami Purchase Association for Historic Preservation, an unusually high percentage of the existing 19th century buildings in the area are historically important.



SCALE

0 2500 5000 FEET

NOTE:

DIRECTION OF GROUNDWATER FLOW BASED ON APRIL 1986 WATER LEVEL CONTOURS AND GROUNDWATER MODELING OUTPUT (3DPART07.OUT)

LEGEND:

GENERALIZED GROUNDWATER FLOW DIRECTION.

BEDROCK OUTSIDE GREAT MIAMI AQUIFER

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FIGURE 1-8. GENERALIZED GROUNDWATER FLOW IN BURIED CHANNEL AQUIFER

Within the vicinity of the FEMP site [a 3.2-km (2-mi) radius from the boundary] there are three properties listed in the National Register of Historic Places (NRHP) and a number of additional structures that have been judged eligible for inclusion in the listing. Six major archaeological sites lie within 8 km (5 mi) of the FEMP and five of these are included in the NRHP.

Ecology

This section describes the regional ecology, ecological communities on the FEMP site, the floodplains and wetlands, and threatened and endangered species at the FEMP site.

Regional Ecology. The FEMP site and surrounding areas lie in a transition zone between two distinct sections of the Eastern Deciduous Forest Province as described by Bailey (1978): the Oak-Hickory and the Beech-Maple. The region is characterized by the presence of a mosaic of these forest types. The Oak-Hickory and Beech-Maple forest sections share many characteristics, including similar fauna and the presence of white oak as a common species. The Beech-Maple section covers northern Ohio, Indiana, and lower Michigan. It is bordered by Oak-Hickory to the southwest, Mixed Mesophytic to the southeast, and Appalachian oak to the east. Beech-Maple forests are typically dominated by beech trees in the canopy, the uppermost layer of the forest, with sugar maples dominant in the understory, below the canopy. The Oak-Hickory section covers southwest Ohio, western Kentucky and Tennessee, and parts of Indiana, Illinois, Missouri, and Arkansas.

The dominant species are oaks, with an abundance of hickories. The fauna vary little between the two forest sections and include white-tailed deer, gray fox, gray squirrel, white-footed mouse, and short-tailed shrew; the cardinal, woodthrush, summer tanager, red-eyed vireo, and the hooded warbler; the box turtle, common garter snake, and timber rattlesnake (Bailey 1978; Shelford 1963).

Ecological Communities on the FEMP Site. Ecological communities on the FEMP site consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and the "reclaimed flyash pile area." The reclaimed flyash pile area coincides approximately with the South Field and the Inactive Flyash Pile, and it was considered a distinct habitat by Facemire et al. (1990) due to the unique plant and animal species composition. 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 inhabit the FEMP site.

Typical grasses found on the FEMP site 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 and Austrian pine, with Norway spruce occurring occasionally. Common trees in the deciduous woodlands are white ash, American elm, shagbark 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 site 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. In addition, the eastern screech owl and great horned owl have been observed in the vicinity of the FEMP site.

Amphibians and reptiles that occur on the FEMP site 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 site habitats. Leaf hoppers are abundant in all habitats, while less abundant groups include short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

Floodplains and Wetlands. Floodplains within the FEMP property are confined to the north-south corridor containing Paddys Run. Outside the boundaries of the FEMP site, the 100-year floodplain of the Great Miami River extends west of the Big Bend area nearly to the eastern boundary of the facility (Figure 1-9). The 100-year floodplain of the river also extends northward along Paddys Run from the confluence of the two streams to a point about 180 m (600 ft) from the southern boundary of

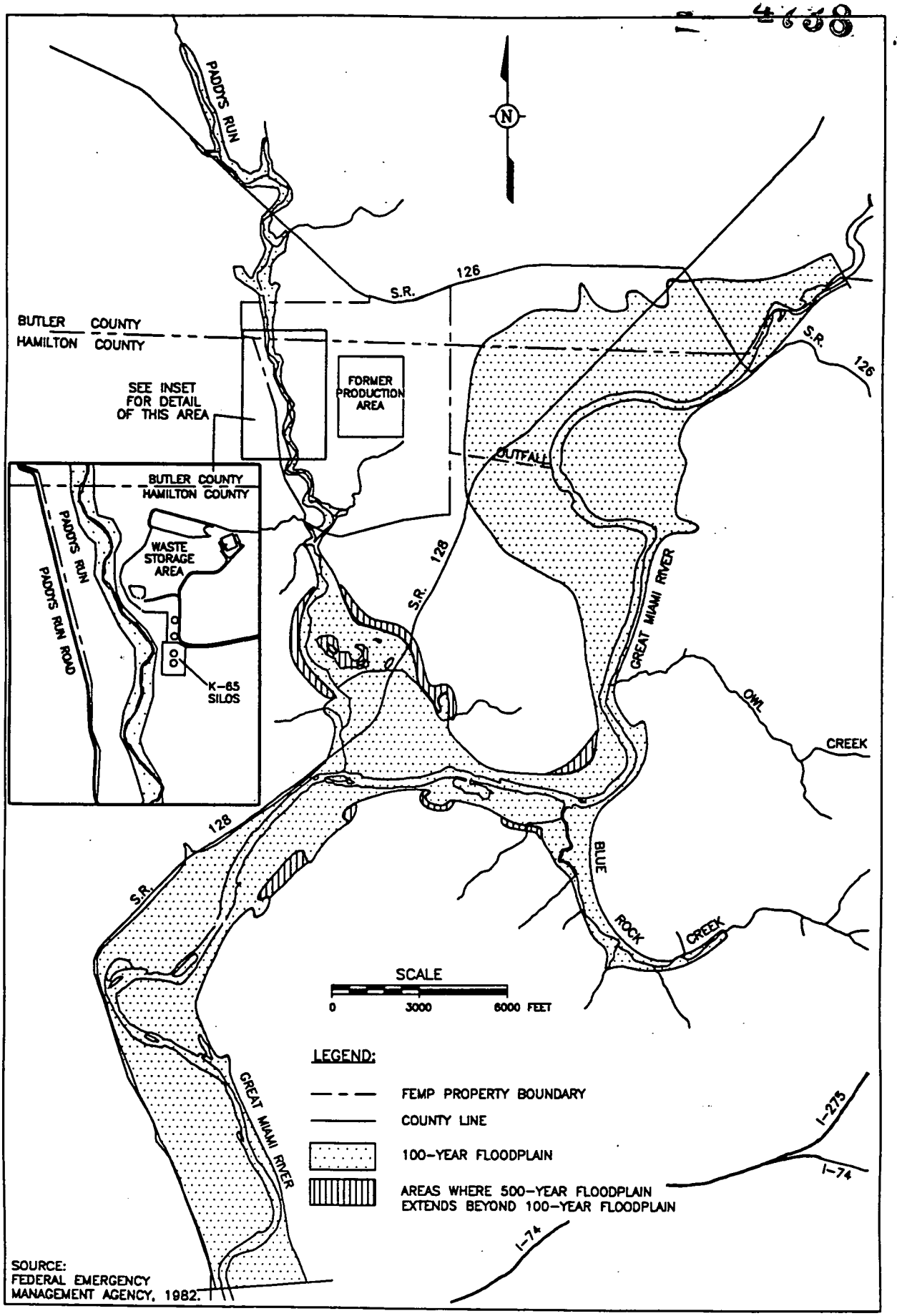


FIGURE 1-9. GREAT MIAMI RIVER AND PADDYS RUN 100-YEAR AND 500-YEAR FLOODPLAIN

the FEMP site. This area overlaps the South Plume, a body of uranium-contaminated groundwater that is a component of Operable Unit 5.

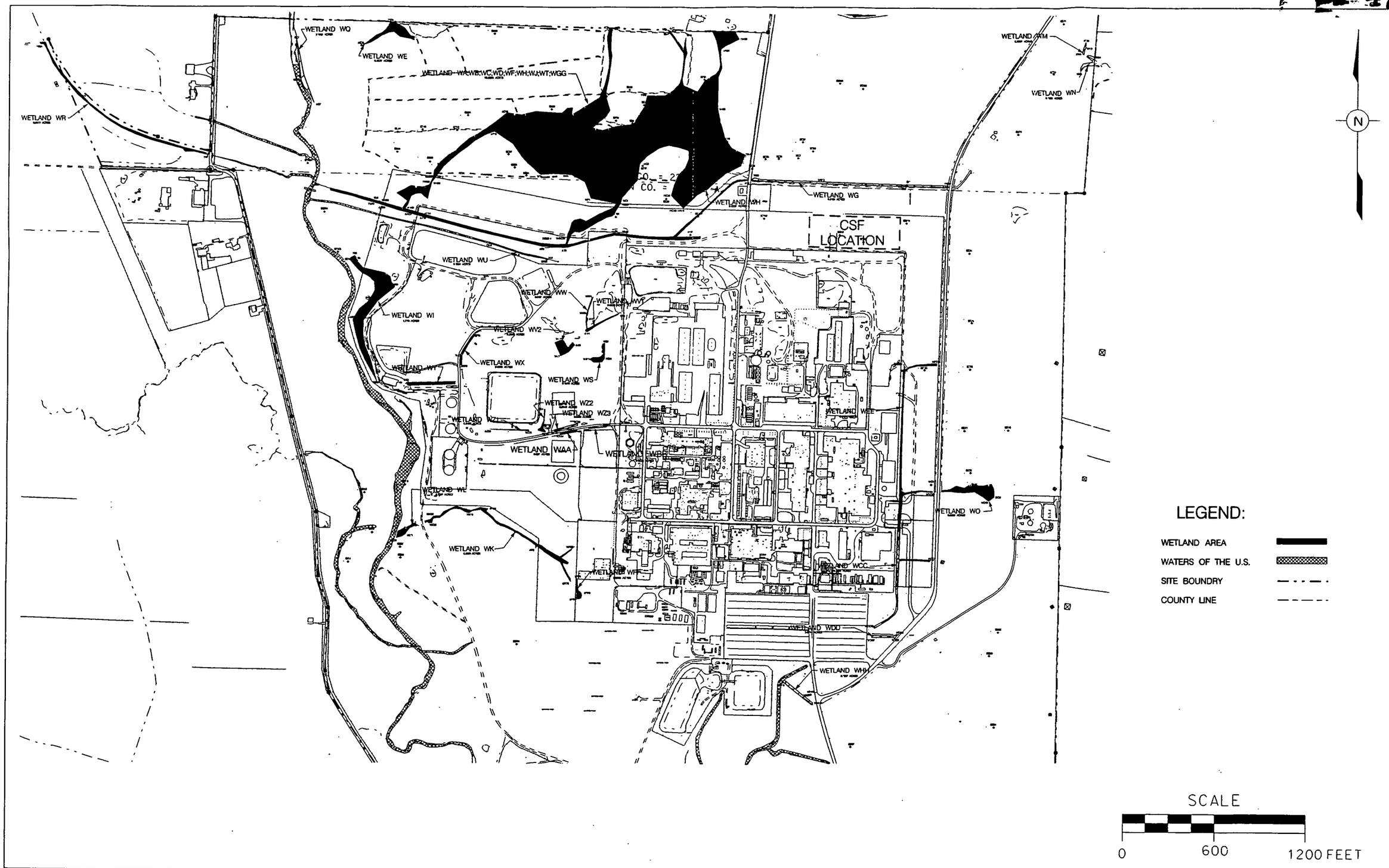
A site-wide wetland delineation was conducted in February 1993 in accordance with the 1987 Army Corps of Engineers (COE) Wetlands Delineation Manual. The purpose of the delineation was to determine the extent of jurisdictional wetlands and waters of the United States and to avoid or minimize impacts to these resources during future activities at the FEMP site. A jurisdictional determination has been requested from the COE to verify the wetland boundaries and waters of the United States. Preliminary results from the site-wide delineation as shown in Figure 1-10, subject to COE approval, indicate a total of 14.4 ha (35.9 acres) of wetlands that include 10.63 ha (26.58 acres) of palustrine forested wetlands, 2.78 ha (6.95 acres) of drainage ditches/swales, and 0.95 ha (2.37 acres) of isolated emergent and emergent-scrub/shrub wetlands.

The largest of the four palustrine forested wetland areas is located north of the former Production Area. The remaining three areas are located: (1) along the east bank of Paddys Run near the northern site border, (2) on the northeast corner of the site, and (3) southwest of the K-65 Silos. Drainage ditches and swales are located in four sections throughout the site: (1) north of the former Production Area traversing west into Paddys Run, (2) drainage of the Waste Pit Area, (3) drainage of the area south of the K-65 Silos, and (4) adjacent to the east boundary of the former Production Area, draining higher elevations of the site to the east.

Two of the four isolated scrub/shrub and/or emergent wetlands are located in the northern part of the site: one near the eastern corner and the other just east of Paddys Run, near the western corner of the site. The remaining two are located in the vicinity of the Waste Pit Area, one to the east and one to the west.

On-property waters of the United States are confined to Paddys Run and its unnamed tributary and total approximately 3.6 ha (8.9 acres).

Threatened and Endangered Species. Potential remedial actions at the FEMP site must comply with the substantive requirements of the Endangered Species Act (ESA) of 1973. To comply with Section 7(a)(2) of the ESA of 1973, as amended, requiring federal agencies "...in consultation with and with the assistance of..." the Secretaries of the Interior and Commerce, to ensure that their actions are "...not likely to jeopardize the continued existence of any endangered species or threatened species or



WETLANDS/RES NO.2227-11x17-FIG1-10.DGN-CRU#4
FERMCO/ENGCAD/REVISON.#0-8/10/93

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DATE-Aug. 10, 1993

FIGURE 1-10 APPROXIMATE BOUNDARIES OF JURISDICTIONAL WETLANDS AT FEMP.

066

result in the destruction or adverse modification of the critical habitat of such species...", Miami University performed an Ecological Characterization Study of the FEMP in 1989. The following discussion concerning threatened and endangered species with potential habitats in the vicinity of the FEMP were drawn from that study as well as from supplemental investigations conducted as part of the Operable Unit 4 RI.

Indiana Bat (*Myotis sodalis*). The Indiana bat is listed as both a federal and state endangered species and occurs in Butler and Hamilton Counties. Surveys were conducted 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 has not been identified at the FEMP, but during the summer of 1988, a population was identified approximately 4.8 km (3.0 mi) northeast of the FEMP on Banklick Creek, a tributary of the Great Miami River (Facemire et al. 1990). Potential habitat for the Indiana bat occurs in portions of the riparian woodland associated with Paddys Run.

Cave Salamander (*Eurycea lucifuga*). The cave salamander, a state listed endangered species, has not been identified at the FEMP site. During the summer of 1988, a population was identified 1.6 km (1.0 mi) northeast of the FEMP at the Ross Trails Girl Scout Camp. Potential habitat occurs along Paddys Run (Facemire et al. 1990).

Others. The northern waterthrush (*Seivrus Noveboraceusis*), a state listed endangered species, was reported as a spring migrant along Paddys Run during the Spring of 1987 by Facemire et al.. The northern harrier (*Circus Yaneus*), a state listed endangered species, and the red-shouldered hawk (*Buteo Lineatus*), a state listed threatened species, were observed flying over the FEMP by Facemire et al. on two separate occasions. Neither species has been reported to nest at the FEMP site. Slender finger-grass (*Digitaria Filiformis*) and mountain bindweed (*Palyganum Cilinode*) are state listed endangered species recorded in low densities along Paddys Run and in the northern pine planation by Facemire et al.. The dark-eyed junco (*Junco Ayemalis*), a state listed endangered species, was observed throughout the FEMP during the winter of 1986 and 1987 by Facemire et al.. Running Buffalo Clover (*Trifolium Stoloniferum*), a state and federally listed endangered species, has not been identified at the FEMP. A population was identified less than 8.0 km (5.0 mi) southwest of the FEMP at Miami Whitewater Forest. Potential habitat exists in introduced grassland areas, and riparian and deciduous woodlands on the FEMP site. Sloan's crayfish (*Orconectes Sloanii*), also known as the Cincinnati crayfish, is a state listed threatened species reported from Paddys Run by Facemire et al.. One individual of this genus, not identified to species, was recorded in Paddys Run

during RI/FS sampling (DOE 1992b). The cobblestone tiger beetle (*Cicendela Margipennis*), which is under review by the U.S. Fish and Wildlife Service for possible consideration as a threatened or endangered species, was found on a gravel bar in the Great Miami River 3.2 km (2.0 mi) southwest of the bridge at New Baltimore, Ohio.

1.4.2 Description of Operable Unit 4

Operable Unit 4 is a geographic area located on the western side of the FEMP, south of the Operable Unit 1 Study Area (Figure 1-2). The geographic area constituting Operable Unit 4 is bounded by the following Ohio State Plane Coordinates: North 481033, East 1378642, and North 480222, East 1378329. Operable Unit 4 comprises 2.3 ha (5.8 acres). Within the boundary of the operable unit is a series of FEMP facilities previously defined in the introduction. The following is a summary description of each of these facilities.

1.4.2.1 Silos 1, 2, 3, and 4 and the Decant Sump Tank

The waste storage silos were constructed to provide storage for the residues resulting from the processing of pitchblende ores and uranium concentrates to extract their uranium content. The silos are large concrete storage structures that were built in 1951 and 1952. Each of the four domed silos is 24.38 m (80 ft) in diameter, 10.97 m (36 ft) high to the center of the silo dome, and 8.15 m (26.75 ft) tall to the top of the vertical side walls.

The side walls are 20-cm (8-in.) thick concrete wrapped with steel post-tensioning wires. The silo sides are covered with a 1.9-cm (0.75-in.) thick layer of gunite. The domed roofs are made of reinforced concrete and taper from 20-cm (8-in.) thick at the silo walls to 10-cm (4-in.) thick at the dome's center. The floors of Silos 1, 2, 3, and 4 consist of 10 cm (4 in.) of reinforced concrete. Residues were originally transferred to Silos 1 and 2 by pumping the residues in the form of a slurry. The residues eventually settled and formed two layers consisting of settled solids covered by the slurry liquid. To remove the layer of clear liquid following settling, Silos 1 and 2 were equipped with a series of decant ports. Silos 3 and 4 were also equipped with decant ports; however, the structures were not designed to accommodate slurried residues. These ports were arranged in two vertical lines located on diametrically opposed sides of each silo. There were 25 ports in each line, totaling 50 ports per silo. The bottom port on each silo is 30 cm (12 in.) from the silo bottom. The remaining 49 ports are located at 15-cm (6-in.) intervals.

At the time of filling, each decant port for Silos 1 and 2 were valved into a single pipe that led to a 34,065 liter (L) [9000-gallon (gal.)] carbon steel decant sump tank. The decant sump tank was located between Silos 1 and 2 at a level below the base of the silos to allow for gravity drainage. At the base of Silos 1 and 2, at the original ground surface, skirt drains were used to contain any seepage through the walls of the silos or leakage from the decant ports. These skirt drains directed any collected water through a concrete pipe trench to an in-ground concrete-lined sump location on the K-65 Drum Handling Building, formerly located between Silos 2 and 3.

Beneath the floor of Silos 1 and 2 is an underdrain system which consists of a 5-cm (2-in.) slotted pipe in a 20-cm (8-in.) gravel layer. The gravel layer is underlain by a 5-cm (2-in.) thick layer of asphaltic concrete followed by a 43-cm (17-in.) thick layer of compacted clay. The underdrain system is connected to the decant sump tank to collect any potential leakage through the base of the silos.

Large areas of spalling occurred on the exterior surface coating of Silos 1 and 2, particularly Silo 2, leaving post-tensioning wires corroded and exposed to weather. The exterior surfaces were patched with a 1.9-cm (0.75-in.) thick coat of cement mortar and a waterproof membrane that was applied in 1964.

In January 1986, two load-spreading dome covers, 9.1 m (30 ft) in diameter, were installed to span a deteriorated portion of the concrete domes of Silos 1 and 2. The covers are self-supporting and sit on a rolled plate-steel skirt. The covers are composed of structural steel members that support 1.9-cm (0.75-in) thick plywood sheeting, which is covered with a weatherproof membrane. The dome cover increases the stresses in the existing concrete, but all stresses are outside the deteriorated area and within acceptable limits. The dome covers were installed so that containment of the silos' contents would be maintained in the event of a center-silo dome collapse (Shanks and Vogel 1988). The dome covers were not designed to be airtight, and therefore do not contain the movement of gases such as radon.

Silo 1 contains 3280 cubic meters (m^3) [115,900 cubic ft (ft^3)] of waste residues and 360 m^3 (12,600 ft^3) of bentonite clay. Silo 2 contains 2840 m^3 (100,400 ft^3) of waste residues and 310 m^3 (11,100 ft^3) of bentonite clay. Silo 3 contains 3890 m^3 (137,500 ft^3) of waste materials. Silo 4 is empty and has never been used for material storage.

1.4.2.2 Radon Treatment System

An existing radon treatment system (RTS) was constructed in 1987 within Operable Unit 4 to support planned interim remedial measure (IRMs), including placement of the dome covers and waterproofing of the domes, for the K-65 Silos. The RTS is approximately 6.5 square meters (m^2) [70 square ft (ft^2)] of pre-engineered aluminum clad building that contains two calcium drier canisters, eight charcoal adsorption canisters, and two fan units, with a 0.8-m (32-in.) thick concrete block wall surrounding the frame of the structure. Also associated with the RTS are multiple lengths of 30-cm (12-in.) diameter polyvinyl chloride (PVC) pipe, a 15-cm (6-in.) diameter flexible hose, and miscellaneous fittings and valves.

1.4.2.3 Concrete Pipe Trench and Miscellaneous Structures

A concrete trench that contained the piping used to transfer residues to Silos 2 and 3 runs 530 m (1750 ft) from the FEMP refinery (Plant 2/3) to the silo storage area. A portion of the concrete trench, as shown in Figure 1-2, resides within the geographical boundaries of Operable Unit 4. The trench is 0.75 m (2.5 ft) by 0.9 m (3 ft) deep with a 0.5-cm (3/16-in.) thick steel plate cover. The piping within the pipe trench was removed prior to placement of the earthen embankment.

Additionally, within the Operable Unit 4 boundary are two concrete structures associated with former K-65 Silos operational facilities. A structure called the K-65 Drum Handling Building was located between Silos 2 and 3 until it was demolished in 1983. While the above-grade structure was demolished and removed, the concrete slab on grade remains within the boundary of Operable Unit 4.

Also associated with the operation of the K-65 Silos was a concrete lift station used to house the pump for the transfer of decant liquids from the decant sump tank to a hold tank in the K-65 Drum Handling Building (Figure 1-2). The concrete foundation associated with the structure remains within the Operable Unit 4 boundary.

1.4.2.4 K-65 Silo Berms

In 1964, an earthen embankment was built surrounding the top of the walls of Silos 1 and 2 to provide relief from tensile stress that had developed within the walls. The embankment was also constructed to provide weather protection, reduce radon emissions, and increase shielding from penetrating radiation. The embankment was originally constructed on a slope of 1.5:1. The slope was subsequently modified to 3:1 in 1983 to reduce soil erosion and facilitate grass cutting.

Prior to berming the silos in 1964, the decant sump system was disconnected from the decant sump tank, but the underdrain system remained intact. The decant sump system collected any leakage into the underdrain system. Access was provided to this decant sump tank by placing an 0.8-m (30-in.) diameter corrugated metal pipe from the tank to above the surface of the soil embankment. This pipe extended upward 10 m (33 ft). The earthen berm was placed around this pipe as the berm was built around the silos.

The soils comprising the earthen berm constructed in 1964 were surface soils and underlying clays removed from an area directly south of the concrete trench and north of a small drainage ditch running parallel to the trench. The soils comprising the earthen berm constructed in 1983 originated from two on-site areas: 1) from the location of the Biodenitrification Surge Lagoon and 2) from a borrow area west of Pit 5. No surveys were performed to determine the potential presence of radiological contamination by site personnel of these soils before excavation and placement in the berms.

1.4.3 Site History

The primary mission of the FEMP site during its 37 years of operation was the processing of "feed" materials to produce high-purity uranium metal, thus the derivation of the site's original title, the Feed Materials Production Center. These high-purity uranium metal products were then shipped to other DOE facilities for use in the nation's ongoing weapons program. A graphic depiction of the FEMP's integration with other DOE facilities is presented in Figure 1-11.

The Atomic Energy Commission (AEC), predecessor to the U.S. Energy Research and Development Administration (ERDA) and then DOE, established the FMPC in conformance with AEC orders in the early 1950s. In 1951, National Lead Company of Ohio, (NLO) Inc., entered into a contract with the AEC as the Operations and Management Contractor for the facility. This contractual relationship lasted, first with the AEC and finally with DOE, until January 1, 1986. Westinghouse Management Company of Ohio (WMCO), a wholly-owned subsidiary of Westinghouse Electric Corporation, then assumed management responsibilities for the site operations and facilities. In 1991, Westinghouse renamed this subsidiary the Westinghouse Environmental Management Company of Ohio (WEMCO). On December 1, 1992, the Fernald Environmental Restoration Management Corporation (FERMCO) assumed responsibility for the site as the first Environmental Restoration Management Contractor (ERMC) for DOE.

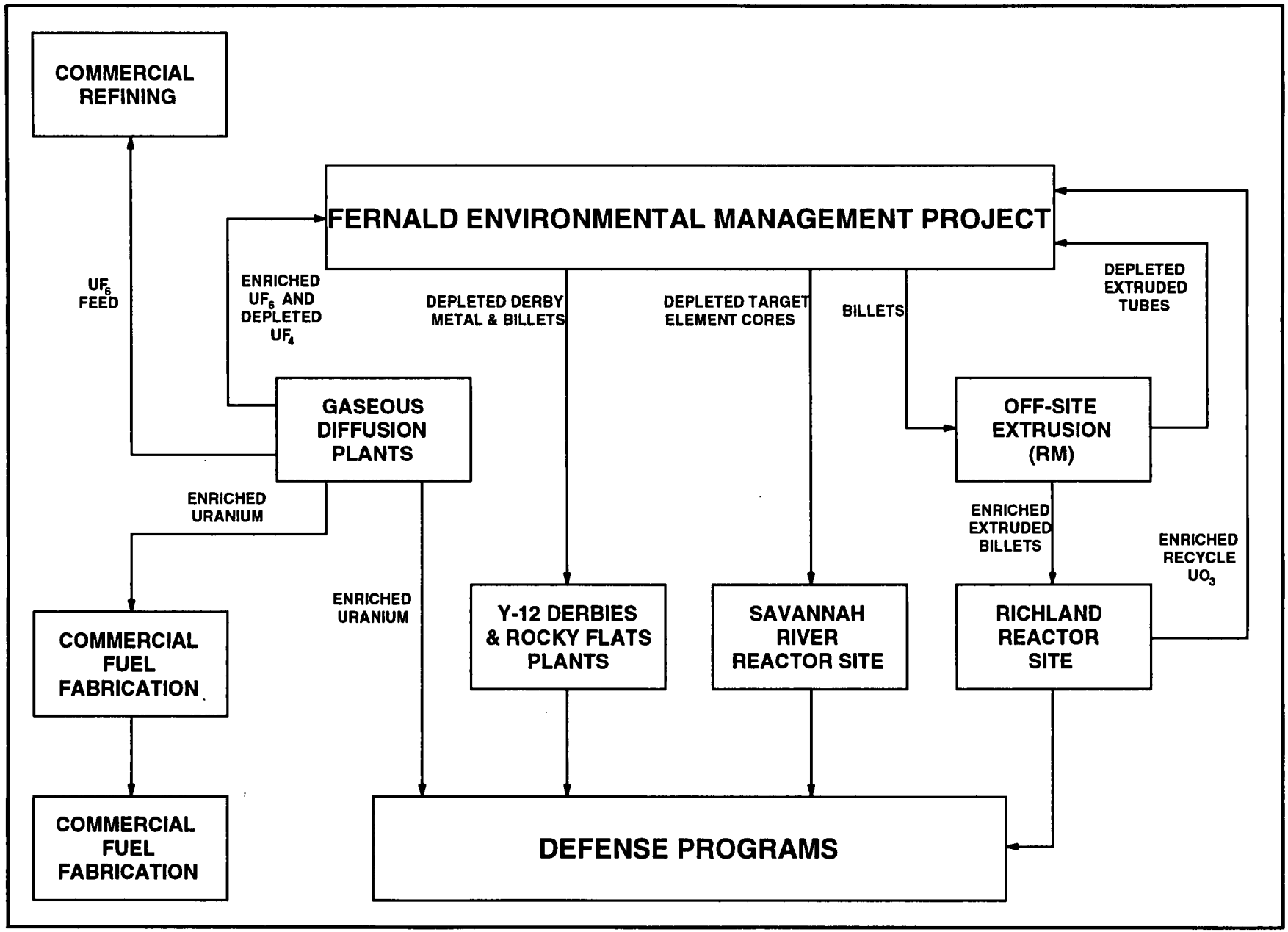

FIGURE 1-11 FEMP INTEGRATION WITH OTHER DOE FACILITIES

The FEMP began operations in 1951 upon completion of the Pilot Plant as the site's first operational facility. Production peaked in 1960 at approximately 12,000 metric tons (13,228 tons) of uranium (mtu) per year. A product decline began in 1964 and reached a low in 1975 of about 1230 mtu. During the 1970s, consideration was given to closing the FEMP. Thus, capital improvements and staffing were minimized. The staffing level, which peaked at 2891 personnel in 1956, slowly declined to 662 personnel in 1972 and then to 538 personnel in 1979. In 1981, the FEMP began planning to accommodate increased production requirements. Production levels significantly increased and there was a rapid staff buildup for several years. The renewed need for uranium metal resulted in the implementation of a major facilities restoration program. Then, production ceased in the summer of 1989 and plant resources were focused on environmental cleanup activities. In June 1991, the site was officially closed as a federal production facility. To indicate its evolution to a new mission, the site was renamed from the Feed Materials Production Center to the Fernald Environmental Management Project.

On July 18, 1986, a Federal Facilities Compliance Agreement (FFCA) was jointly signed by DOE and EPA detailing actions to be taken by DOE to assess environmental impacts associated with the FEMP site. The FFCA was entered into pursuant to Executive Order 12088 [43 *Federal Register (FR)* 47707] to ensure compliance with existing environmental statutes and implementing regulations such as the CAA, Resource Conservation and Recovery Act (RCRA), and CERCLA. In particular, the FFCA was intended to ensure that environmental impacts associated with past and present activities at the FEMP site would be thoroughly and adequately investigated so that appropriate remedial response actions could be formulated, evaluated, and implemented. As required by the FFCA, a RI/FS was initiated at the FEMP site in July 1986, pursuant to CERCLA.

In November 1989, the FEMP site was placed on the NPL for investigation and remediation under CERCLA. This placement, in addition to progressive findings in the RI/FS program, resulted in the amendment of the existing agreement between DOE and EPA. The 1986 the FFCA was amended by a Consent Agreement under Section 120 and 106(a) of CERCLA (Consent Agreement) providing for the implementation of the operable unit concept for the FEMP RI/FS and revising the milestone commitments for the RI/FS program without modifying the underlying objectives in the FFCA. The Consent Agreement was signed on April 9, 1990, and became effective on June 29, 1990, following a period of public comment. In September 1991, certain terms of the 1990 Consent Agreement, including the provisions relating to schedules for completion of the RI/FS for each operable unit, were amended.

1.4.4 Operable Unit 4 History

1.4.4.1 History of Silo 1

Silo 1 was constructed in 1952, as one of the first facilities at the FEMP site, with the intent to store drummed residues in inventory at other United States facilities. The residues stored in Silo 1 were generated at the Mallinckrodt Chemical Works (MCW) in St. Louis, Missouri, as a result of processing to extract uranium from pitchblende ores. The pitchblende ores processed at MCW and the great majority of the pitchblende ores processed at the FEMP site came from one mine, the Shinkolobwe Mine in the Belgian Congo. These ores contained relatively high concentrations of uranium oxides (U_3O_8) in the range of 40 to 50 percent (Litz 1974). The Shinkolobwe Mine, owned by the African Metals Corporation, began operation in 1921 for the purpose of obtaining radium. The mine was re-opened in 1943 for its uranium. Based on the high value of radium at the time, the agreement reached between the AEC and the African Metals Corporation stipulated that the African Metals Corporation would retain ownership of the radium within any processing residues. That is, after the United States had processed the pitchblende ore to extract uranium, the residue would be returned to the African Metals Corporation. The K-65 Silos were constructed at the FEMP site to provide interim storage of the residues, pending the return of the materials to the country of origin. For more than 30 years, these materials remained in storage at the FEMP site, under the terms of the original agreement, awaiting transfer. In 1984, ownership of the K-65 residues was transferred to DOE.

Initially, the residues from the MCW refining operations were sent back to the African Metals Corporation. Beginning in April 1949, the residues were no longer returned to the African Metals Corporation following processing but were stored at MCW for future disposition. As production continued, storage became a problem. As a result, the drummed K-65 residues were sent from MCW to Lake Ontario Ordinance Works (LOOW) near Niagara Falls, New York, for storage. Some of the drums sent to LOOW were emptied into a concrete tower at that site. Approximately 6000 drums were shipped from LOOW to the FEMP site for storage. Beginning in 1951, continuing production at MCW resulted in approximately 25,000 drums being sent directly from St. Louis to the FEMP site.

Approximately 24,000 of the 31,000 drums of pitchblende ore processing residues received at the FEMP site from MCW and LOOW were transferred to Silo 1 for storage. The remaining 7000 drums of K-65 residues received from MCW and LOOW were transferred to Silo 2. As the drums were received by railroad car at the FEMP, the drums were temporarily staged in an area to the east

of Silos 3 and 4. The drummed material was transferred to Silo 1 from July 1952 until November 1953 through the use of a specially constructed K-65 Drum Handling Building. Within the K-65 Drum Handling Building, the drummed residue was transferred to a hold tank and slurried with the addition of water.

The slurry was then pumped into Silo 1 where it was allowed to settle into two layers. The slurry liquor, which consisted of either water or a metal nitrate solution, formed the top layer over a bed of the settled, wet solids. This layer of clear liquid was decanted from the silos through decant ports and collected in a decant sump tank. From here, the decanted liquid was periodically pumped back to the K-65 Drum Handling Building where it passed through a pressure filter and was stored in a filtrate storage tank. The filtered liquid was then used for slurry preparation in the K-65 Drum Handling Building. Excess liquids were transported back to Plant 8 at the FEMP site for treatment, then to the general sump for final treatment before discharge to the Great Miami River. The K-65 Drum Handling Building was demolished in 1983 to allow for the renovation of the earthen berm surrounding Silos 1 and 2.

1.4.4.2 History of Silo 2

While Silo 1 was completely filled by the residues from MCW and LOOW, Silo 2 was filled with a mixture of MCW K-65 material and FEMP-generated K-65 material. As previously stated, 7000 drums of K-65 residues transferred from MCW and LOOW to the FEMP were emptied into Silo 2. The transfer of the drummed residues received from off site into Silo 2 occurred between late 1953 and January 1956. The generating process and the methodology to transfer the MCW/LOOW materials to Silo 2 is similar to those used in Silo 1 as discussed in the previous section.

Additionally, Silo 2 received residues generated at the FEMP site resulting from the processing of pitchblende ores shipped directly from the Shinkolobwe Mine and a small quantity of Australian ores from two mines, the Rum Jungle Mine and the Radium Hill Mine. The processing completed at the FEMP was performed to extract the uranium values from these very rich pitchblende ores. Processing of these ores was conducted at the FEMP from May 1954 until February 1959. Belgian Congo ores were processed at the FEMP from May 1954 until August 1958. Australian ores were processed at the FEMP following the Belgian ores from May 1957 until March 1958. The last K-65 slurry was added to Silo 2 in January 1959. The Australian ore residues constitute less than 180,000 kilograms (kg) (200 tons) of the estimated 4.4 million kg (4900 tons) in Silo 2. The term K-65 was used to describe both the Belgian Congo and the Australian ores processed at the FEMP.

Following completion of K-65 processing operations at the FEMP, approximately 150 drums of radium-contaminated material, consisting of soils from the MCW/LOOW drum staging area, cleanup materials, and excess K-65 samples were placed into Silo 2 in June 1960. In 1979, in response to concerns on the part of the FEMP Operating Contractor, NLO, Inc., relative to the chronic radon emissions from the silos, all vents, manways, and other penetrations through the domes of Silos 1 and 2 were sealed. No materials (with the exceptions of decant liquid and RI/FS samples) have been removed from Silos 1 or 2 since final filling.

1.4.4.3 History of Silos 3 and 4

Silos 3 and 4 were constructed in 1952 for storing metal oxides generated through the operation of the FEMP refinery. Unlike Silos 1 and 2, which received residues from the processing of ores from one mine, Silo 3 received metal oxides generated consequentially from all FEMP refinery operations from May 1954 until late 1957. During this period, the FEMP refinery processed the previously mentioned pitchblende ores and uranium ore concentrates received from a number of foreign and domestic uranium mills. Raffinates from the refinery extraction process were passed through a pre-coated rotary vacuum filter to separate the solid phase from the aqueous phase. In the case of pitchblende ore processing, the filter cake was transferred to Silo 2 to hold the radium; the filtrate from the vacuum filter was subjected to further waste processing and eventually was transferred to Silo 3.

The filtrate waste streams from the extraction process were transferred to a series of agitating hold tanks in the former FEMP refinery area. These surge tanks fed a set of evaporators where approximately 90 percent of the liquids were evaporated and the remaining 10 percent concentrates were withdrawn for further processing. Evaporator temperatures ranged from 90°C (200°F) to 120°C (250°F). The concentrates from the evaporator were transferred to one of two processing operations depending on the time period in which they were transferred. From plant start-up through the mid-1950s, the concentrates were transferred to a spray calciner. The spray calciner operated at a temperature of 510°C (950°F) to remove the remaining liquids and convert the metal nitrates present in the concentrates into oxides.

Due to operational difficulties experienced with the spray calciners, a second process was installed to complete the drying of the concentrates. In this process, the concentrates from the evaporators were transferred to a drum dryer where the materials were spread in a rotating dryer. In the dryer, liquids were removed from the concentrates by centrifugal force. The drum-dried concentrates were then

transferred to a rotary calciner to remove the remaining liquids and complete conversion of the metal nitrates into oxides. The concentrates were retained in the furnace zone at 650°C (1200°F) to 820°C (1500°F) for approximately 10 minutes. The finely powered, dried metal oxides were transferred to a surge hopper from where the materials were pneumatically conveyed through a pipeline to Silo 3. A dust collector, which was used to control discharges to the atmosphere resulting from the discharge of the powdered material into Silo 3, was located at the top of the silo. Silo 3 was filled to its present level using this rotary calcining system. No materials (except samples) have been removed from Silo 3 since filling in 1957.

Following a programmatic decision in early 1957 to utilize raffinate surface impoundments, the spray calcining and rotary calcining systems were eventually abandoned. As a result of this decision, Silo 4 was never employed for the storage of cold metal oxides or other site materials and remains empty. Inspections completed on Silo 4 during the RI-related site investigations confirmed that no waste materials were present within the silo.

1.4.4.4 History of the Radon Treatment System

The RTS was installed in November 1987 to reduce the radon inventory within the headspace of each silo (Silos 1 and 2) prior to the application of a polyurethane foam to the exposed surfaces of the domes of Silos 1 and 2. The RTS was originally designed to withdraw the radon gas from the headspace of each silo separately. The RTS operated as a closed, re-circulating system so that the radon component of the gas flow from the silo was directed continuously across charcoal beds. The basic operation of the RTS involved the removal of the radon-laden air from the silo headspace, transport to the treatment building, removal of moisture on two calcium sulfate canisters, adsorption of the radon on the charcoal beds and return of the dry air to the silo. The RTS was utilized on numerous occasions following the initial run to support the foam installations. The RTS was used extensively during RI sampling efforts, which are described in Section 2.0 of the RI Report for Operable Unit 4.

In March 1990, a cracked PVC pipe tee in the RTS piping system was discovered and attributed to degradation brought on by ultraviolet (UV) radiation and thermal stresses. In response to this finding, the RTS was upgraded in July 1991. The upgrades included new piping, a new fan, and the installation of remote controlled butterfly valves. The RTS was last used in November 1991 to support the K-65 Silos Removal Action. The RTS remains intact within the Operable Unit 4 Study Area.

1.5 NATURE AND EXTENT OF CONTAMINATION

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This section summarizes the nature and extent of contamination both on a site-wide basis and for Operable Unit 4. The site-wide summary is presented in this section to frame Operable Unit 4 within the entire FEMP, consistent with the role of this Operable Unit 4 FS document to include the CRARE, which was described in Section 1.3.

1.5.1 Site-Wide Summary

DOE submitted the final FEMP SWCR to EPA in March 1993. It is incorporated herein by reference and is available in the Administrative Record. The SWCR compiles all FEMP site data available as of December 1, 1991. The major purpose of the SWCR is to support the preparation of the individual operable unit RI and FS Reports by: describing the regional environment of the FEMP; providing the site-wide information necessary for FS cumulative response action risk evaluations; and providing a number of detailed technical appendices on ecological studies, population estimates, and modeling efforts supporting the RI/FS. Data required for describing the sources, and nature and extent of contamination related to specific operable units were still being collected when preparation of the SWCR began. Accordingly, data interpretation in the SWCR is limited. Comprehensive data usability assessments and interpretations are provided in the respective operable unit RI/FS reports.

The site characterization work performed to determine the nature and extent of contamination at the FEMP has generated thousands of data points. Additional data continue to be collected through an ongoing environmental monitoring program and remaining RI/FS characterization activities. The results of six primary data collection programs were compiled by the SWCR as summarized below:

- DOE Litigation Study
- Characterization Investigation Study (CIS)
- RCRA Groundwater Compliance Monitoring
- DOE Sampling and Analysis
- Annual Environmental Monitoring Program
- RI/FS Characterization Studies

These data collection programs encompass solid and liquid waste, structures and equipment, and all environmental media including air, surface water and groundwater, soils, and flora and fauna. Table 1-1 presents a general overview of the results of these investigations by environmental medium and source area. The discussion below briefly highlights major observations as reported in the SWCR Volume 2, Part I, Section 4.0 Data Summary. Readers are referred to the SWCR for full details.

TABLE 1-1

SUMMARY OF NATURE AND EXTENT OF CONTAMINATION AT THE FEMP

Source Area/Environmental Medium	Description
A. ENVIRONMENTAL MEDIA	
Air Quality	
Site-wide air quality.	Emissions of radionuclides site wide have been substantially reduced from the time of active production. Radon emissions decreased significantly with the placement of bentonite over the contents of Silos 1 and 2 during November 1991. **Key Contaminants:** **Particulate-borne uranium and radon**
Surface Water/Sediments	
Great Miami River, Paddys Run, on-property surface drainages.	Data indicate that the FEMP has only a slight effect on uranium concentrations in the Great Miami River, with no effect on sediment. On-property concentrations of uranium in Paddys Run surface waters and sediment trend higher than downstream off-property locations. Radionuclide levels in various on-property drainageways including the storm sewer outfall ditch have decreased since the construction of the storm water retention basins in 1986. **Key Contaminants:** **Uranium**
Groundwater	
Perched groundwater zones and Great Miami Aquifer.	Perched groundwater zones on the FEMP are contaminated by a variety of constituents originating from major sources including the Former Production Area, solid waste landfill and South Field, waste pits, and Silos 1 and 2. Data for samples collected from the Great Miami Aquifer generally show lower concentrations of contaminants than the perched water. The majority of off-property wells sampled had total uranium concentrations less than 2 picoCuries/liter (pCi/L). **Key Contaminants:** **Uranium**

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TABLE 1-1
(Continued)

Source Area/Environmental Medium	Description
Surface Soils	
On-property soils outside the boundary of specific operable units and off-property soils.	Annual sampling of surface soil indicates that uranium concentrations decrease with distance from the center of the FEMP. The highest concentrations of uranium were consistently measured in samples in the vicinity of the former incinerator at the Sewage Treatment Plant. **Key Contaminants:** **Uranium**
Subsurface Soils	
On-property subsurface soils contiguous with source areas.	Consistent with past waste management and disposal practices (i.e., waste pits, K-65 Silos) on-property subsurface soils adjacent to source areas are contaminated with radionuclides and organic/inorganic constituents. The ranges of concentrations and vertical distributions of constituents in subsurface soil samples verify process knowledge regarding waste disposal practices. **Key Contaminants:** **Uranium**
Biological Receptors	
Macroinvertebrates and fish in Paddys Run and the Great Miami River; grass/forage; produce; milk; and mammals.	Various ecological surveys contaminant uptake studies have been performed over the years. Although isotopic uranium has been detected in a variety of biological samples (both flora and fauna), no significantly elevated concentrations have been detected. Generally, concentrations declined since FEMP production shut down and with increasing distance from the site. **Key Contaminants:** **Uranium**

TABLE 1-1
(Continued)

Source Area/Environmental Medium	Description
B. SOURCE AREAS	
OU1 Waste Pits 1 through 6, Clearwell and Burn Pit, and associated contaminated soils within the operable unit boundary.	The six waste pits previously received large quantities of solid and slurried wastes from FEMP processes. The Clearwell received process water, settleable solids, and storm water runoff from Waste Pit 5. The Burn Pit was used to burn laboratory chemicals and waste oils. **Key Contaminants:** **Uranium, thorium, radium, and technetium**
OU2 Solid Waste Landfill, Lime Sludge Ponds, Active and Inactive Flyash Piles and the South Field, and associated contaminated soils within the operable unit boundary.	The Solid Waste Landfill reportedly contains cafeteria wastes, rubbish, and wastes from nonprocess areas. The Lime Sludge Ponds received spent lime sludges and boiler plant blowdown. The Flyash Piles received flyash from the FEMP coal-fired boiler plant and were periodically sprayed with waste oils for dust control. The South Field reportedly received construction rubble containing low levels of radioactive materials. **Key Contaminants:** **Uranium, thorium, radium, and cadmium**
OU3 Former Production Area, all above and below ground production associated facilities and equipment.	The former Production Area occupies about 55 ha (136 acres) and encompasses structures, utilities, drums, tanks, solid wastes, product (e.g., uranium metal, and thorium), effluent lines, wastewater treatment and fire training facilities, scrap metal piles, feedstock, and the coal pile. **Key Contaminants:** **Uranium, thorium, lead, asbestos, and trichlorethylene**
OU4 Silos 1 through 4, earthen berms, decant sump, and associated contaminated areas within the operable unit boundary.	Earthen bermed concrete Silos 1 and 2 contain K-65 residues that are high-specific activity, radium-bearing residues resulting from the pitchblende refining process. Concrete Silo 3 contains metal oxides. Concrete Silo 4 is unused. The decant sump tank contains liquids collected from Silos 1 and 2 via an underdrain system. **Key Contaminants:** **Radium, thorium, lead, radon, and arsenic**

1.5.1.1 Air Quality

Air quality monitoring at the FEMP has focused on uranium (U)-238, as a measure of the impact of production operations and waste handling activities and radon as a measure of the impact of continued storage of the contents of Silos 1 and 2 in Operable Unit 4.

Annual U-238 emissions, as determined by a combination of point-source and nonpoint-source monitoring and modeling, declined from a total of 35,400 microCuries per year (μCi/year) in 1988 (the last full year of production at the FEMP site) to 9890 μCi/year in 1989 and 1080 μCi/year in 1990. Corresponding reductions in concentrations of airborne uranium occurred at the 16 air monitoring sites in and around the FEMP site.

Compared to data collected in October 1991, on-property radon concentrations decreased by 90 percent and off-property concentrations, which were already near background, decreased by 50 percent after the placement of bentonite in Silos 1 and 2 in November 1991.

1.5.1.2 Surface Water and Sediment

The major surface water features of concern at the FEMP site are the Great Miami River, the receiving body for a NPDES permitted discharge, Paddys Run, a small stream traversing the western border of the property, and the storm sewer outfall ditch, a major tributary to Paddys Run. Data collection has focused on monitoring total uranium concentrations in the surface water and sediments, supplemented by sampling and analysis for other parameters during the RI/FS. Uranium concentrations in surface water samples collected downstream from the Great Miami River FEMP effluent discharge are typically 1 to 2 picoCuries/liter (pCi/L) higher than the usual concentration of 1 pCi/L in upstream samples. Samples collected from river sediments are typically 1 picoCurie/gram (pCi/g) both above and below the effluent discharge. The concentrations of inorganic chemical constituents show no upstream/downstream variability with respect to the effluent discharge.

Surface water samples collected from an on-property location in Paddys Run have averaged 76 pCi/L total uranium. Concentrations measured from off-property sampling locations averaged less than 7 pCi/L total uranium. Uranium concentrations in Paddys Run sediment adjacent to the confluence with the storm sewer outfall ditch have been reported at up to 62 pCi/g, but average less than 2 pCi/g. In addition, environmental monitoring data from 1988 to 1990 show no variability for upstream/downstream samples collected relative to the confluence of Paddys Run with the Great Miami River.

The storm sewer outfall ditch is normally dry, but uranium concentrations in runoff from various drainages to Paddys Run have been recorded as high as several milligrams per liter (mg/L). Environmental monitoring data indicate that radionuclide levels in Paddys Run and storm sewer outfall ditch sediment have decreased since the construction of the storm water retention basins in 1986. Recent sampling of the storm sewer outfall ditch sediment found a maximum of about 17 pCi/g total uranium.

1.5.1.3 Groundwater

The major focus of groundwater investigations at the FEMP has been on radionuclide contamination of the regional Great Miami Valley Aquifer. Related studies have been conducted on the extensive zones of perched groundwater on and adjacent to the FEMP site.

Both radiological and nonradiological constituents have been detected in perched and regional aquifer groundwater. The highest concentrations of uranium in perched groundwater and the regional aquifer were found in the former Production Area. Total uranium concentrations greater than 1 mg/L in former production area were observed in perched groundwater beneath Plant 2/3, Plant 6, and Plant 8 areas. The highest average total uranium concentrations in the former Production Area are 568 mg/L in perched groundwater and 0.071 mg/L in the regional aquifer. Concentrations of uranium in the perched groundwater are generally higher than those shown in the regional aquifer groundwater. Other radiological constituents that have been recurrently detected in the perched groundwater at the FEMP site, primarily in the vicinity of the former Production Area, include radium (Ra)-226, Ra-228, strontium (Sr)-90, technetium (Tc)-99, thorium (Th)-228, Th-230, and Th-232.

Above background concentrations of a number of inorganic constituents were found in perched groundwater and the regional aquifer, with concentrations generally lower in the latter. General chemical constituents with statistically elevated concentrations in the regional aquifer groundwater beneath the Waste Storage Area and the former Production Area were similar to those found in the perched groundwater in these areas.

A variety of volatile and semivolatile organic compounds were detected in perched groundwater and aquifer groundwater from the vicinity of the Waste Storage Area, the Former Production Area, and the South Field. Various volatile and semivolatile organic compounds were also detected in perched groundwater in the vicinity of the sewage treatment plant and fire training area and in the regional aquifer near and south of the local industries south of the FEMP property.

1.5.1.4 Surface Soils

Annual sampling and analysis of surface soil by the FEMP environmental monitoring program indicates that uranium concentrations decrease with distance from the center of the FEMP. In 1990, total uranium concentrations reported for samples collected at on-property locations 0.1 km (0.06 mi) and 1.1 km (0.7 mi) from the FEMP center were 41 pCi/g and 15 pCi/g, respectively. Off-property concentrations ranged from 1.1 to 7.2 pCi/g total uranium at distances from 40 to 1.3 km (25 to 0.8 mi) from the FEMP center. Sampling and analysis of surface soils conducted to characterize Waste Storage and the former Production Areas reported higher concentrations of uranium, as well as other radioisotopes including Ra-226, Th-228, Th-230, and Th-232. The highest concentrations of uranium occurred adjacent to the former incinerator near the sewage treatment plant, with total uranium values ranging up to 23,000 milligrams per kilogram (mg/kg). Elevated thorium and radium concentrations (up to 7901 pCi/g Th-228 and up to 2950 pCi/g Ra-226) were found in samples collected from the former Production Area.

Inorganic and organic constituents were also detected in surface soil samples collected for the RI/FS. Inorganic constituents found include aluminum, arsenic, barium, beryllium, cadmium, calcium, cobalt, copper, iron, magnesium, nickel, vanadium, and zinc. Forty-seven volatile and semivolatile organics were detected, with polychorinated biphenyls (PCBs), benzo(a)pyrene, and methylene chloride found in all RI/FS samples for which those constituents were analyzed. The highest concentrations of inorganics and organics were found in the former Production Area.

1.5.1.5 Subsurface Soils

Sampling and analysis of subsurface soils has focused on contamination sources including the Waste Storage Area, the flyash piles and South Field, the solid waste landfill soils, beneath Silos 1 and 2, and the former Production Area. Uranium and thorium isotopes were consistently detected in subsurface samples collected from the waste pits. RI/FS samples from the Pit 1 berm had mean concentrations of 349 pCi/g U-234, 894 pCi/g U-238, and 3811 pCi/g Th-230. U-238 was the most abundant radionuclide detected in CIS samples from the solid waste landfill, with a maximum concentration of 338 pCi/g and an average of 11.3 pCi/g. Radionuclides detected in CIS samples from the flyash piles and South Field include isotopes of uranium, thorium, radium, and lead (Pb)-210. Uranium isotopes, Th-230, and Ra-228 were the most abundant radionuclides detected in RI/FS samples from borings in structures in the former Production Area. Concentrations of U-238, Th-230, and Ra-228 ranged up to 19,100 pCi/g, 127 pCi/g, and 170 pCi/g, respectively.

Inorganic constituents were detected in subsurface soil samples collected from the Waste Pit Area. For example, concentration ranges of aluminum (4730 to 24,061 mg/kg), calcium (22,190 to 156,000 mg/kg), iron (2750 to 20,250 mg/kg), and magnesium (12,184 to 30,700 mg/kg) were detected in samples collected throughout the waste pits and the Clearwell. Average ranges of arsenic (102 to 530 mg/kg), lead (232 to 158 mg/kg), sodium (2800 to 5417 mg/kg), and vanadium (870 to 2700 mg/kg) were among the higher concentration inorganic constituents detected in Waste Pits 3 and 5, respectively. Aluminum, calcium, iron, and magnesium were found in concentrations exceeding 7000 mg/kg in samples collected from the flyash piles and the South Field. Antimony, arsenic, lead, molybdenum, selenium, and silver exceeded background levels in both flyash areas. Aluminum, calcium, iron, and magnesium had the highest concentrations among inorganics in samples collected from the solid waste landfill. Aluminum, calcium, iron, and magnesium were the most abundant inorganic constituents in former Production Area subsurface soil.

A variety of organic compounds were detected in subsurface soil samples collected in the Waste Pit Area, including PCBs, phenanthrene, fluoranthene, and pyrene. Aroclor-1254 was detected at 2.3 mg/kg in the Burn Pit. Semivolatile organics were detected in higher levels [up to 2700 micrograms per kilogram (μg/kg)] in the active flyash pile than in the inactive flyash pile (up to 310 μg/kg). A variety of organic compounds, including semivolatiles, volatiles, and PCBs were detected in subsurface soil samples collected from the former Production Area.

1.5.1.6 Ecological Assessments

A number of investigations have been conducted to support site-specific ecological assessments at the FEMP. These studies fall into three general categories: characterizations of habitats and species compositions, analyses of organisms for uptake of FEMP contaminants, and toxicity tests of FEMP effluent, soils, and sediments.

The major ecological characterization study at the FEMP was conducted by researchers from Miami University under contract to WEMCO. They described five major habitats at the FEMP: introduced grasslands, pine plantations, deciduous woodlands, a riparian zone along Paddys Run, and an area coincident with the Inactive Flyash Disposal Area and South Field. This study and several follow-up studies also examined possible stress effects on one species of bird and one species of amphibians occupying these habitats. The studies did not establish a correlation between observed effects and contamination from the FEMP.

Benthic macroinvertebrate communities in the Great Miami River and Paddys Run were surveyed five times over a two year period to examine potential effects of the FEMP on aquatic communities. The results of the Great Miami River surveys suggest that the FEMP effluent has minimal impact on the macroinvertebrate community. While some environmental stress on these communities were observed in Paddys Run, they may be attributable to the stressful physical environment of the stream. Observed concentrations of radionuclides and chemicals in Paddys Run are not consistent with those reported in the literature to be toxic to aquatic organisms.

Over the years, various samples of grass and forage, produce, milk, fish, vegetation, and mammal tissue have been collected at and adjacent to the FEMP site. Although concentrations of isotopic uranium were detected in some grass and vegetation samples at values as much as to 35 pCi/g concentrations declined both with increasing distance from the center of the site and with the shutdown of plant operations. Uranium was detected at 18 pCi/g in one of eight mammal samples and was sporadically detected at low levels in fish and macroinvertebrate samples collected from the Great Miami River and Paddys Run.

Acute and chronic aquatic toxicity tests were conducted on the FEMP effluent five times over a two-year period following standard EPA protocols. Acute toxicity was never observed. Chronic toxicity was observed in three of five algal growth tests and in one of three dephnid tests. No correlation was observed between effluent toxicity and uranium or other effluent variables. The concentrations causing toxicity were at least eight times the maximum concentrations of effluent, which would be observed in the Great Miami River under worst-case conditions. Aqueous extracts of soils and sediment from the FEMP were tested for acute toxicity to aquatic organisms. No acute toxicity was observed.

1.5.2 Operable Unit 4 Summary

This section summarizes the nature of contamination at the source and the nature and extent of contamination within the receptor media in the Operable Unit 4 Study Area. Sources include Silos 1 and 2, the decant sump tank, the RTS, Silo 3 and Silo 4. Receptor media within the Operable Unit 4 Study Area include surface soil, berm soil, subsurface soil, perched groundwater, Great Miami Aquifer groundwater, surface water, sediment, air, and direct radiation. Full detail is provided in Section 4.0 of the RI Report for Operable Unit 4. Some data tables not included in this section are located in Appendix A.

1.5.2.1 Contaminant Source Data

This section summarizes characterization data regarding the nature of contaminants, or sources, within the physical structures contained in Operable Unit 4. Sources considered in this section include Silos 1 and 2, the decant sump tank, the RTS, Silo 3 and Silo 4.

Silos 1 and 2

Silos 1 and 2 sample analyses confirmed prior process knowledge and provided additional data regarding the distribution of constituents within the silos and their specific concentrations. They also identified the presence of previously unknown organic constituents. Table 1-2 presents a summary of radionuclide analyses of the Silos 1 and 2 residues. Table 1-3 presents an inventory of the radiological constituents in Silos 1 and 2.

Silos 1 and 2 contain 6120 m^3 (216,300 ft^3) of K-65 residues and 670 m^3 (23,700 ft^3) of bentonite clay for total content of 6790 m^3 (240,000 ft^3). The materials are primarily a silty clay with an average moisture content of 40 percent. In excess of 70 Curies (Ci) of Ac-227, 3700 Ci of Ra-226, 600 Ci of Th-230, 2400 Ci of Po-210, and 1900 Ci of Pb-210 are present within the residue volumes of the two silos. Furthermore, it is estimated that the silos contain 27 metric tons (30 tons) of uranium. Radiological contaminants show a well-defined distribution pattern in the silos. Analytical results confirm homogeneity in the horizontal direction and heterogeneity in the vertical direction. These results are consistent with the waste materials having been slurried into Silos 1 and 2 in 15-cm (6-in.) lifts. Concentrations of Ra-226, Th-230, Pb-210, and uranium generally increase in concentration with depth. This observation is consistent with the knowledge that higher assay ores were processed earlier in the project. The 1990/1991 sampling event that provided analytical results from samples obtained near the bottom of Silos 1 and 2 allowed engineers to establish an upper bound on the waste contents of the silos. Significant inorganics include nearly 120 metric tons (130 tons) of barium, 830 metric tons (915 tons) of lead, 210 metric tons (230 tons) of calcium, and 190 metric tons (210 tons) of iron. The silos also contain elevated concentrations of Aroclor-1248, Aroclor-1254, and Aroclor-1260 (PCBs) and tributyl phosphate (a solvent for uranium extraction). Toxicity Characteristic Leaching Procedure (TCLP) results show that lead (approximately 500 pm) exceeds RCRA limits of 5.0 ppm. However, based on the generation process of the residues stored in the silos, they are classified as by-product material as defined in Section 11(e)2 of the Atomic Energy Act and, therefore, are excluded from regulation under RCRA.

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TABLE 1-2

SUMMARY OF RADIONUCLIDE ANALYSES FOR SILOS 1 AND 2 RESIDUES

Analyte [a]	Frequency of Detection[b]	Rejected	Arithmetic Mean[c] (pCi/g)[d]	Upper 95% CI on Mean[c] (pCi/g)	Range of Detects[c] (pCi/g)
SILO 1					
Actinium-227	13/20	0	5960	7670	4320-17390
Lead-210	20/20	0	165000	202000	48980-381400
Polonium-210	13/13	0	242000	281000	144000-434000
Radium-226	20/20	0	391000	477000	89280-890700
Thorium-228	2/20	0	422	2280	835-2280
Thorium-230	24/24	0	60000	68900	10569-105372
Thorium-232	8/20	0	424	1110	661-1106
Uranium-234	21/21	0	800	932	326-1548
Uranium-235/236	14/20	0	38	54	19.1-105
Uranium-238	20/20	0	642	693	387-920
SILO 2					
Actinium-227	11/14	0	5100	6640	2905-10450
Protactinium-231	1/14	0	2350	4040	4041-4041
Lead-210	14/14	0	145000	190000	58160-399200
Polonium-210	8/8	0	139000	231000	55300-241000
Radium-226	14/14	0	195000	263000	657-481000
Thorium-228	5/14	0	645	7360	411-7360
Thorium-230	15/15	0	48400	76200	8365-132800
Thorium-232	3/14	0	402	985	851-985
Uranium-234	13/13	0	961	1160	121-1465
Uranium-235/236	11/13	0	73	94	35.6-172
Uranium-238	14/14	0	912	1120	46-1925

[a]Sample numbers used in this data set include: (Silo 1) 99728, 99743, 99870, 99885, 99909, 99930, 99939, 99948, 99966, 99975, 100004, 100025, 100039, 100108 through 100114; and (Silo 2) 99359, 99710, 99774, 99802, 99811, 99831, 99846, 99861, and 100115 through 100120.
[b]Rejected data not included in total number of samples.
[c]Values qualified with an R are excluded. The mean and upper 95% confidence interval (CI) on mean have been rounded to show three significant figures. The mean is calculated using one-half the SQL for nondetects.
[d]Values expressed in picoCuries per gram (pCi/g).

TABLE 1-3

SUMMARY OF THE INVENTORY OF RADIOLOGICAL CONSTITUENTS IN SILOS 1 AND 2

Analyte	Silo 1[a] Mean Inventory[c] (Ci)	Silo 1[a] UCL Inventory[c] (Ci)	Silo 2[b] Mean Inventory[c] (Ci)	Silo 2[b] UCL Inventory[c] (Ci)
Actinium-227	40	52	30	39
Protactinium-231	ND[e]	ND[e]	14	24
Lead-210	1110	1360	844	1110
Polonium-210	1630	1890	809	1340
Radium-226	2630	3210	1140	1530
Thorium-228	2.8	15.3	3.8	43
Thorium-230	403	463	282	444
Thorium-232	2.9	7.5	2.3	5.7
Uranium-234	5.4	6.3	5.6	6.8
Uranium-235/236	0.26	0.36	0.43	0.55
Uranium-238	4.3	4.7	5.3	6.5
Total Uranium[d]	12.9	14.1	15.9	19.5

[a]Based on a volume of 3280 m^3 and a dry mass density of 2.050 grams per cubic centimeters (gm/cm^3).
[b]Based on a volume of 2840 m^3 and a dry mass density of 2.050 gm/cm^3.
[c]Values for mean and Upper Confidence Limit (UCL) taken from Table 1-2 of the RI Report for Operable Unit 4.
[d]Total uranium mass in metric tons. Calculated from the isotopic distribution of uranium.
[e]ND-Analyte was not detected.

Decant Sump Tank

Samples taken during this 1991 removal action reveal elevated concentrations of Pb-210 (8660 pCi/L), Po-210 (7080 pCi/L), Ra-226 (1380 pCi/L), and U-238 (23,200 pCi/L). Analytical results also revealed the presence of above background concentrations of Sr-90 and Tc-99. With the exception of these latter two constituents, radiological contaminants present in the decant sump tank are consistent with the relative concentrations of contaminants found in Silos 1 and 2. This result confirms that the decant sump tank is continuing to collect leachate from the underdrains in Silos 1 and 2, as it was designed to do. Sr-90 and Tc-99 are by-products of nuclear fission and are not present in Silos 1 and 2. Their presence in the decant sump tank indicates existence of some surface water infiltration into the decant sump tank or anomalous analytical results.

One sludge sample was taken during the 1991 removal action. Results from that sample showed measurable levels of Ac-227 (5783 pCi/g), Pb-210 (123,200 pCi/g), Ra-226 (128,500 pCi/g), and Th-230 (52,130 pCi/g). The ratio of these concentrations are consistent with measured values for the residues in Silos 1 and 2.

Metals found in the decant sump tank liquid samples included aluminum, antimony, arsenic, chromium, copper, lead, molybdenum, selenium, silver, vanadium, and zinc. These data are consistent with Extraction Procedure Toxicity (EP Tox) test results and TCLP analyses performed on materials in Silos 1 and 2.

Eighteen organic compounds were detected in the decant sump tank liquids at concentrations near the detection limits. With the exception of toluene, all volatile compounds detected were at or below the contract required quantitation limit (CRQL) or were common laboratory contaminants.

Radon Treatment System

The RTS was sampled during a removal site evaluation in January 1992. The predominant contaminants present are approximately 9.5 Ci of Pb-210 and progeny [polonium (Po)-210 and bismuth (Bs)-210] in secular equilibrium. The contaminants are located in the radon system calcium sulfate drier canisters, the charcoal canisters and, to a lesser extent, the system piping.

Periodic surveys for direct radiation and removable fixed radioactive contamination reveal that only isolated contamination is present in accessible portions of the RTS. Only one accessible location yielded a measurement that was above the DOE guidelines for unrestricted release.

Silo 3

Silo 3 contains 3890 m^3 (137,500 ft^3) of residues. During the 1989 sampling of Silo 3 contents, 12 radionuclides were identified including actinium (Ac)-227, Pb-210, protactinium (Pa)-231, and isotopes of radium, thorium, and uranium. Thorium-230 had the highest activity concentration, ranging from 21,010 to 71,650 pCi/g. These sample results are consistent with process knowledge. Present within the silo waste is approximately 450 Ci of Th-230, 26 Ci of Ra-226, and nearly 40 metric tons (44 tons) of uranium. Table 1-4 provides a summary of radionuclide concentrations in Silo 3 residues. Table 1-5 presents an inventory of Silo 3 radiological constituents.

Of the 23 inorganic constituents detected, those which represent the highest relative hazard include arsenic at 1950 mg/kg and vanadium at 1820 mg/kg. EP Toxicity results from sampling in 1989 indicate that the Silo 3 residues leach arsenic (mean 9.481 mg/L), chromium (mean 5.05 mg/L), and selenium (mean 2.65 mg/L) at levels exceeding RCRA limits of 5.0 mg/L, 5.0 mg/L, and 1.0 mg/L respectively. However, based on the generation process of the residues, they are classified as by-product material as defined in Section 11(e)2 of the Atomic Energy Act and, therefore, are excluded from regulation under RCRA.

The 1989 Silo 3 volatile organic analyses and a portion of the semivolatile data were rejected during data validation. Additional sampling was deemed unwarranted based on process knowledge and the organic sample results from Silos 1 and 2. Only two organics, kerosene and tributyl phosphate, were used in the extraction process. Silo 3 materials were generated as part of the same process which produced the materials in Silos 1 and 2. Before transfer to Silo 3, however, waste residues were first dried and then calcined. The calciners operated in a temperature range from 510°C (950°F) to 820°C (1500°F). This process would have combusted or volatilized organics present in the metal oxides prior to their transfer to Silo 3. This hypothesis is confirmed by the absence of PCBs/Aroclors in Silo 3 samples in spite of their presence in Silos 1 and 2 residues.

Silo 4

As related in the Silo 4 history discussion, due to a programmatic decision in early 1957 to utilize raffinate surface impoundments, the spray calcining and rotary calcining systems were eventually abandoned. As a result of this decision, Silo 4 was never employed for the storage of cold metal oxides and remains empty. Inspections completed on Silo 4 during the RI-related site investigations confirmed that no waste materials were present within the silo. Production and waste disposal records also show that Silo 4 was never used for production, waste storage, or waste disposal activities. Site

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TABLE 1-4

RADIONUCLIDE CONCENTRATIONS IN SILO 3 RESIDUES

Analyte [a]	Frequency of Detection[b]	Rejected	Arithmetic Mean[c] (pCi/g)[d]	Upper 95% CI on Mean[c] (pCi/g)	Range of Detection[c] (pCi/g)
SILO 3					
Actinium-227	9/9	2	618	925	234-1363
Lead-210	11/11	0	2620	3480	454-6427
Protactinium-231	9/11	0	487	627	266-931
Radium-224	11/11	0	290	367	64-453
Radium-226	11/11	0	2970	3870	467-6435
Radium-228	9/11	0	297	406	82-559
Thorium-228	7/11	0	590	747	459-996
Thorium-230	11/11	0	51200	60200	21010-71650
Thorium-232	8/11	0	656	842	411-1451
Uranium-234	11/11	0	1480	1730	348-1935
Uranium-235/236	10/11	0	93.6	117	42-158
Uranium-238	11/11	0	1500	1780	320-2043

[a] Sample numbers used in this data set include: 100097 through 100107.
[b] Rejected data not included in total number of samples
[c] Values qualified with an R are excluded. The mean and upper 95% confidence interval (CI) on mean have been rounded to show three significant figures. The mean is calculated using one-half the SQL for nondetects.
[d] Values expressed in picoCuries per gram (pCi/g)

TABLE 1-5

INVENTORY OF SILO 3 RADIOLOGICAL CONSTITUENTS

Analyte	Silo 3[a] Mean Inventory[b] (Ci)	Silo 3[a] UCL Inventory[b] (Ci)
Actinium-227	5.4	8.2
Protactinium-231	4.3	5.5
Lead-210	23.2	30.8
Radium-224	2.6	3.2
Radium-226	26.3	34.2
Radium-228	2.6	3.6
Thorium-228	5.2	6.6
Thorium-230	453	532
Thorium-232	5.8	7.4
Uranium-234	13.1	15.3
Uranium-235/236	0.83	1.04
Uranium-238	13.3	15.7
Total Uranium[c]	39.9	47.2

[a]Based on a volume of 3900 m^3 and a dry mass density of 2.267 gm/cm^3.
[b]Values for mean and UCL concentrations from Table 1-4 of the RI Report for Operable Unit 4.
[c]Total uranium mass in metric tons. Calculated from isotopic distribution of uranium

records indicate that water has been periodically removed from Silo 4, and treated through the FEMP wastewater treatment system.

Water samples collected in 1989 contained 121 micrograms per liter (μg/L) of uranium. Hazardous Substance List (HSL) metal results were consistent with water in contact with cement. Water samples collected in May 1991 revealed an average uranium concentration of 0.3 μg/L. Thorium results were reported as below the lower limit of detection, 0.4 μg/L. HSL inorganics were again consistent with water in contact with cement.

1.5.2.2 Nature and Extent of Contamination of Environmental Media

This section summarizes characterization data regarding the nature and extent of contamination in environmental media within Operable Unit 4. Environmental media considered include surface soil, berm soil, subsurface soil, perched groundwater, Great Miami Aquifer groundwater, air, and direct radiation.

Surface Soil

Radiological analytical data from the CIS focused on the upper 0 to 5.1 cm (0 to 2 in.) of soils. Radionuclide concentrations for U-238 ranged from 2.6 to 37.4 pCi/g with a mean of 9.04 pCi/g. Concentrations of Ra-226 ranged from less than 0.5 pCi/g to 35.8 pCi/g with a mean of 5.54 pCi/g. In addition, two samples that were analyzed in an off-site laboratory yielded Th-230 concentrations of 14.0 and 295 pCi/g.

Results from the RI showed that U-238 concentrations ranged from 2.4 to 20.8 pCi/g with a mean of 8.3 pCi/g. Radium-226 concentrations ranged from 0.6 to 2.3 pCi/g with a mean of 1.24 pCi/g. Thorium-230 results ranged from 1.4 to 4.8 pCi/g with a mean of 3.1 pCi/g.

The Waste Pit Area Runoff Control Removal Action included 10 surface soil samples for inorganic constituents, 9 samples for HSL pesticides, and 8 samples for HSL volatile and semivolatile organics in the Operable Unit 4 Study Area. Of the inorganic constituents, antimony, beryllium, chromium, copper, magnesium, nickel, silver, and sodium were consistently above background. For organic analyses, the only detected volatile compounds consisted of common laboratory contaminants. With the exception of one sample containing elevated concentrations of semivolatiles (including benzo(a)pyrene), all semivolatile compounds were at or only slightly above the CRQL.

In general, the results of the studies are consistent with one another and show that surface soils across Operable Unit 4 are contaminated with U-238 and, to a lesser extent, Ra-226 and Th-230. Concentrations decrease rapidly with depth, to background below 15.2 cm (6 in.). The results of these samples show no direct link between surface soil contamination and the silo contents. Instead, the data show uniform distribution of low-level radiological surface contamination throughout the Operable Unit 4 Study Area consistent with air deposition of contaminants from the Waste Pit Area and/or the Former Production Area.

Berm Soil

With the exception of two sampling locations, berm sample results revealed only background concentrations for all constituents. The first location was at a depth of 1.5 m (5 ft) in the boring near the northeast manway of Silo 1. This sample revealed radionuclide concentrations of 3.38 pCi/g for U-238, 4.01 pCi/g for Th-230, 4.02 pCi/g for Po-210, and 3.67 pCi/g for Ra-226. The sample is considered to be more consistent with general surface soil than berm soil. The second sample was collected at a depth of 9.1 m (30 ft) from the boring located near the northwest manway of Silo 1. The sample yielded radionuclide concentrations of 24.7 pCi/g for U-238, 51.2 pCi/g for Th-230, 876 pCi/g for Ra-226, and 417 pCi/g for Pb-210. At this depth, the borehole had penetrated the native soil that was present prior to installation of the berm. Thus, this contamination could be the result of spillage during silo filling operations, leakage of the silo to surface soils prior to berm installation, or leakage of the silo underdrains to near subsurface soils immediately adjacent to the silos.

Subsurface Soil

Radiological analyses on soil from the slant borings yielded Pb-210, Po-210, Ra-226, Th-230, U-234, and U-238 at concentrations significantly above background. Concentration ranges are Pb-210 (0.46 to 101 pCi/g), Po-210 (0.938 to 86.5 pCi/g), Ra-226 (0.61 to 206 pCi/g), Th-230 (0.80 to 53.7 pCi/g), U-234 (0.8 to 35.9 pCi/g), and U-238 (0.76 to 53.4 pCi/g). In general, elevated concentrations of radiological contaminants were found near the interface of the berm soil with the pre-existing surface soil and near the base of the silos at their perimeter. The data suggest potential spillage on pre-existing surface soils and potential leakage of the silo underdrains to the subsurface soils in the immediate vicinity of Silos 1 and 2.

Metals analyses were performed on 13 samples from the slant borings. Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, cyanide, iron, lead, molybdenum, nickel,

selenium, silver, sodium, thallium, and zinc were detected at concentrations above background or represent elements for which no background is available.

Only seven volatile and three semivolatile organic compounds were detected in the slant borings. Of 13 samples, organics were detected in very low concentrations in no more than four samples. Most are common laboratory contaminants.

As part of the RI, radiological analyses were performed on 12 subsurface soil samples collected from two borings within Operable Unit 4 and eight borings immediately adjacent to Operable Unit 4. Furthermore, 16 subsurface soil samples were collected from six borings located in trenches to the west of Silos 1 and 3.

In general, subsurface soil contained concentrations of uranium and progeny at levels less than 4.0 pCi/g. The data indicate that soil contamination in Operable Unit 4, outside of the areas immediately adjacent to and under Silos 1 and 2, is limited primarily to the surface. There appears to be no contamination from the surface through the vadose zone except in samples collected from trenches located west of the silos. Above background uranium concentrations at depths up to 4.6 m (15 ft) below the surface indicate that this area may be contaminated with construction debris.

Perched Groundwater

Perched groundwater data consist of RI samples collected from the slant borings under Silos 1 and 2, RI and FEMP Environmental Monitoring Program samples collected from five shallow wells located in or near the Operable Unit 4 Study Area, and samples collected for the "Additional Characterization of Vadose and Perched Water in the K-65 Area."

In general, the data show that perched groundwater contamination whose constituents are consistent with those of silo leachate is present directly beneath and to the west of Silos 1 and 2. Perched groundwater contamination, containing U-238 contamination in the range of 1.1 to 1313 pCi/L, is migrating to the west toward Paddys Run from the areas beneath Silos 1 and 2. Data from the "Additional Characterization" program confirm previous findings (See Tables A.3-19 through A.3-22 in Appendix A). Additionally, new perched water data indicates the presence of constituents consistent with those found in the decant sump tank. Elevated levels of radium indicate that the decant sump tank and/or associated piping are leaking.

Great Miami Aquifer Groundwater

Groundwater data from the Great Miami Aquifer consist of samples from three 2000-series wells and two 3000-series wells. Great Miami Aquifer groundwater in the vicinity of Operable Unit 4 flows to the east. 2000-series wells, both upgradient and downgradient of Operable Unit 4, show similar uranium concentrations in the range of less than 1 μg/L to 40 μg/L. 3000-series wells, both upgradient and downgradient of Operable Unit 4, show comparable uranium concentrations in the range of less than 1 to 15 μg/L. The data show no direct link between contamination in the Great Miami Aquifer and the contents of Operable Unit 4 silos.

Air

Air data consist of FEMP Environmental Monitoring Program quarterly radon monitoring results obtained during the period 1989 through 1992. Monitoring results were obtained from 24 sampling stations along the FEMP site perimeter, 4 sampling stations within the FEMP site proper, 13 sampling stations along the fence surrounding Silos 1 and 2, and 8 sampling stations located along the perimeters of the Silos 1 and 2 domes. These data not only demonstrate the effectiveness of the K-65 Silos Removal Action conducted in November 1991, they also define the nature and extent of air contamination from radon emanating from Silos 1 and 2.

Fenceline monitoring for radon performed under the FEMP Environmental Monitoring Program shows small variations from year to year. For example, FEMP site boundary fenceline monitoring stations recorded annual average concentration for 1990 ranging from 0.4 to 1.5 pCi/L as compared to 0.5 to 1.0 pCi/L in 1989. These concentrations are, however, in the background range.

In November 1991, the FEMP site completed the K-65 Silos Removal Action. This removal action consisted of installing a layer of bentonite clay over the residues stored in Silos 1 and 2. While the action resulted in a significant reduction in direct radiation at the FEMP site fenceline, changes in radon concentrations at the fenceline were not discernable and remained at background levels. In the vicinity of Operable Unit 4, however, radon concentrations immediately outside Silos 1 and 2 were reduced by as much as a factor of 20.

Direct Radiation

Direct radiation data consist of quarterly direct radiation exposure data measured at 12 points along the FEMP site perimeter and at 2 points within the FEMP perimeter, northeast of the former Production Area. A comparison of the average quarterly direct radiation data for 1990 with those

data from 1992, which represent the 1-year periods before and after the K-65 Silos Removal Action, show a substantial reduction in direct radiation along the FEMP site fenceline.

Natural background radiation measurements for the areas surrounding the FEMP ranged from 6.1 to 6.9 millirem (mrem)/hour during 1990. During 1990, the FEMP site perimeter monitoring station, which exhibited the highest average radiation exposure rate (12.6 mrem/hour) was located 335 m (1100 ft) directly west of Operable Unit 4. The 1992 monitoring data for this location, after the removal action, yielded a dose rate of 5.2 mrem/hour. Thus, along the FEMP site perimeter, direct radiation from Operable Unit 4 is no longer discernable above background. This condition equates to no additional risks posed to a member of the general public at the fenceline.

The data presented herein have been reviewed and found adequate to meet the objectives established in Section 2.0 to determine the nature and extent of contamination within Operable Unit 4. That is, source terms are sufficiently defined and the extent of contaminant migration sufficiently characterized to support identification and evaluation of remedial action alternatives that may be deemed necessary to address migration of contamination originating from Operable Unit 4.

1.6 SUMMARY OF SITE RISKS

The chemical and radiological constituents present within the stored waste inventories and environmental media on the FEMP site and within the Operable Unit 4 Study Area present certain risks to human and environmental receptors. The type and degree of this risk has been estimated for existing, or baseline, conditions using EPA risk assessment methodology.

A baseline risk assessment estimates the risks that could occur in and around the FEMP site in the event no further cleanup actions are taken. These risks are evaluated for the situation as it presently exists and for how it could exist up to 1000 years in the future.

The baseline risk assessment is completed for three land use scenarios. The Current Land Use with Access Controls scenario examines potential risks to human health under existing land use conditions as a DOE industrial type facility with security forces and fences to limit access to the facility. The Current Land Use Without Access Controls scenario estimates potential risks attributable to site contaminants if the FEMP site was to remain an industrial facility, but with enforced the access controls being discontinued. Lastly, a Future Land Use scenario is examined. Under this scenario, the FEMP site is assumed to be transferred to an agricultural farming land use where a family farm is

hypothetically placed within the boundary of the FEMP site. These land use scenarios are examined to provide a bounding of the potential risks attributable to the site. Under all of these land use scenarios, assumptions are made to account for the potential impacts due to the expected deterioration of manmade waste containment structures presently in use at the site.

Baseline risks at the FEMP have been evaluated for both the site as a whole and on an operable unit basis. The following is a brief summary of the results of these risk assessments.

1.6.1 Preliminary Site-Wide Baseline Risk Assessment

A preliminary site-wide baseline risk assessment was prepared for the FEMP and included as part of the SWCR. The objective of this baseline risk assessment was to present the site-wide risks for the current and potential future land use scenarios under existing conditions, i.e., assuming no further remedial response actions are implemented. The risk assessment characterizes the current and potential future threat to human health and the environment that may be posed by all hazardous constituents and all viable exposure pathways from the FEMP site. The preliminary site-wide baseline risk assessment was based on all data pertaining to the FEMP site, which were available as of December 1, 1991. The preliminary site-wide risk assessment includes an assessment of the ecological impacts of the FEMP and is supplemented by a NEPA analysis of the environmental consequences of the no-action alternative.

To support the risk assessment, available data were compiled and evaluated to characterize the site and to select the constituents of concern (COC). The results of the compilation and statistical evaluation of the data is embodied within the SWCR and will not be repeated here. On the basis of the compiled data and summary statistics, the risks associated with the viable pathways for exposure of the site contaminants to human and environmental receptors were characterized employing the methodology identified in the Risk Assessment Work Plan Addendum (DOE 1992).

For Current Land Use with Access Controls conditions, the highest calculated risk to human receptors due to the presence of radiological constituents at the FEMP site exceeded an Incremental Lifetime Cancer Risk (ILCR) of $1x10^{-4}$ for a farmer hypothetically located off the FEMP site and using groundwater for consumption and irrigation. Risks were similar under the same land use scenario to a hypothetical trespassing child. CERCLA generally regards an ILCR from a waste site in the range of $1x10^{-4}$ to $1x10^{-6}$ to be acceptable and the ILCR of $1x10^{-6}$ as a point of departure. The highest

ILCR for chemical constituents under the Current Land Use with Access Controls scenarios was calculated to approximate 10^{-3} for the same off-property farmer.

Hazard indices (HI) were calculated to provide an indication of the risks due to presence of noncarcinogenic constituents of concern. An HI of less than one for exposures to a given receptor from all constituents of concern is generally regarded as acceptable. The calculated HI for the hypothetical off-property farmer under the Current Land Use with Access Controls scenarios exceeded 1500, primarily due to the intake of cadmium.

For the Current Land Use Without Access Control scenario, the highest calculated ILCR for radiological constituents approached $1x10^{-2}$ for external radiation exposures to the hypothetical trespassing child and exceeded $1x10^{-4}$ for the off-property farmer using groundwater for consumption and irrigation. For chemical carcinogens, the highest calculated ILCR associated with this land use scenario approached $1x10^{-4}$ for the hypothetical trespassing child. An HI of 1.7 (primarily due to the presence of arsenic) was calculated for this same trespassing child.

For the Future Land Use scenario (which assumes the site is transferred to a family farm and no further clean up takes place), the highest calculated ILCR for radiological constituents exceeded 10^{-1} to the hypothetical on-property farmer. Similarly, the calculated ILCR to the on-property farmer due to the presence of nonradiological carcinogenic constituents approached $1x10^{-1}$. The HI for the on-property farmer exceeded 2400, primarily due to the presence of arsenic.

As part of the preliminary site-wide baseline risk assessment, an evaluation was completed to estimate the risks due to the presence of naturally occurring or background constituents. Such risks were calculated for the hypothetical on-property farmer. The aggregate ILCR due to the presence of the naturally occurring concentrations of radiological constituents (i.e., uranium and thorium decay products) was calculated to approach $1x10^{-3}$. The highest calculated risk from a single radionuclide and pathway to this receptor was about $1x10^{-3}$ and was due to the inhalation of ambient concentrations of radon (Rn)-222 in air. Background concentrations of naturally occurring noncarcinogenic metals yielded HI which exceeded 0.2 to this same receptor for nine of these elements: arsenic (0.3), mercury (4.2), molybdenum (0.4), silver (1.2), thallium (6), and zinc (3).

1.6.2 Site-Wide Baseline Ecological Risk Assessment

The purpose of the ecological risk assessment, which was completed as a companion to the preliminary site-wide baseline risk assessment in the SWCR, was to estimate the potential and future baseline risks of FEMP contaminants to ecological receptors.

The EPA and DOE have agreed in the Amended Consent Agreement (September 1991) that the Site-Wide Ecological Risk Assessment will be performed as part of the RI for Operable Unit 5. The Site-Wide Ecological Risk Assessment in the RI for Operable Unit 5 will quantify and assess the possible risks from current concentrations of site contaminants to ecological receptors inhabiting on-site and off-site areas not presently targeted for remediation based on human-health concerns. More discussion on the Risk Assessment and Ecological Risk issues specific to Operable Unit 4 can be found in the Operable Unit 4 Proposed Plan.

The ecological receptors potentially exposed to FEMP contaminants include all organisms, exclusive of humans and domestic animals. The ecological risk assessment focused on a group of indicator species selected to represent a variety of exposure pathways and trophic positions. Terrestrial vegetation was represented by a generic plant species. Terrestrial wildlife species to be evaluated were selected based on species abundance on the FEMP site, trophic level position, and habitat requirements. The species evaluated were the white-tailed deer (*Odocoileus vriginianus*), white-footed mouse (*Peromyscus leucopus*), racoon (*Procyon lotor*), red fox (*Vulpes*), muskrat (*Ondatra zibethica*), American robin (*Turdus migratorius*), and red-tailed hawk (*Bueto jamaicensis*).

The assessment examined risks to terrestrial organisms associated with contaminants in two environmental media -- surface soils, summarized for the entire site, and surface water in Paddys Run from the northern boundary of the FEMP site to the confluence with the storm sewer outfall ditch. Risks to aquatic organisms were evaluated for exposure to contaminants in Paddys Run, the Great Miami River, and in runoff into the storm sewer outfall ditch. All nonradioactive and radioactive constituents of greatest human health risk were considered to be of concern for the ecological risk assessment. Estimated ecological risks associated with exposure to FEMP site constituents of concern are primarily due to nonradioactive inorganic chemicals in soils, rather than to organic chemicals or radionuclides. This is true for both terrestrial and aquatic organisms and for plants as well as wildlife. In particular, estimated intakes of arsenic, cobalt, lead, and silver from FEMP soils were all higher than estimated no observed effect levels (NOELs) for at least six of the seven indicator species selected for this assessment. The relative hazards to individual species varied, but the white-footed

mouse consistently had the highest indices of these chemicals. This can be attributed to the assumed intake by the mouse of insects (using earthworms as surrogates), which in turn were assumed to assimilate chemicals from soil with a transfer coefficient of 1.0.

Estimated hazards to terrestrial organisms of exposure to constituents of concern in FEMP surface waters were relatively low, with HIs greater than one only for arsenic, lead, molybdenum, and silver. These chemicals presented hazards of two, five, four and three to species, respectively, and the highest HI estimated was for lead intake by the mouse. Surface water exposure is therefore unlikely to be a significant source of risk to terrestrial ecological receptors at the FEMP site.

Estimated doses to terrestrial organisms at the FEMP site, originating from soil uptake by plants and earthworms, were below levels expected to cause detectable effects. However, as with inorganic chemicals, this conclusion is sensitive to assumptions about muscle-to-muscle transfer of radionuclides. Highly efficient transfer or biomagnification of uranium, in particular, could expose terrestrial wildlife at the FEMP to potentially harmful radiation levels. Radiation doses due to water intake were insignificant.

Exposure to radiological contaminants does not appear to pose a risk to aquatic organisms at the measured concentrations in the surface waters and sediments impacted by the FEMP site. However, modelled concentrations of radionuclides in runoff from the FEMP site into surface water would cause estimated exposures to exceed the upper limit of 1 rad/day. The most affected organisms would be aquatic plants, receiving a total dose from internal and external exposure of about 140 rad/day. The total dose to fish is minimally over the limit, at 1.6 rad/day, and the total dose to benthic macroinvertebrates is about 14 rad/day. Although the maximum concentrations at low flow were used in source runoff calculations, the minimum values in the storm sewer outfall ditch and Paddys Run are within the same magnitude of values. Doses to aquatic organisms in the Great Miami River would be well below 1 rad/day. The measured concentrations of cadmium, copper, mercury, and silver in surface water exceeded chronic toxicity criteria for the protection of freshwater organisms.

Field studies on the impact of the FEMP site on terrestrial and aquatic communities do not indicate any effects consistent with contaminant impacts expected for above-background levels of arsenic and mercury recorded in RI/FS plant samples. In addition, although potential impacts at the individual level were predicted for wildlife species, detrimental or adverse impacts have not been observed in the field. This suggests that the potential effects may not occur. A comparison of the concentrations

of inorganic chemical concentrations in FEMP soils to regional background values indicate the mean FEMP concentrations may be similar to the upper 95 percent confidence levels of background values. This indication suggests that ecological risks estimated using background values of inorganics would be comparable to those estimated for the FEMP site, and emphasizes the conservative nature of the method used.

In summary, although radionuclides are the most ubiquitous contaminants at the FEMP, estimated ecological risks to both terrestrial and aquatic organisms are primarily associated with nonradioactive inorganic chemicals. Although estimated risks are substantial in some instances, they are based on soil inorganic chemical concentrations comparable to background levels, and deleterious effects have not been observed in the field. This suggests that current FEMP site-specific ecological risks are low. However, remedial actions are appropriate to address contaminants which have potential to cause harm in the future.

1.6.3 Operable Unit 4 Baseline Risk Assessment

This section summarizes the results of the Operable Unit 4 baseline risk assessment as presented in the RI Report for Operable Unit 4.

The baseline risk assessment is a process that estimates the human health risk associated with exposure to the chemical sources in Operable Unit 4 under the no-action alternative. The process quantifies the health risks to hypothetical receptors due to exposure from chemical sources in Operable Unit 4. The process analyzes the health consequences that could occur under different scenarios if no remedial actions are taken to address these identified environmental concerns. The baseline risk is the fundamental measure used to make comparisons against any changes that occur when various remedial alternatives are proposed to reduce the exposure levels of these chemicals. A health risk is calculated under each of the proposed remedies, and the resulting values are compared with the baseline value to identify where the reduction in human health risk is greatest. The process thereby provides a measure of the relative effectiveness of the different proposed remedial alternatives and their ability to reduce the risk to human health.

Baseline risks were calculated under two source-term scenarios to evaluate potential exposures to hypothetical receptors under the three land use scenarios previously described in section 1.6. The "current source term" scenario evaluates potential exposure to current sources within Operable Unit 4, including surface and berm soil, airborne contaminants, and surface water. The "future source term"

scenario evaluates additional sources that could result in the event that the Silo 3 structure collapsed and Silos 1 and 2 domes failed. Sources under the future source term scenario include contaminated ground water and sediment, in addition to Silo 3 wastes within the soil, air, and surface water. Under the current land use without access control and the future land use scenarios, risks are calculated for both the current source-term scenario and the future source-term scenario. Under the current land use with access control scenario, the future source-term scenario does not exist; if the site remains under the institutional control of DOE, the silos will not be allowed to fail. Thus, under the current land use with access control scenario, risk was calculated only for the current source-term scenario.

In summary, the five land use/source-term scenario combinations evaluated under the baseline risk assessment included:

Land Use Scenario	Source-Term Scenario
1. Current Land Use Without Access Control	Current Source Term
2. Current Land Use Without Access Control	Future Source Term
3. Current Land Use with Access Control	Current Source Term
4. Future Land Use	Current Source Term
5. Future Land Use	Future Source Term

Under the Current Land Use Without Access Controls scenarios in which the FEMP site is assumed to have been turned over to an industrial concern other than the DOE, potential receptors evaluated included an off-property farmer, a trespassing child, an on-property worker (groundskeeper), and an off-property user of surface water from the Great Miami River.

Under the Current Land Use with Access Controls scenarios where the site is assumed to remain under federal ownership and access restrictions continued, the potential receptors considered included an off-property farmer, a trespassing child, and an off-property user of surface water from the Great Miami River.

For the Future Land Use scenario where access controls are assumed to be absent, hypothetical receptors evaluated included a Reasonable Maximum Exposure (RME) resident farmer, a central tendency (CT) resident farmer, a resident child, an off-property farmer, and an off-property user of surface water from the Great Miami River.

The RME resident farmer considered under this scenario represents the maximum potential exposure to chemical and radiological constituents that a hypothetical on-property farmer could reasonably be expected to receive through viable pathways. The CT resident farmer is similar to the RME resident farmer except that risk assessment parameter values employed to calculate risks to this hypothetical receptor are adjusted to more closely reflect what an average person would normally receive from site contaminants through the same pathways.

The risk characterization results from the Operable Unit 4 risk assessment are presented in Tables 1-6 and 1-7. The tables summarize maximum radiological and chemical risks, as well as cumulative risk for each receptor by exposure scenario. Table 1-6 provides Incremental Lifetime Cancer Risks (ILCR) estimates for these exposure scenarios for both the current and future source-terms. The largest reported radiological risk values are from the silo and sediment environmental media. Table 1-7 provides the Hazard Indices (HIs) for noncarcinogenic constituents for each receptor by exposure scenario.

Of the scenarios evaluated, the current land use with access controls/current source-term scenario most closely approximates current conditions at the FEMP site. However, conservative assumptions were made in the evaluation of this scenario, consistent with those made for other scenarios, to ensure that the calculated baseline risk represents an upper bound. ILCR and HI results for this scenario are numerically the same as the results for the current land use scenario without access controls assuming the current source term; the presence or absence of access controls does not change the numerical values of exposure parameter values for receptors.

Under this scenario, the dominant radiological risk (5.0×10^{-3}) is to the trespassing child from Ra-226 plus progeny in soil and external radiation from the intact silos. The dominant chemical risk (4.0×10^{-5}) is to the off-property resident farmer due to ingestion of Indeno (1,2,3-cd) pyrene through meat and milk exposure routes, which is transported via the air pathway. The total calculated risk under this scenario is 5.0×10^{-3}.

The highest HI is 1.0 to the trespassing child and due primarily to antimony, chromium, and uranium in soil.

Of the remaining scenarios, the future land use/future source-term scenario represents the most conservative scenario considered under the baseline risk assessment. Within this scenario, a family is

TABLE 1-6

INCREMENTAL LIFETIME CANCER RISK SUMMARY ALL SOURCES/ALL PATHWAYS

Land Use/ Source Term Scenario	Type of Risk	Trespassing Child	Grounds Keeper	Off-Property Resident Farmer	Off-Property User of Surface Water	CT On-Property Resident Farmer	RME On-Property Resident Farmer	On-Property Resident Child
Current Land Use without Access Control/Current Source Term Scenario	Radiological Risk	5.0×10^{-3}	1.0×10^{-4}	1.0×10^{-8}	1.0×10^{-7}	NA*	NA	NA
	Chemical Risk	1.0×10^{-5}	2.0×10^{-5}	4.0×10^{-5}	1.0×10^{-7}	NA	NA	NA
	Total Risk	5.0×10^{-3}	1.0×10^{-4}	4.0×10^{-5}	3.0×10^{-7}	NA	NA	NA
Current Land Use without Access Control/Future Source Term Scenario	Radiological Risk	9.0×10^{-3}	2.0×10^{-2}	1.0×10^{-5}	1.0×10^{-6}	NA	NA	NA
	Chemical Risk	7.0×10^{-4}	5.0×10^{-4}	1.0×10^{-4}	7.0×10^{-7}	NA	NA	NA
	Total Risk	1.0×10^{-2}	2.0×10^{-2}	1.0×10^{-4}	2.0×10^{-6}	NA	NA	NA
Current Land Use with Access Control/Current Source Term Scenario	Radiological Risk	5.0×10^{-3}	NA	1.0×10^{-8}	1.0×10^{-7}	NA	NA	NA
	Chemical Risk	1.0×10^{-5}	NA	4.0×10^{-5}	1.0×10^{-7}	NA	NA	NA
	Total Risk	5.0×10^{-3}	NA	4.0×10^{-5}	3.0×10^{-7}	NA	NA	NA
Future Land Use/Current Source Term Scenario	Radiological Risk	NA	NA	1.0×10^{-8}	1.0×10^{-7}	4.0×10^{-4}	4.0×10^{-3}	9.0×10^{-3}
	Chemical Risk	NA	NA	4.0×10^{-5}	1.0×10^{-7}	5.0×10^{-3}	7.0×10^{-2}	5.0×10^{-2}
	Total Risk	NA	NA	4.0×10^{-5}	3.0×10^{-7}	5.0×10^{-3}	7.0×10^{-2}	6.0×10^{-2}
Future Land Use/ Future Source Term Scenario	Radiological Risk	NA	NA	1.0×10^{-5}	1.0×10^{-6}	1.0×10^{-1}	1.0×10^{0}	1.0×10^{-1}
	Chemical Risk	NA	NA	1.0×10^{-4}	7.0×10^{-7}	1.0×10^{-2}	2.0×10^{-1}	8.0×10^{-2}
	Total Risk	NA	NA	1.0×10^{-4}	2.0×10^{-6}	1.0×10^{-1}	>1.0	2.0×10^{-1}

*NA signifies not applicable.

TABLE 1-7

HAZARD INDEX SUMMARY ALL SOURCES/ALL PATHWAYS

Land Use/ Source Term Scenario	Type of Risk	Trespassing Child	Grounds Keeper	Off-Property Resident Farmer	Off-Property User of Surface Water	CT On-Property Resident Farmer	RME On-Property Resident Farmer	On-Property Resident Child
Current Land Use without Access Control/Current Source Term Scenario	Chemical Hazard Index	1.0	0.1	0.05	0.0004	NA*	NA	NA
Current Land Use without Access Control/Future Source Term Scenario	Chemical Hazard Index	60.0	20.0	5.0	0.002	NA	NA	NA
Current Land Use with Access Control/Current Source Term Scenario	Chemical Hazard Index	1.0	NA	0.05	0.0004	NA	NA	NA
Future Land Use/Current Source Term Scenario	Chemical Hazard Index	NA	NA	0.05	0.0004	6.0	10.0	70.0
Future Land Use/Future Source Term Scenario	Chemical Hazard Index	NA	NA	5.0	0.002	200	400	2000

*NA signifies not applicable.

assumed to have established a residence within the Operable Unit 4 boundaries. Additionally, the domes of Silos 1 and 2 are assumed to have failed and Silo 3 is assumed to have suffered total structural failure, spreading its contents to the surface soil of Operable Unit 4. The dominant radiological risk under this scenario approaches unity (1). The highest risk is to the RME on-property resident farmer and is due to external radiation exposure to concentrations of Ra-226 and Th-228 in soils. The dominant chemical risk (2.0×10^{-1}) is also to the RME on-property resident farmer and is due primarily to ingestion of arsenic and indeno (1,2,3-cd) pyrene through the meat and milk ingestion exposure routes. The total risk to the RME on-property resident farmer exceeds unity and is due primarily to the radiological risk associated with external exposure from Ra-226 and Th-228 in soil. The highest HI (2000) under this scenario is to the on-property resident child and is due primarily to ingestion of soil and foodstuffs along with dermal contact with soil materials containing arsenic.

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

2.1 INTRODUCTION

Identification, screening, and evaluation of potentially applicable technology types and process options are key steps in the FS process. The primary objective of this phase of the FS is to develop an appropriate range of remedial technologies and process options that will be developed into preliminary remedial alternatives. The criteria for identifying potentially applicable technologies are provided in EPA guidance (EPA 1988a) and in the NCP (EPA 1990). There is strong statutory preference for remedies that will result in a permanent solution, significant decrease toxicity, mobility, or volume, and provide long-term protection as identified in Section 121 of CERCLA, as amended. The primary requirements for the final remedy are that it be both protective of human health and the environment and comply with applicable regulatory requirements.

This section discusses the development and screening of the technologies and process options used to assemble the remedial action alternatives for Operable Unit 4. The technology screening process consists of a series of analytical steps that involve making successively more specific definitions of potential remedial activities. The steps include the following:

- Identification of volumes or areas of media
- Development of Remedial Action Objectives (RAOs)
- Identification of general response actions
- Identification and screening of remedial technologies and process options
- Selection and evaluation of process options

Figure 2-1 illustrates the general flow of the FS process and relates the process elements to the relevant section of the FS Report for Operable Unit 4.

The information in Section 2.0 is presented in a format consistent with EPA RI/FS guidance (EPA 1988a). In brief, Section 2.2 presents the development of RAOs for the media of concern in Operable Unit 4, including an estimate of the volume and area of contamination. Also addressed in Section 2.2 are preliminary remediation goals (PRGs) by media or cleanup criteria, where appropriate. Section 2.3 identifies components of Operable Unit 4 areas as subunits. Section 2.4 identifies the general response actions (GRAs) that will meet the RAOs identified in Section 2.2. Section 2.5 identifies the full range of potentially applicable technologies and associated process options and screens them based upon technical feasibility. Technologies and process options which

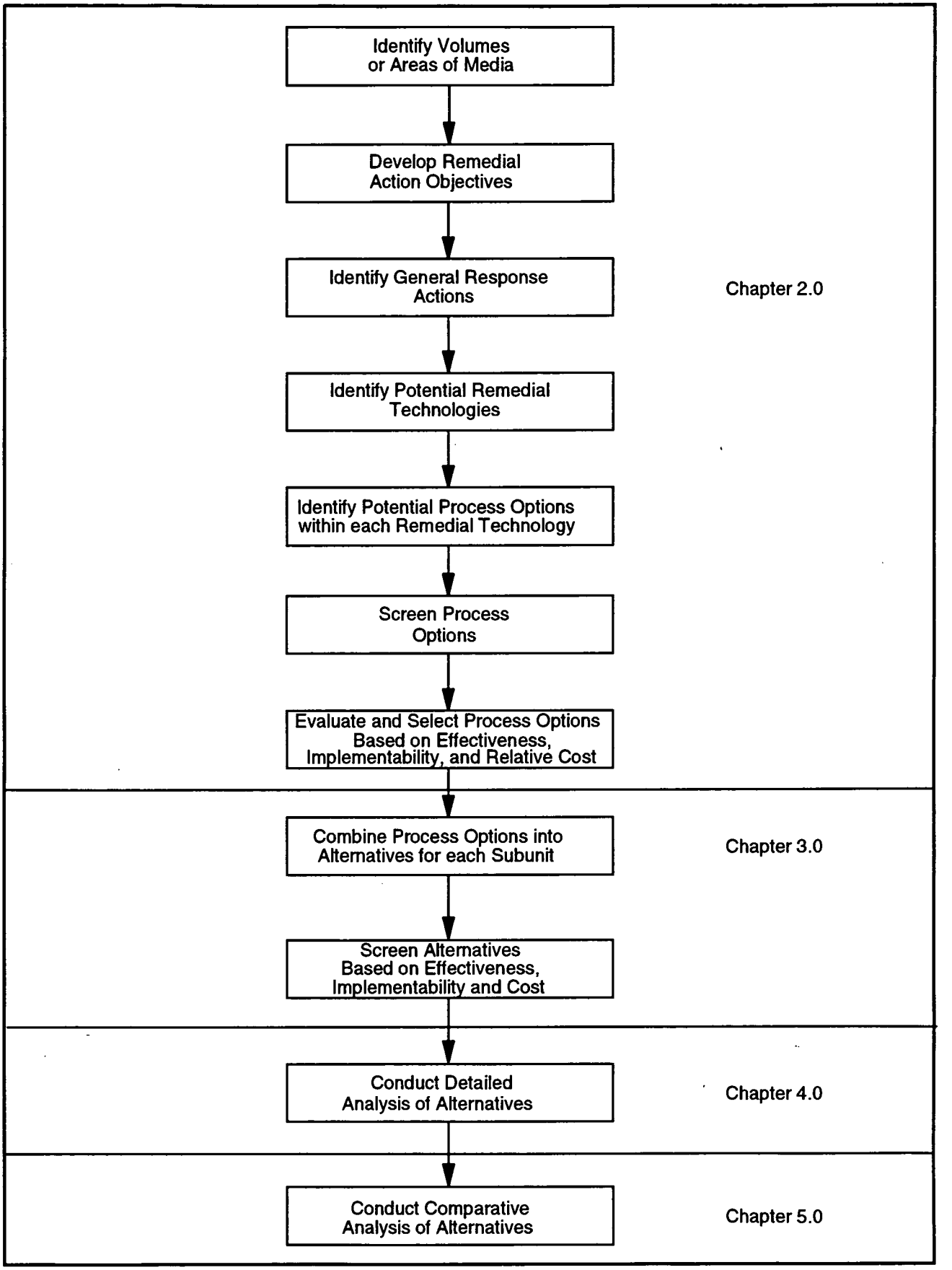

FIGURE 2-1
ELEMENTS OF THE FS PROCESS

pass the initial screening are evaluated in Section 2.6 against the criteria of effectiveness, implementability, and cost to select representative options for alternatives.

2.2 REMEDIAL ACTION OBJECTIVES

RAOs are site-specific, qualitative goals that define the objective of taking remedial actions. RAOs specify:

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

Because RAOs for protecting environmental receptors typically seek to preserve or restore a resource (e.g., groundwater and surface soil), they are expressed in terms of the medium of interest and target cleanup levels whenever possible (EPA 1988a).

Potential risks associated with exposures due to Operable Unit 4 contamination were assessed in considerable detail in the RI Report for Operable Unit 4 (DOE 1993a) to identify those media that should be addressed to achieve RAOs. From this assessment, contaminated media contained in Operable Unit 4 were identified:

- Waste material including K-65 residues, also known as "hot raffinates," contained in Silos 1 and 2 and the decant sump tank; and metal oxides, also known as "cold metal oxide," contained in Silo 3
- Structural material and equipment including concrete and metal structural materials used in the construction of Silos 1, 2, and 3, and contaminated equipment including the decant sump tank, process piping, process piping trench material, and existing RTS equipment
- Soil within the Operable Unit 4 boundaries including surface soil around the silos, subsurface soil beneath the silos and around pipe trenches, and berm soil around Silos 1 and 2
- Residual water including water contained in the decant sump tank, any water contained in Silo 4, and perched groundwater that may be encountered during potential remedial actions within the Operable Unit 4 boundaries

With the exception of perched water encountered during potential remedial actions, surface water and groundwater are not addressed as source media within this Operable Unit 4 FS. With regard to

surface water, there are no surface water impoundments within Operable Unit 4. Thus, surface water runoff during a rain event acts only as a transport mechanism for surface soil contamination not as a source. Potential remediation of groundwater contamination for the entire FEMP site is being addressed as part of Operable Unit 5. Thus, within this FS Report, groundwater is considered as an environmental receptor medium but not as a source term for which remedial actions are addressed. A preliminary volume estimate for materials considered for remediation under Operable Unit 4 is presented in Table 2-1. It should be noted that process knowledge clearly indicates that Silo 4 has never been used at the FEMP to store product or waste materials. On this basis, none of the estimated [510 m^3 (670 yd^3)] of construction materials comprising Silo 4 are considered contaminated.

To address the above three requirements, the development of RAOs is presented in three parts. First, the constituents of concern, by media, are identified. Second, allowable exposures in terms of the medium of interest are identified, and PRGs are established for environmental media. Third, these data are used to develop RAOs.

2.2.1 Constituents of Concern

Not all constituents identified during the Operable Unit 4 RI pose significant health risks. The Baseline Risk Assessment (BRA) evaluated constituents and exposure pathways to ascertain their potential present and future impacts on human health. Methods for establishing constituents of concern are defined in Appendix D of the RI Report for Operable Unit 4. In general, constituents that resulted in risks to a receptor of greater than 10^{-6} or which yielded a hazard quotient greater than 0.2 were designated as constituents of concern.

Radiological constituents of concern, by media, are shown in Table 2-2. Chemical constituents of concern, by media, are shown in Table 2-3.

2.2.2 Preliminary Remediation Goals

In the early stages of the RI/FS, as stated in the SWCR (DOE 1993b), PRGs are used as action levels to determine if constituents in the environment need to be further addressed. PRGs are not action levels for remedial actions. PRGs are chemical-specific, medium-specific concentration limits necessary to address all contaminants and all pathways found to be of concern during the BRA process. PRGs are based on the following:

TABLE 2-1

MATERIAL VOLUME ESTIMATES
OPERABLE UNIT 4

Media	Volume		
Waste Material	Waste Residue	Bentonite Clay	Total Waste
Silo 1 contents[a]	4,293 yd^3	467 yd^3	4,760 yd^3 (3,640 m^3)
Silo 2 contents[a]	3,719 yd^3	411 yd^3	4,130 yd^3 (3,150 m^3)
Silo 3 contents[b]	5,088 yd^3		5,088 yd^3 (3,890 m^3)
Decant sump tank sludge[b]			1,000 gallons (3,785 L)
Structural Material and Equipment[c]			
Silo 1, 2, and 3 structures			2,000 yd^3 (1,530 m^3)
Silo 4 structure			670 yd^3 (510 m^3)
Decant sump tank, process piping, process piping trenches, radon treatment system			370 yd^3 (280 m^3)
Drum handling building pad, sump lift station concrete			30 yd^3 (20 m^3)
Soil			
Berm soil[d]			10,540 yd^3 (8,060 m^3)
Surface soil[e]			4,440 yd^3 (3,400 m^3)
Subsoil[f]			14,650 yd^3 (11,200 m^3)
Residual Water			
Decant sump tank water[g]			8000 gallons (30,280 L)
Residual water (Silo 4)[h]			13,000 gallons (49,210 L)
Water encountered during remedial actions			Unknown

[a]Volume estimate based on silo surface mapping results
[b]Volume estimate based on visual observations during sampling operations
[c]Volume estimate based on available construction drawings. Note that Silo 4 structure considered non-contaminated by process knowledge.
[d]Volume estimate based on quantity of soils comprising berms
[e]Volume estimate based on soil depth of 6 inches across entire OU4 area
[f]Volume estimate based on soil depth of 5 feet extending beneath Silos 1 and 2 to toe of berm, includes 5 foot soil depth beneath decant sump tank
[g]Assumes refilling of decant sump tank by infiltrating liquid after the most recent pumping of the decant sump tank as a maintenance action (January 1993).
[h]Volume assumed to collect based on historical in-leakage of rainwater through silo dome.

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TABLE 2-2

RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN OPERABLE UNIT 4

	Silos 1 & 2	Silo 3	Structure/ Equipment[a]	Soil	Residual Water[b]
Actinium-227	X	X	X	NA	X
Lead-210	X	X	X	X	X
Polonium-210	X	c	X	X	X
Protactinium-231	X	X	X	NA	X
Radium-224	d	X	X	e	X
Radium-226	X	X	X	X	X
Radium-228	d	X	X	X	X
Strontium-90	NA	NA	NA	X	X
Technetium-99	NA	NA	NA	X	X
Thorium-228	X	X	X	X	X
Thorium-230	X	X	X	X	X
Thorium-232	X	X	X	X	X
Uranium-234	X	X	X	X	X
Uranium-235/236	X	X	X	NA	X
Uranium-238	X	X	X	X	X

[a]No samples were collected from structures/equipment; however, it is assumed that constituents present in silos have permeated into the concrete structure.
[b]Constituents are primarily based on results of decant sump tank sampling. In addition, constituents detected in silos are assumed to be present in residual water.
[c]This radionuclide is not listed as a constituents of concern in the RI BRA; however, the risk contribution is included in the risk calculations for Pb-210 plus progeny.
[d]Ra-224 is not listed as a constituents of concern in the RI BRA; however, the risk contribution is included in the risk calculations for Th-228 plus progeny. Ra-224 and Ra-228 sample analytical results for the silos are reported as non-detections.
[e]Constituent detected once and UTL test suggests that data are less than background while histogram comparison suggests concentration exceeds background. Also, given the fact parents of this constituent are not constituents of concern, this constituent is assumed to be an anomaly.

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TABLE 2-3

CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN
OPERABLE UNIT 4

Chemical	Silos 1 & 2	Silo 3	Structure/ Equipment[a]	Soil	Residual Water[b]
Inorganics					
Antimony	X	NA	X	X	X
Arsenic	X	X	X	X	X
Barium	X	X	X	X	X
Beryllium	X	X	X	X	X
Boron	X	NA	X	NA	X
Cadmium	X	X	X	X	X
Chromium	X	X	X	X	X
Cobalt	X	X	X	NA	X
Copper	X	X	X	X	X
Cyanide	X	NA	X	X	X
Lead	X	X	X	NA	X
Manganese	NA	X	X	NA	X
Mercury	X	X	X	NA	X
Molybdenum	X	NA	X	X	X
Nickel	X	X	X	X	X
Selenium	X	X	X	NA	X
Silver	X	X	X	X	X
Thallium	X	X	X	X	X
Uranium	X[c]	X[c]	X	X[c]	X
Vanadium	X	X	X	X	X
Zinc	X	X	X	X	X
Organics					
2-Butanone	X	NA	X	X	X
2-Hexanone	X	NA	X	NA	X
2-Nitrophenol	NA	X	X	NA	X
4-Methyl-2-pentanone	X	NA	X	NA	X

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TABLE 2-3
(Continued)

Chemical	Silos 1 & 2	Silo 3	Structure/ Equipment[a]	Soil	Residual Water[b]
Organics (Continued)					
4-Nitrophenol	NA	X	X	NA	X
Acenaphthylene	NA	NA	NA	X	X
Acetone	X	NA	X	X	X
Aldrin	X	NA	X	NA	X
Anthracene	NA	NA	NA	X	X
Aroclor-1248	X	NA	X	NA	X
Aroclor-1254	X	NA	X	X	X
Aroclor-1260	X	NA	X	NA	X
Benzo(a)anthracene	NA	NA	NA	X	X
Benzo(a)pyrene	NA	NA	NA	X	X
Benzo(b)fluoranthene	NA	NA	NA	X	X
Benzo(g,h,i)perylene	NA	NA	NA	X	X
Benzoic acid	X	NA	X	X	X
Bis(2-ethylhexyl)phthalate	X	NA	X	X	X
Carbon tetrachloride	X	NA	X	NA	X
Chrysene	NA	NA	NA	X	X
4,4'-DDE	X	NA	X	NA	X
4,4'-DDT	X	NA	X	NA	X
Di-n-butyl phthalate	X	NA	X	X	X
Di-n-octyl phthalate	X	NA	X	NA	X
Dibenzo(a,h)anthracene	NA	NA	NA	X	X
Dieldrin	X	NA	X	NA	X
Diethyl phthalate	X	NA	X	NA	X
Dimethyl phthalate	X	NA	X	NA	X
Endosulfan I	X	NA	X	NA	X
Endosulfan II	X	NA	X	NA	X
Endrin	X	NA	X	NA	X

TABLE 2-3
(Continued)

Chemical	Silos 1 & 2	Silo 3	Structure/ Equipment[a]	Soil	Residual Water[b]
Organics (Continued)					
Fluoranthene	X	NA	X	X	X
Heptachlor epoxide	X	NA	X	NA	X
Indeno(1,2,3-cd)pyrene	NA	NA	NA	X	X
Methylene chloride	X	NA	X	X	X
N-nitroso-di-n-propylamine	X	NA	X	NA	X
Phenanthrene	NA	NA	NA	X	X
Phenol	X	NA	X	X	X
Pyrene	X	NA	X	X	X
Tetrachloroethene	X	NA	X	NA	X
Toluene	X	NA	X	X	X
Tributyl phosphate	X	NA	X	NA	X
Xylenes (total)	X	NA	X	X	X

[a]No samples collected from structures/equipment; however, it is assumed that constituents present in silos have permeated into the concrete structure.
[b]Constituents are primarily based on results of decant sump tank sampling. In addition, constituents detected in silos and soils are assumed to be present in residual water.
[c]Analysis for uranium by inductively coupled argon plasma was not performed, analysis by radiological methods.

- For chemical toxicants, an HI = 0.2
- For chemical and radiation carcinogens, an ILCR = 10^{-6}
- For radionuclides, dose limit ARARs and to be considered (TBCs) requirements
- Pertinent ARARs

PRGs must comply with applicable or relevant and appropriate requirements (ARARs) and be protective of human health and the environment. However, ARARs do not exist for all constituents of concern. Moreover, some ARAR-based PRGs are less stringent than PRGs based on a 10^{-6} to 10^{-4} risk range and therefore do not necessarily meet the "protectiveness of human health" objective. Therefore, both ARAR-based and risk-based PRGs have been developed for the FEMP site.

Certain media associated with Operable Unit 4, such as groundwater, are outside the scope of remedial actions being considered under this FS. PRGs are presented for groundwater, however, because groundwater does serve as an environmental receptor and a pathway for uptake of constituents of potential concern by man. PRGs are not presented for waste material contained in the silos because this material is heavily contaminated and would never be suitable for release. Table 2-4 summarizes the media addressed within this section and provides the rationale for development of PRGs, or cleanup criteria, for those media.

The following sections identify the basis for the PRGs presented herein. Further, they address the ARARs, TBCs, risk ranges, and hazard quotients for radiological and chemical constituents in surface soil and groundwater used in developing the PRGs.

2.2.2.1 RISK-BASED PRG DEVELOPMENT

Potential health effects resulting from exposures to radioactive and chemical contaminants are divided into two categories: carcinogenic and noncarcinogenic effects. For carcinogens, EPA has identified in the NCP a target range for incremental risks of 10^{-6} to 10^{-4}, or 1 in 1,000,000 to 1 in 10,000, to limit the possibility that an individual will develop cancer due to exposures to residual contaminants at an NPL site [40 (Code of Federal Regulations) CFR 300]. As part of cleanup at NPL sites, EPA strives to manage possible incremental cancer risks within the target range with 10^{-6} generally serving as the point of departure. For sites where the total estimated ILCR for each receptor is less than 10^{-4} and the HI is less than 1, action is usually not warranted.

TABLE 2-4

DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS OPERABLE UNIT 4

Medium	Source of Preliminary Remediation Goals	Comments
Waste Material	Preliminary remediation goals are not relevant for waste material such as that contained in Silos 1, 2, and 3 because this material is heavily contaminated and would not be considered releasable. Residual material remaining after the potential removal of silo contained wastes will be addressed as part of structural materials and soil.	Exposure mitigation measures (e.g., containment, treatment, removal and disposal) will be considered as part of this FS.
Structural Material and Equipment	Radiological release criteria were previously developed for structural building material and equipment with superficial contamination (NRC). These criteria were adopted from guidelines established by the U.S. Nuclear Regulatory Commission (NRC) guidance and incorporated into DOE Order 5400.5. Therefore, no new radiological release criteria (or preliminary remediation goals) for structural material and equipment will be developed as part of this FS.	Radiological release criteria have not been established by the DOE or the NRC for material with volumetric contamination, such as concrete. Protocol for demonstrating construction materials such as concrete are not contaminated will be provided in Remedial Design/Remedial Action Work Plan.
Soil	Regulatory-based chemical and radiological cleanup criteria are not available for most constituents of concern in soil. FEMP site soil cleanup criteria will be developed as part of OU5, which includes remediation of site-wide soils. Soil PRG's developed as part of this FS will be subject to modification on the basis of additional information developed through Operable Unit 5.	No comments.
Residual Water	Regulatory-based cleanup criteria are not available for all constituents of concern existing in residual liquids or that may be transported from OU4 sources. Residual liquids will be directed through existing plant wastewater treatment systems. Discharges will be consistent with existing NPDES permit requirements and commitments defined under the South Groundwater Contamination Plume Removal Action. PRGs were therefore not derived for residual water within Operable Unit 4.	No comments.

TABLE 2-4
(Continued)

Medium	Source of Preliminary Remediation Goals	Comments
Groundwater	Regulatory-based chemical and radiological cleanup criteria are not available for all contaminants of concern in groundwater. Final FEMP site groundwater cleanup criteria will be developed as part of OU5 which includes remediation of site-wide groundwater. The chemical and radiological PRGs in this FS represent the concentration of a particular constituent of concern in groundwater presenting a specific ILCR or HI. These concentrations could occur in groundwater as a result of migration from residuals within OU4 or stabilized source materials. These PRGs are established to provide a relative performance measure for groundwater protection that a given alternative must attain to be protective of human health and the environment.	Decisions regarding remediation of groundwater will be addressed by DOE as a part of FEMP site OU5. Separation of final groundwater cleanup decisions from those considered under OU4 allow further characterization of groundwater and consideration of remedial action for site groundwater as a whole.

Although the upper end of the target range is generally used to make risk management decisions to determine whether or not remedial actions are necessary or warranted, EPA does not consider 10^{-4} a discrete limit. That is, risks above that level may be considered acceptable based on site-specific conditions (EPA 1991). In addition, factors other than the results of the site-specific risk assessment are used to make the final risk management decision including conservative assumptions applied to estimate risks from possible exposures at the site and other health-based guidance available for certain constituents.

These considerations were incorporated into the development of PRGs for Operable Unit 4. The following general principles for carcinogenic and noncarcinogenic constituents were applied to identify general risk-based objectives for remedial actions:

- Exposures to radionuclides should be reduced to levels as low as reasonably achievable (ALARA) as limited by the natural presence of radionuclides in the soil and groundwater.

- Exposures to carcinogenic chemicals should not result in an ILCR of more than 10^{-6} to 10^{-4} as limited by the natural presence of chemicals in soil and groundwater.

- Exposures to noncarcinogenic constituents should not result in significant adverse health effects, indicated by a HI greater than 1.0, as limited by the natural presence of chemicals in the soil and groundwater.

- Exposures of biota should be limited to levels that are not associated with significant adverse ecological effects as limited by the natural presence of radionuclides and chemicals in the soil and groundwater.

The methods and assumptions used to estimate carcinogenic and noncarcinogenic effects from exposures to site constituents are described in the RI Report for Operable Unit 4 (DOE 1993a) and are also described in Appendix D of this FS. The discussions presented in the remainder of this section are based on those detailed analyses.

In developing risk-based PRGs, target risk levels are established for carcinogens, and target hazard quotients and target HIs (the sum of the target hazard quotients) are established for noncarcinogens.

Once established, these target risk levels are used in calculating the PRGs. Toxicity data used to develop PRGs are cancer slope factors and reference doses from the Integrated Risk Information System (IRIS) database (EPA 1992a) and Health Effects Assessment Summary Tables (EPA 1992b).

One goal of the NCP is to manage total, site-wide risks such that the sum of all risks does not exceed 10^{-4}. The default target risk of 10^{-6} is suggested by EPA (1991) as the point of departure. In keeping with the NCP, PRGs were calculated for both 10^{-4} and 10^{-6} risk levels, using 10^{-6} as the target risk to ensure that cumulative site-wide risk does not exceed 10^{-4}.

EPA indicates that the cumulative site HI should be less that 1.0. However, no EPA guidance is available on apportioning the allowable level among the range of constituents in various environmental media. The most relevant guidance is provided by the Office of Drinking Water which, in calculating maximum contaminant level goals (MCLGs), uses a relative source contribution (RSC) factor to account for other sources of exposure (EPA 1989a). Because it is not known what additional sources are contributing to total exposure, this default RSC of 0.20 was used to develop chemical-/media-specific PRGs to ensure that the total HI does not exceed 1.0.

Following completion of the BRA, the land use scenarios, exposure parameters, and constituents of concern employed to derive PRGs were reviewed to determine whether refinements were required. As a result of this review, the PRGs originally appearing in the SWCR have been revised to more appropriately reflect Operable Unit 4 conditions. The risk-based PRGs presented in Part III of the SWCR were typically based upon the consideration of a single exposure pathway for each media for the identified receptors. For example, for the groundwater media, an ingestion pathway was examined assuming consumption of 2 liters of water per day for 52 years. An exception to this single pathway framework was the development of PRGs for the recreational user as defined in the SWCR. For the recreational user, the SWCR report considered ingestion and external exposure for the development of PRGs for the soil media. Subsequent to the SWCR, the BRA for Operable Unit 4 provided a more comprehensive quantitative examination of the viable pathways of exposure to each of the receptors considered. The relative significance of a given pathway to an individual receptor was examined in the BRA through the derivation of Unit Risk Factors. Unit Risk Factors were derived for each constituent of concern to describe the risk contribution by pathway for a unitized (i.e., typically per pCi/g or pCi/m^3) exposure point concentration. These Unit Risk Factors were then multiplied by the respective exposure point concentrations determined from fate and transport

modeling for each constituent of concern to arrive at ILCRs. Unit Risk Factors from the RI Report for Operable Unit 4 were employed to support development of the PRGs appearing in this section.

While the RI Report/BRA presented risk information, including Unit Risk Factors, for a range of receptors under current and future land use scenarios, these land use assumptions and receptors were refined to provide managers with the range of necessary information to support informed decisions in establishing final cleanup goals. In accordance with the Risk Assessment Work Plan Addendum (DOE 1992) and to ensure consistency with EPA's guidance "Part B, Development of Risk-Based PRGs," the BRAs for Operable Unit 4 evaluated a future land use scenario which included the loss of federal/governmental ownership of the FEMP and the establishment of a family farm on the site. This land use scenario was evaluated to understand the potential worst-case exposures to site contaminants. This future land use scenario is completely described in the RI Report for Operable Unit 4 (DOE 1993a). In addition to the future land use scenario examined in the RI Report, it is conceivable as part of any future land use of the FEMP, the federal government could retain ownership of the property to preclude further development of the property including the establishment of residential or farming units. This future land use scenario, termed Future Land Use With Continued Federal Ownership, does not assume any form of perpetual maintenance or active access restrictions to the site following the completion of remedial actions and attainment of site-wide remedial goals. This retention of ownership would support the application of some form of institutional control.

For purposes of providing added information for use in decision making, PRGs were developed for both the future land use with and without the assumption of continued federal ownership. To establish the PRGs for the future land use without continued ownership scenario, a on-property resident farmer was adopted as the receptor. For PRG development, the on-property resident farmer was assumed to be exposed to constituents of concern in the soil via the inhalation of dusts, consumption of farm products contaminated by dust deposition, oral ingestion of soil, dermal contact, and external radiation pathways associated with the soils. Additionally, the on-property farmer was assumed to be exposed to constituents of concern in groundwater through ingestion. Unit Risk Factors from the RI Report were employed to evaluate each of these pathways.

For the purposes of establishing a PRG for the future land use with continued federal ownership scenario, an on-property receptor was employed assuming a recreational type exposure scenario. The recreational type scenario was employed because it represents an upper bound estimate of the

exposures a receptor could reasonably be expected to receive under the assumption that the federal government continues to exercise it rights of ownership to preclude site development.

Unit Risk Factors were not presented for the recreational user in the RI Report. Equations used for evaluating exposure under the future land use with continued federal ownership scenario are modified versions of the equations employed for the future land use without federal ownership. The receptor considered for PRG development for the future land use with continued federal ownership is an individual who plays on the property as a child and uses the property less frequently for recreational activities as an adult, perhaps for baseball games, picnics, or similar activities. It is assumed that the child is exposed to the site two hours/day for 120 days/year over a period of six years (age 7-12). The adult is assumed to visit the site one hour/day for 40 days/year over a period of 32 years. To evaluate cancer risk, both the child and adult exposure periods were evaluated. The recreational user is assumed to be exposed to soil contaminants via the oral ingestion, dermal contact, inhalation of dusts, and external radiation pathways. Groundwater PRGs were not developed for the recreational user as there were no viable pathways of exposure.

Finally, PRGs were developed for soil for an off-property farmer. Exposure pathways from soil to this receptor were considered identical for both the Future Land Use With and Without Continued Federal Ownership scenarios. The off-property farmer is assumed to be exposed to soils within the Operable Unit 4 area through the inhalation of re-suspended dust containing constituents of concern and the consumption of farm products (i.e., milk, meat, and vegetables) contaminated by dust deposition. Example calculations are provided in the respective sections presenting soil and groundwater PRGs.

ARAR/TBC PRG Development

Chemical-specific ARARs were also examined to identify PRGs for Operable Unit 4 constituents of concern. These ARARs included non-zero MCLGs and Maximum Contaminant Levels (MCLs) for drinking water. Select other considerations, including available guidance and health advisories were examined to identify PRGs, termed TBC based PRGs. TBC guidance examined included DOE orders, ecological benchmark criteria, and drinking water health advisories.

2.2.2.2 As Low As Reasonably Achievable

In addition to establishing PRGs that comply with ARARs and are protective of human health and the environment, DOE plans to apply the principles of ALARA during remedial actions at the FEMP site.

The goal of DOE's ALARA process is to reduce exposures and the risk associated with residual contamination to levels that are "as low as reasonably achievable" considering technical, economic, and social constraints as appropriate. In applying the ALARA process at the FEMP site, the two factors used in developing PRGs (ARARA-based environmental standards and protectiveness of human health and the environment) are combined with technical and economic considerations in order to identify the levels of risk reduction that might reasonably be achieved.

The ALARA process includes both planning and field components. The discussions presented in this section are consistent with the planning component of ALARA, in which PRGs are estimated for residual contamination based on hypothetical exposures. This initial analysis will be used to support implementation of ALARA in the field, where additional contamination might be removed below those levels determined in the planning phase when reasonably achievable based on specific field conditions.

As specified previously, ALARA is site specific. The application of ALARA at another site, with different contaminants and exposure scenarios, would invariably produce different results.

2.2.2.3 Preliminary Remediation Goals for Soils

Table 2-5 presents the PRGs for soil. It should be noted that PRGs for soils were only derived for those carcinogenic COCs exhibiting an ILCR greater than 10^{-6} to the on-property farmer, under a current source term scenario as defined in Table D.II-17 of the RI Report for Operable Unit 4. As previously discussed, risk-based PRGs have been derived for receptors under two land use scenarios, Future Land Use With and Without Continued Federal Ownership. For the derivation of these risk-based PRGs, the progeny isotopes of radionuclides present at the FEMP site have been included within the results of the PRG calculation for the parent isotope. For example, U-238 is a radionuclide of concern at the FEMP site. If the presence of its two immediate short-lived progeny is neglected, the risk-based PRG for a residential farmer exposed to U-238 in soil is approximately 23 pCi/g. Including its two short-lived progeny yields a PRG of 0.47 pCi/g (Table 2-5). In another example, Ra-226 without progeny would have a PRG of about 1.5 pCi/g for the same scenario. Including its short-lived progeny reduces the PRG in soil to 0.04 pCi/g (Table 2-5). The PRGs presented in Table 2-5 consider contributions of radioactive progeny to be an integral part of the total risk from the parent nuclide.

PRELIMINARY REMEDIATION GOALS - SOILS

Chemical	Future Land Use Without Continued Federal Ownership (Resident Farmer)			Future Land Use With Continued Federal Ownership (Recreational User)			Off-property Resident Farmer			ARAR/ TBC	Background
	HI=0.20 RfD-Based PRG[a]	10^{-4} Risk-Based PRG, Above Background[b]	10^{-6} Risk-Based PRG, Above Background[b]	HI=0.20 RfD-Based PRG[d]	10^{-4} Risk-Based PRG, Above Background[e]	10^{-6} Risk-Based PRG, Above Background[f]	HI=0.20 RfD-Based PRG[a]	10^{-4} Risk-Based PRG, Above Background	10^{-6} Risk-Based PRG, Above Background	PRG	95th Percentile
Radionuclides (pCi/g)											
Pb-210 + 2 progeny		3.3	0.033		7700	77		392,000	3920		1.33
Ra-226 + 5 progeny[h]		4.0	0.04		37	0.37		1,170,000	11700	5[g]	1.45
RA-228 + 1 progeny		0.83	0.0083		77	0.77		2,780,000	27800		1.19
Sr-90 + 1 progeny		1.3	0.013		142,000	1420		606,000	6060		
Tc-99		1.6	0.016		3,870,000	38,700		417,000	4170		
Th-228		0.43	0.0043		40	0.4		73,300	733		1.43
U-238 + 2 progeny[h]		47	0.47		6000	60		109,000	1090		1.22
Inorganics (mg/kg)											
Antimony	0.65			1030			1120				7.7
Arsenic	2.7	12	0.012	770	1600	16	990	220	2.2		8.45
Barium	128			9120			c				91.3
Cadmium	0.71			2560			715				0.82
Chromium (III)	29			c			c				15.5
Copper[i]											14.1
Molybdenum	5			c			5800				2.6
Nickel	30			c			c				20.9
Silver	0.89			2560			1140				2.6
Thallium	0.32			154			209				0.58

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Chemical	Future Land Use Without Continued Federal Ownership (Resident Farmer)			Future Land Use With Continued Federal Ownership (Recreational User)			Off-property Resident Farmer			ARAR/ TBC	Background
	HI=0.20 RfD-Based PRG[a]	10^{-4} Risk-Based PRG, Above Background[b]	10^{-6} Risk-Based PRG, Above Background[b]	HI=0.20 RfD-Based PRG[d]	10^{-4} Risk-Based PRG, Above Background[e]	10^{-6} Risk-Based PRG, Above Background[e]	HI=0.20 RfD-Based PRG[a]	10^{-4} Risk-Based PRG, Above Background	10^{-6} Risk-Based PRG, Above Background	PRG	95th Percentile
Vanadium	109			c			c				30.4
Zinc	8.1			c			10600				62.2
Organics (mg/kg)											
2-Butanone	0.21			c			278				
Benzo(a)anthracene[i]		0.2	0.002		7.9	0.079		35	0.35		
Benzo(a)pyrene		0.063	0.00063		7.9	0.079		14	0.14		
Benzo(b)fluoranthene[i]		0.081	0.00081		3.8	0.38		15	0.15		
Benzo(g,h,i)perylene[i]											
Chrysene		0.2	0.002		7.9	0.079		35	0.35		
Di-benzo(a,h)anthracene[i]		0.17	0.0017		7.9	0.079		31	0.31		
Fluoranthene	64			36			c				
Indeno(1,2,3-cd)pyrene[i]		0.0088	0.000088		73	0.73		1.7	0.017		
Methylene chloride	0.68	1.0	0.01	c	43,000	430	1230	280	2.8		
Phenanthrene[i]											
Toluene	21			7760			c				

[a] PRG developed using unit Risk Factors from the OU4 baseline risk assessment.
[b] PRG developed using unit Risk Factors from the OU4 baseline risk assessment.
[c] PRG is greater than 10,000 mg/kg
[d] PRGs developed using parameters for recreational exposures and HEAST.
[e] PRGs developed using parameters for recreational exposures and HEAST and IRIS.
[f] PRG based on 100 mrem dose limit for exposures to the general public (10 CFR 20) and a CEDE DCFs from EPA (1988b). The calculated dose-based PRG has been divided by 100 to account for the fact that the 100 mrem limit is for all exposures, while the PRG is for a single exposure pathway and radionuclide. Exposure pathways and parameters are the same as those used for risk-based recreational PRGs.
[g] First 15 cm depth (40 CFR 192).
[h] The methodology used to calculate PRGs results in different values for different isotopes of a given radionuclide. In most cases, this is due to differences in external dose rate factors among isotopes. The lowest value calculated for a given radionuclide will drive the choice of the PRG used in design of remedial alternatives.
[i] No toxicity data available to develop a PRG.
[j] Requirements for PCB Spill Cleanup, 40 CFR 761.125.
[k] Underground storage tank soil cleanup levels for Category I Situations OAC 1301-7-9-13.

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The PRGs for soils were calculated using the unit risk factors presented in Appendix D.1 of the RI Report for Operable Unit 4 for all receptors with the exception of the recreational user. One example calculation is provided for each of the receptors below.

For each of the receptors, the PRG was derived as being:

$$\text{PRG} = \frac{\text{Target Risk}}{\text{Sum of Unit Factors}}$$

For PRG development, a target risk for both chemical and radiological carcinogenic effects of both 10^{-4} and 10^{-6} were employed to derive PRGs for each of the receptors. A target value (HI) of 0.2 was employed for non-carcinogenic effects.

To support the derivation of PRGs, it is assumed that dust from soils are inhaled by the receptor and deposited on the crops and forage. The on- and off-property farmers are assumed to then consume the crops, eat meat from cows grazing on the forage, and drink milk from cows grazing on the forage. Dust resuspension and transport modeling was performed for the RI Report for Operable Unit 4 to examine exposure point concentrations both on-property and off-property as a result of baseline conditions with Operable Unit 4. These modeling results were used to calculate resuspension factors and ultimately soil concentration based PRGs.

$$\text{Resuspension Factor} = \frac{\text{COC Exposure Point Concentration From RI}}{\text{COC Soil Concentration Source Term in RI}}$$

For U-238:

Off-property Farmer - 1.5×10^{-7}

On-property Farmer - 2.2×10^{-6}

Recreational User - Same as On-property Farmer

To convert from a given exposure point air concentration to a soil concentration

$$\text{Soil concentration (pCi/g)} = \frac{\text{Air Concentration}}{\text{Resuspension Factor}}$$

For the Off-Property farmer for U-238, the PRG was calculated as follows:

Off-property farmer is assumed to inhale the dust particulate and consume the farm produce contaminated by particulate deposition from Operable Unit 4 for a lifetime of 70 years.

Unit Risk Factor Inhalation of Dust	=	6.0×10^{-3} $(pCi/m^3)^{-1}$
Unit Risk Factor Ingestion of Vegetables	=	5.0×10^{-5} $(pCi/m^3)^{-1}$
Unit Risk Factor Ingestion of Meat	=	6.9×10^{-7} $(pCi/m^3)^{-1}$
Unit Risk Factor Ingestion of Milk	=	8.3×10^{-6} $(pCi/m^3)^{-1}$
Sum Unit Risk Factor	=	6.1×10^{-3} $(pCi/m^3)^{-1}$
Air PRG = $1 \times 10^{-6} / 6.1 \times 10^{-3}$	=	1.64×10^{-4} (pCi/m^3)

Soil PRG for U-238 for the off-property farmer then would be calculated as:

Soil PRG (pCi/g) = $1.64 \times 10^{-4}/1.5 \times 10^{-7}$ = 1093 pCi/g

For the on-property Resident Farmer for U-238 for 10^{-6} ILCR the PRG was calculated as follows:

The on-property resident farmer is assumed to live on the residual soils within Operable Unit 4. The resident farmer is exposed to COCs in soils by incidental ingestion, dermal contact, consumption of meat, milk, and produce, and direct radiation. These are summarized through the use of unit risk factors for air and soil exposure pathways as follows:

Air Exposures:		
Unit Risk Factor Inhalation of Dust	=	6.0×10^{-3} $(pCi/m^3)^{-1}$
Unit Risk Factor Ingestion of Vegetables	=	5.0×10^{-5} $(pCi/m^3)^{-1}$
Unit Risk Factor Ingestion of Meat	=	6.9×10^{-7} $(pCi/m^3)^{-1}$
Unit Risk Factor Ingestion of Milk	=	8.3×10^{-6} $(pCi/m^3)^{-1}$
Sum Unit Risk Factor	=	6.1×10^{-3} $(pCi/m^3)^{-1}$
Soil Exposures:		
Unit Risk Factor Incidental Ingestion	=	1.2×10^{-7} $(pCi/g)^{-1}$
Unit Risk Factor External Radiation	=	1.5×10^{-6} $(pCi/g)^{-1}$
Unit Risk Factor Ingestion of Vegetables	=	3.3×10^{-7} $(pCi/g)^{-1}$
Unit Risk Factor Ingestion of Meat	=	9.5×10^{-9} $(pCi/g)^{-1}$
Unit Risk Factor Ingestion of Milk	=	1.1×10^{-7} $(pCi/g)^{-1}$
Sum Unit Risk Factor	=	2.1×10^{-6} $(pCi/g)^{-1}$

These two exposure pathways were then combined to arrive at a soil PRG.

Air Unit Risk-Based on Soil Concentration = Air Unit Risk x Resuspension Factor

$1.3 \times 10^{-8} = 6.1 \times 10^{-3} \times 2.2 \times 10^{-6}$

Sum air and soil pathways:

Air Exposure Unit Risk Factor	=	1.3×10^{-8}
Soil Exposure Unit Risk Factor	=	2.1×10^{-6}
		2.1×10^{-6}

$$\text{Soil PRG} = \frac{1 \times 10^{-6}}{2.1 \times 10^{-6}} = 0.47 \text{ pCi/g U-238}$$

For the Recreational User for U-238 for 10^{-6} ILCR, the PRG was calculated as follows:

The recreational user is assumed to be exposed to Operable Unit 4 soil via incidental ingestion, inhalation of particulates, and external radiation. The recreational user is assumed to be present with Operable Unit 4 as an adult and a youth for 40 days and 110 days respectively each year for a period of one and two hours per day respectively. The breathing rate is assumed to be $20m^3$/day and the ingestion rate is assumed to be 100 mg soil per day.

The Unit Risk Factors are:

Unit Risk Factor Incidental Ingestion	=	5.5×10^{-10} $(pCi/g)^{-1}$
Unit Risk Factor External Radiation	=	1.6×10^{-8} $(pCi/g)^{-1}$
Unit Risk Factor Inhalation of Particulates	=	3.7×10^{-11} $(pCi/g)^{-1}$

Sum Unit Risk Factor		1.67×10^{-8}

The soil PRG for the recreational user for a 10^{-6} ILCR for U-238 then would be calculated as:

$$\text{Soil PRG (pCi/g)} = 1 \times 10^{-6} / 1.67 \times 10^{-8} = 60 \text{ pCi/g}$$

Values representing 10^{-6} risk-based PRGs under the future land use without continued federal ownership residential farmer scenario differ from the ARARs-based PRG for Ra-226 by several orders of magnitude. Moreover, the 10^{-6} risk-based PRGs for U-238 and Ra-226 are 2.6 and 36 times less than background, respectively.

EPA has promulgated standards for Ra-226 and Ra-228 in soil at uranium and thorium mill tailings sites (40 CFR 192 Subpart B). In brief, these radionuclides are not to exceed background concentrations by more than 5 pCi/g in the top 15 cm (6 in.) of soil or 15 pCi/g in each 15 cm (6 in.)

layer beneath the surface, averaged over an area of 100 m^2 (1100 ft^2). Because the FEMP site is not a mill tailings site, these standards do not specifically apply. However, the requirements are considered relevant and appropriate because the waste material at the site is similar to mill tailings.

EPA has identified standards for airborne emissions of radionuclides other than Rn-222 which limit exposures such that a member of the public will not exceed an effective dose equivalent of 10 mrem/year (40 CFR 61 Subpart H). EPA has also identified annual dose limits of 25 mrem/year whole body, 75 mrem/year to the thyroid, and 25 mrem/year to any other organ for exposures associated with management of uranium and thorium by-product material.

As a general standard for radiological exposures, DOE requires compliance with all federal requirements for limiting doses from specific exposure modes. DOE Order 5400.5 also establishes requirements for nonspecific radiological exposures from DOE facilities. This order requires that the committed effective dose equivalent to a member of the public not exceed 100 mrem/year above background from all nonoccupational exposure routes and that these exposures be reduced to ALARA levels. With this order, DOE defines the ALARA process for reducing residual exposures and risks to levels as low as reasonably achievable below applicable standards considering technical, economic, and social constraints as appropriate. This DOE Order is comparable to the requirements of 10 CFR 20 for the exposure of the public to radioactive materials.

These radiological dose standards and requirements are considered as applicable, relevant and appropriate or TBCs to remediation efforts at the FEMP site. Current dose estimates for the site perimeter are within the specified limits. Applying ALARA to reduce residual concentrations of specific radionuclides would result in a similar reduction in the resulting radiological exposures and associated risk. The greatest reduction is associated with decreasing residual levels of Ra-226 because this radionuclide and its progeny account for the greatest portion of the total risk estimate within Operable Unit 4, from both external gamma irradiation and inhalation of radon.

EPA has identified two different guidelines for establishing a residual level for lead in soil in a residential setting. These guidelines are considered TBCs. The first is an interim guidance that considers the natural presence of lead in soil and recommends a cleanup level of 500 to 1000 mg/kg, as determined by site-specific conditions (EPA 1992a). The second is draft guidance in the form of an uptake/biokinetic model that can be applied to site-specific data to estimate lead levels in blood for

children, the most sensitive population. A blood lead level of 10 μg/L or less is EPA's preferred level. This model yields a health-based level of 450 mg/kg for lead in surface soil.

A standard for cleanup of soil following a spill of material containing more than 50 mg/kg PCBs is identified in the Toxic Substances Control Act. The standard indicates that soil in areas of unrestricted access at which a spill occurs can be decontaminated to 10 mg/kg by weight by excavating at least 25 cm (10 in.) of soil and backfilling with material containing less than 1 mg/kg PCBs. Because PCB contamination in soil would have resulted from spills of material that occurred long before the effective date of these standards, they do not specifically apply; however, they are considered relevant and appropriate.

A literature search was conducted to identify any ecological benchmark criteria for use as guidelines for establishing PRGs for soils. No relevant criteria could be identified for the Operable Unit 4 COCs.

2.2.2.4 Preliminary Remediation Goals for Groundwater

Table 2-6 presents the PRGs for groundwater. For groundwater, the PRGs for the future land use with continued federal ownership (recreational user) are the same as those for the future land use without continued federal ownership (RME resident farmer). The only difference is the source of groundwater. Under the RME resident farmer scenario, it is assumed that an individual takes up residence on the FEMP site and installs a domestic drinking water well at that location. Under the recreational user scenario, there are no individuals establishing residences on the FEMP site. Consistent with this assumption, there will be no domestic drinking water wells on the FEMP site. Thus, the groundwater PRGs established under the recreational use scenario must be met at the FEMP site boundary, while PRGs under the RME resident farmer scenario would need to be met for groundwater directly beneath the FEMP site. For most radionuclides listed in Table 2-6 and one of the metals (beryllium), values representing risk-based PRGs differ from the ARARs-based PRGs by at least one order of magnitude.

The risk-based PRGs for groundwater were calculated using the unit risk factors presented in Appendix D.1 of the RI Report for Operable Unit 4. For the off-property farmer and on-property resident farmer, the PRG for U-238 was calculated as follows:

TABLE 2-6

PRELIMINARY REMEDIATION GOALS - GROUNDWATER

Chemical	Risk-Based PRGs			ARAR/TBC-Based PRGs		
				Federal Standards		State Standards
	HI=0.20 RfD-Based PRG[a]	10^{-4} Risk-Based PRG, Above Background[b]	10^{-6} Risk-Based PRG, Above Background[b]	Source[c]	Concentration[d]	Groundwater[e]
Radionuclides (pCi/L)						
Ac-227 + 7 progeny		5	0.05	4 mrem dose limit[f]	0.4	
Pb-210 + 2 progeny		2	0.02	4 mrem dose	1	
Pa-231		20	0.2	4 mrem dose	0.5	
Ra-226 + 5 progeny		10	0.1	PMCL[g]	20	5
Ra-228 + 1 progeny		15	0.2	PMCL[g]	20	5
Rn-222				PMCL[g]	300	
Sr-90		9	0.1	4 mrem dose	8	
Tc-99		9	0.1			
Th-228 + 7 progeny		30	0.3	4 mrem dose	14	
Th-230		120	1.2	4 mrem dose	10	
Th-232		130	1.3	4 mrem dose	2	
U-234		90	0.9	PMCL	7	
U-235 + 1 progeny		90	0.9	PMCL (Total U)	30	
U-238 + 2 progeny		50	0.5			
Inorganics (mg/L)						
Antimony	0.002			MCL[h]	0.006	

TABLE 2-6
(Continued)

Chemical	Risk-Based PRGs			ARAR/TBC-Based PRGs		
				Federal Standards		State Standards
	HI=0.20 RfD-Based PRG[a]	10^{-4} Risk-Based PRG, Above Background[b]	10^{-6} Risk-Based PRG, Above Background[b]	Source[c]	Concentration[d]	Groundwater[e]
Arsenic	0.002	2×10^{-3}	2×10^{-5}	MCL	0.05	0.05
Barium	0.30			MCL	2.0	1.0
Beryllium	0.03	5×10^{-3}	5×10^{-5}	MCL	0.004	
Boron	0.03					
Cadmium	0.003			MCL	0.005	0.001
Chromium	0.004			MCL	0.1	0.05
Cobalt	0.23					
Copper[i]				MCLG[j]	1.3	
Cyanide	0.1			MCL	0.2	
Lead	0.005			MCLG	0.0	0.05
Manganese	0.03					
Mercury	0.00003			MCL	0.002	0.002
Molybdenum	0.01					
Nickel	0.05			MCL	0.1	
Silver	0.003			MCL	0.05	0.05
Thallium	0.0003			MCL	0.002	
Uranium	0.02			PMCL	0.02	
Vanadium	0.04					

TABLE 2-6
(Continued)

Chemical	Risk-Based PRGs			ARAR/TBC-Based PRGs		
				Federal Standards		State Standards
	HI=0.20 RfD-Based PRG[a]	10^{-4} Risk-Based PRG, Above Background[b]	10^{-6} Risk-Based PRG, Above Background[b]	Source[c]	Concentration[d]	Groundwater[e]
Zinc	1					
Organics (mg/L)						
2-Butanone	0.4					
Acenaphthylene						
Acetone	0.7					
Anthracene						
Aroclor-1254		5×10^{-4}	5×10^{-6}	MCL	0.0005	
Aroclor-1260		5×10^{-4}	5×10^{-6}	MCL	0.0005	
Benzo(a)anthracene		6×10^{-4}	6×10^{-6}	PMCL	0.0001	
Benzo(a)pyrene		1×10^{-4}	1×10^{-6}	MCL	0.0002	
Benzo(b)fluoranthene		1×10^{-4}	1×10^{-6}	PMCL	0.0002	
Benzo(g,h,i)perylene						
Benzoic acid	29					
Bis(2-ethylhexyl)phthalate	0.1	0.3	0.003			
Chrysene				PMCL		
Di-n-butyl phthalate						
Dibenzo(a,h)anthracene				PMCL		
Fluoranthene	0.3					

TABLE 2-6
(Continued)

Chemical	Risk-Based PRGs			ARAR/TBC-Based PRGs		
				Federal Standards		State Standards
	HI=0.20 RfD-Based PRG[a]	10^{-4} Risk-Based PRG, Above Background[b]	10^{-6} Risk-Based PRG, Above Background[b]	Source[c]	Concentration[d]	Groundwater[e]
Indeno(1,2,3-cd)pyrene		1×10^{-4}	1×10^{-6}	MCL		
Methylene chloride[k]	0.4	0.5	0.005	PMCL	0.005	
Phenanthrene						
Phenol	4					
Pyrene	0.2					
Toluene	1			MCL	1.0	
Xylenes (total)	15			MCL	10.0	

[a]PRG developed using equation and parameters for drinking water ingestion and chemical-specific RfDs from Health Effect Assessment Summary Tables (HEAST) (EPA 1992b) and the Integrated Risk Information System (IRIS) (EPA 1992a).
[b]PRG developed using equations and parameters for drinking water ingestion and chemical-specific SFs from HEAST and IRIS values represent cleanup goal above background since 10^{-6} represents an incremental lifetime cancer risk goal.
[c]ARAR-based PRGs are developed from several sources. The primary source is promulgated or proposed Maximum Contaminant Levels (MCLs) developed under the Safe Drinking Water Act, 40 CFR 141, 142. If no MCL exists that strictly applies to the individual radionuclide, a PRG is developed using the 4 mrem dose limit that strictly applies to man-made beta and gamma emitters.
[d]Concentration in pCi/L for radionuclides and mg/L for chemicals corresponding to MCL or proposed MCL (PMCL) values.
[e]Based on OAC 3745-81-16; for many radionuclides, values are based on an average dose of beta particle and photon (e.g., gamma) of 4 mrem/yr.
[f]PRG based on interpretation to 4 mrem/yr dose limit for beta and gamma emitters may be applicable to alpha emitters. PRG developed using Committed Effective Dose Equivalents (CEDE) to 4 mrem/yr of intake at a rate of 730 L/yr, using Dose Conversion Factors (DCFs) from EPA (1988b).
[g]Proposed MCLs from "Federal Register," Vol. 55, No. 138, p. 33050.
[h]PRG developed using the strictly applicable MCL of 4 mrem/yr for man-made beta and gamma emitters (40 CFR 141, 142). Value developed using a CEDE or critical organ dose equivalent (if available or if more conservative) to 4 mrem/yr intake at a rate of 730 L/yr, using DCFs from EPA (1988b).
[i]No toxicity data available to develop a PRG.

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TABLE 2-6
(Continued)

[j]MCL goal based on best available treatment technology, no value for MCL.
[k]Methylene chloride also commonly referred to as Dichloromethane.
[l]Tetrachloroethene also commonly referred to as Tetrachloroethylene.

The off-property and on-property resident farmer are assumed to drink the groundwater, bathe in the groundwater, and consume the farm produce contaminated by irrigation with the groundwater for a lifetime of 70 years.

Unit Risk Factor for Water Consumption	=	1.4×10^{-6} (pCi/L)$^{-1}$
Unit Risk Factor for Irrigation of Vegetables	=	5.2×10^{-7} (pCi/L)$^{-1}$
Unit Risk Factor for Irrigation of Forage; Meat	=	3.7×10^{-9} (pCi/L)$^{-1}$
Unit Risk Factor for Irrigation of Forage; Milk	=	4.6×10^{-8} (pCi/L)$^{-1}$
Sum of Unit Risk Factors		2.0×10^{-6} (pCi/L)$^{-1}$

Soil PRG for U-238 for the off-property and on-property resident farmer then would be calculated as:

$$\text{Soil PRG (pCi/g)} = 1.0 \times 10^{-6} / 2.0 \times 10^{-6} = 0.5 \text{ pCi/L}$$

For organics, most PRGs based on the 10^{-6} risk level are well below the CRQLs established by EPA. To date, these CRQLs have been used for the site characterization study at the FEMP site. MCLs for many of the organic carcinogens appear to be equivalent to a 10^{-4} risk level (e.g., for PCBs, benzo(a)pyrene, chlordane, and vinyl chloride). For noncarcinogens, the MCLs appear to be close to risk-based values. This is not surprising because the method used to develop MCLs is the same method used to develop the risk-based values.

EPA has promulgated standards for Ra-226 and Ra-228 in groundwater through three separate regulations, all with the same basic requirements. The regulations include 40 CFR 141.15, 40 CFR 141.15, and 40 CFR 257.3-4. Similar Ohio state regulations include OAC 3745-81-15, OAC 3745-27-10, and OAC 3745-1-32. In brief, the regulations specify that the combined concentration of Ra-226 and Ra-228 in groundwater used as a drinking water source is not to exceed 5 pCi/L. In addition, the gross alpha particle activity (including Ra-226 but excluding radon and uranium) is not to exceed 15 pCi/L.

EPA has proposed standards for uranium and Rn-222 and revised standards for Ra-226 and Ra-228 in drinking water. Under these proposed regulations, the concentration of uranium in drinking water is not to exceed 0.02 mg/L or 30 pCi/L, Rn-222 is not to exceed 300 pCi/L, and the combined concentration of Ra-226/228 are not to exceed 20 pCi/L.

As a general standard for radiological exposures, the DOE requires compliance with all federal requirements for limiting doses from specific exposure modes. DOE Order 5400.5 also establishes standards for nonspecific radiological exposures. These standards require that the Effective Dose Equivalent (EDE) to a member of the public not exceed 100 mrem/year above background from all nonoccupational exposure routes and that these exposures be reduced to ALARA levels.

The Safe Drinking Water Act, 40 CFR 141, establishes MCLs and MCLGs for specific inorganic and organic chemicals to protect drinking water quality. MCLs are the maximum permissible levels of a contaminant in water that is delivered to a free flowing outlet of the ultimate user of a public water system. The MCLs are not directly applicable because no public water system, as defined in 40 CFR 141, is involved. The MCLs are relevant and appropriate, however, to protect the underlying aquifer, which may be used as a drinking water source, from contaminants that may leach or migrate from waste materials contained in Operable Unit 4.

The State of Ohio also provides MCLs in OAC 3745-81-11. The state MCLs are more stringent than the federal MCLs for barium, cadmium, chromium, silver, and selenium.

EPA provides additional MCLs in RCRA, Subtitles D and C, 40 CFR 257 and 264, respectively. These MCLs are also continued in Ohio state regulations, OAC-3745-27. The regulations require that a facility must comply with the requirements specified in the facility permit (i.e., the MCLs) for the uppermost aquifer underlying the waste management area beyond the point of compliance, which is a vertical surface located at the hydraulically downgradient limit of the waste management area. These MCLs are not directly applicable because Operable Unit 4 is not designated as a RCRA waste management area. The MCLs are relevant and appropriate, however, because Operable Unit 4 contains RCRA constituents and because silo leachate may migrate into the underlying aquifer, potentially contaminating drinking water systems.

The Safe Drinking Water Act also establishes MCLGs for specific inorganic and organic chemicals. The MCLGs are reflected in Ohio regulations OAC 3745-81-11. MCLGs are nonenforceable drinking water health goals intended to represent a contaminant concentration that presents "no known or anticipated adverse effects on the health of persons" while allowing for an adequate margin of safety. The MCLG is more stringent than the MCL for thallium. Similar to the MCLs, the MCLGs are considered to be relevant and appropriate. CERCLA Section 121(d)(2)(A) requires on-site remedies to attain MCLGs where relevant and appropriate under the circumstances of the release. If

MCLG is equal to zero, EPA believes it is not appropriate for setting clean-up levels, and corresponding MCL will be the relevant and appropriate requirement.

Beyond the MCLGs, the Safe Drinking Water act establishes secondary MCLs in 40 CFR 143. Secondary MCLs are also contained in Ohio regulations, OAC 3745-82-02. Secondary MCLs are nonenforceable goals for drinking water established for contaminants whose presence in excessive quantities may discourage the use of a public water supply due to poor qualities such as taste, color, odor, and corrosivity. The secondary MCLs are a TBC in evaluating potential remedial actions.

A summary of the MCLs, MCLGs, and secondary MCLs previously discussed is presented in Table 2-7.

2.2.3 Development of Remedial Action Objectives

EPA guidance requires that RAOs be developed in the initial phase of the FS and used as the framework for developing the detailed remedial alternatives. RAOs are presented in Table 2-8 for each of the material type and environmental media within Operable Unit 4.

2.2.3.1 Waste Material

Waste material includes K-65 residues, also known as "hot raffinates," contained in Silos 1 and 2 and the decant sump tank; and the cold metal oxides contained in Silo 3.

RAOs for the waste material include:

- Prevent direct contact with or ingestion of waste material
- Prevent release or migration of waste material that would result in soil concentrations in excess of the PRGs identified in Section 2.2.2.3 and Table 2-5
- Prevent release or migration of waste material that would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6
- Prevent exposures to waste material that may cause an individual to exceed annual dose limits of 25 mrem/year whole body, 75 mrem/year to the thyroid, or 25 mrem/year to any other organ
- Prevent exposures to waste material that may cause an individual to exceed a 100 mrem/year effective dose equivalent, above background, from all exposure routes

TABLE 2-7

SUMMARY OF MCLs, MCLGs, AND SECONDARY MCLs

Constituents	40 CFR 141.62 SDWA MCL (mg/L)	OAC 3745-81-11 MCL (mg/L)	40 CFR 257.3-4 and 264.94 Subparts C and D OAC-3745-27-10 MCL (mg/L)	40 CFR 141.50 and 141.51 SDWA-NPDWS OAC 3745-81-11 MCLG (mg/L)	40 CFR 143 OAC 3745-82-02 SMCL (mg/L)
Antimony	0.006			0.006	
Arsenic	0.05[a]	0.05	0.05		
Barium	2.0	1.0	1.0	2.0	
Beryllium	0.004			0.004	
Cadmium	0.005	0.001	0.01	0.005	
Chloride					250
Chromium	0.1	0.05	0.05	0.1	
Copper	1.3			1.3	1.0
Cyanide	0.2			0.2	
Fluoride					2.0
Iron					0.3
Lead	0.015	0.05	0.05		
Manganese					0.05
Mercury	0.002	0.002	0.002		
Nickel	0.1			0.1	
Nitrate			10.0		
Radium-226/228	20 pCi/L[b]	5 pCi/L			
Radon-222	300 pCi/L[b]				
Selenium	0.05	0.01	0.01	0.05	
Silver					
Thallium	0.001			0.0005	
Uranium	0.02[b]				
Zinc					5.0

TABLE 2-7
(Continued)

Constituents	40 CFR 141.61 SDWA MCL (mg/L)	OAC 3745-81-12 MCL (mg/L)	40 CFR 257.3-4 and 264.94 Subparts C and D OAC-3745-27-10 MCL (mg/L)	40 CFR 141.50-51 SDWA-NPDWS OAC 3745-81-11 MCLG (mg/L)
2,4-D			0.1	
2,4,5 - TP Silvex			0.01	
Benzo(a)anthracene	0.0001[b]			
Benzo(a)pyrene	0.0002			
Benzo(a)fluoranthene	0.0002[b]			
Carbon tetrachloride	0.005	0.005		
Chrysene	0.0002[b]			
Dibenzo(a,h)anthracene	0.0003[b]			
Endrin	0.002	0.002	0.002	0.002
Heptachlor epoxide	0.0002			
Indeno(1,2,3-c,d)pyrene	0.0004[b]			
Lindane			0.004	
Methoxychlor			0.1	
Polychlorinated biphenyls	0.0005			
Toluene	1.0			1.0
Toxaphene			0.005	
Trihalomethanes	0.10[c]	0.10		
Xylenes	10.0			10.0

[a]The MCL for arsenic, contained in 40 CFR 141.11, is the only inorganic MCL not superseded by 40 CFR 141.62.
[b]Proposed MCL
[c]The MCL for total trihalomethanes, contained in 40 CFR 141.12, is the only organic MCL not superseded by 40 CFR 141.61.

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TABLE 2-8

REMEDIAL ACTION OBJECTIVES
OPERABLE UNIT 4

Environmental Media	Remedial Action Objectives
Waste Material	For Human Health: Prevent direct contact with or ingestion of waste material. Prevent release or migration of waste material which would result in soil concentrations in excess of the PRGs identified in Section 2.2.2.3 and Table 2-5. Prevent release or migration of waste material which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6. Prevent exposures to waste material which may cause an individual to exceed annual dose limits of 25 mrem/yr whole body, 75 mrem/yr to the thyroid or 25 mrem/yr to any other organ. Prevent exposures to waste material which may cause an individual to exceed a 100 mrem/yr effective dose equivalent, above background, from all exposure routes. For Environmental Protection: Prevent release or migration of waste material which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6.
Structural Material and Equipment	For Human Health: Prevent direct contact with or release from the site of equipment with surface contamination in excess of the free release limits provided in DOE Order 5400.5. Prevent leaching or migration of surface contamination which would result in soil concentrations in excess of the PRGs identified in Section 2.2.2.3 and Table 2-5. Prevent leaching or migration of surface contamination which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6. For Environmental Protection: Prevent leaching or migration of surface contamination which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6.

TABLE 2-8
(Continued)

Environmental Media	Remedial Action Objectives
Soil	For Human Health: Prevent direct contact with, inhalation of, or ingestion of soil having constituent concentrations in excess of the PRGs identified in Section 2.2.2.3 and Table 2-5. Prevent release or migration of soil constituents which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6. Prevent exposures to soil materials which may cause an individual to exceed annual dose limits of 25 mrem/yr whole body, 75 mrem/yr to the thyroid or 25 mrem/yr to any other organ. Prevent exposures to soil materials which may cause an individual to exceed a 100 mrem/yr effective dose equivalent, above background, from all exposure routes. For Environmental Protection: Prevent release or migration of soil constituents which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6.
Residual Water	For Human Health: Prevent direct contact with or ingestion of residual water having constituent concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6. Prevent release or migration of residual water which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6. For Environmental Protection: Prevent release or migration of residual water which would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6.

2.2.3.2 Structural Material and Equipment

Structural material and equipment includes concrete and metal used in the construction of Silos 1, 2, 3 and 4 and contaminated equipment including the decant sump tank, K-65 Drum Handling Building pad, process piping, pipe trench material, and the existing RTS equipment. Approximate material volumes to be addressed include: 1530 m^3 [2000 cubic yards (yd^3)] of contaminated concrete from Silos 1, 2 and 3; 510 m^3 (670 yd^3) of non-contaminated concrete from Silo 4; 280 m^3 (370 yd^3) of contaminated concrete and metal from the decant sump tank, process piping, pipe trenches, and the RTS; and 20 m^3 (30 yd^3) of contaminated concrete from the K-65 Drum Handling Building pad and the sump lift station. Based on past efforts at the FEMP, decontamination of concrete is not readily performed. Due to its porous nature relative to metal and lack of established clean levels for free release, it is assumed for the purpose of this report that all concrete, excluding Silo 4, generated from remedial actions within Operable Unit 4 is contaminated. Silo 4 is presumed to be non-contaminated on the basis of process knowledge, which is supported by available smear data from Silo 4 which indicates no elevated levels of radiological contamination. It is assumed that Silo 4 will be razed and generated rubble will be demonstrated non-contaminated.

Concrete material will be treated like contaminated soil; therefore, RAOs for concrete are addressed under the RAOs for soil. RAOs for metal structural material and pipe include:

- Prevent direct contact with or release from the site of equipment with surface contamination in excess of the free release limits provided in DOE Order 5400.5
- Prevent leaching or migration of surface contamination that would result in soil concentrations in excess of the PRGs identified in Section 2.2.2.3 and Table 2-5
- Prevent leaching or migration of surface contamination that would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6

2.2.3.3 Soil

Soil within the Operable Unit 4 boundaries includes surface soil around the silos, subsurface soil beneath the silos and around pipe trenches, and berm soil around Silos 1 and 2. Approximate material volumes to be addressed include 3400 m^3 (4440 yd^3) of potentially contaminated surface soil, 8060 m^3 (10,540 yd^3) of potentially contaminated berm soil, and 11,200 m^3 (14,650 yd^3) of potentially contaminated subsurface soil.

RAOs include:

- Prevent direct contact with, inhalation of, or ingestion of soil having constituent concentrations in excess of the PRGs identified in Section 2.2.2.3 and Table 2-5

- Prevent release or migration of soil constituents that would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6

- Prevent exposures to soil materials that may cause an individual to exceed annual dose limits of 25 mrem/year whole body, 75 mrem/year to the thyroid, or 25 mrem/year to any other organ

- Prevent exposures to soil materials that may cause an individual to exceed a 100 mrem/year effective dose equivalent, above background, from all exposure routes

2.2.3.4 Residual Water

Residual water includes water contained in the decant sump tank, water contained in Silo 4, and perched groundwater that may be encountered during potential remedial actions within the Operable Unit 4 boundaries. Approximate material volumes to be addressed include 30,280 L (8000 gallons) of contaminated water in the decant sump tanks, 49,210 L (13,000 gallons) of residual water in Silo 4, and an unknown quantity of perched groundwater that may be encountered during potential remedial actions. The volume estimate for the decant sump tank assumes that the tank will refill with leachate from Silos 1 and 2 following the January 1993 removal action. The volume of liquid assumed to collect in Silo 4 is based on historical infiltration of rainwater through the silo dome.

RAOs for residual water include:

- Prevent direct contact with or ingestion of residual water having constituent concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6

- Prevent release or migration of residual water that would result in groundwater concentrations in excess of the PRGs identified in Section 2.2.2.4 and Table 2-6

2.3 SUBUNIT DESIGNATIONS

Defining areas or volumes of media should include a consideration of not only acceptable exposure levels and potential exposure routes, but also site conditions and the nature and extent of contamination. For areas with discrete hot spots or areas of more concentrated contamination, it may be more useful to define areas and volumes for remediation based on the site-specific relationship of volume or area to contaminant level (EPA 1988a). In accordance with this approach, components of

areas and volumes of media identified for Operable Unit 4 were assembled into groupings designated as subunits.

The areas and volumes of media identified within Operable Unit 4 were assembled into a total of three subunits and were designated as Subunit A, B, and C. These subunits are defined as follows:

- Subunit A - Includes the contents of Silos 1 and 2 and the sludge in the decant sump tank

- Subunit B - Includes the contents of Silo 3

- Subunit C - Includes the structures of Silos 1, 2, 3, and 4, the K-65 Drum Handling Building pad, sump lift station concrete, the berms surrounding Silos 1 and 2, the existing RTS on Silos 1 and 2, the surface soil within the Operable Unit 4 Study Area, the contaminated soils beneath Silos 1, 2, and 3, the underground decant sump tank and related piping, decant sump tank water, any standing water within Silo 4, the underground process piping and concrete trenches containing the piping, and any rubble or debris (i.e., D&D of waste processing facilities) generated consequential to the implementation of remedial actions for all Operable Unit 4 subunits.

These subunits will be utilized in the remainder of the FS Report to support the assembly, detailed evaluation, and comparative analysis of the remedial action alternatives.

2.4 GENERAL RESPONSE ACTIONS

GRAs describe actions that could satisfy the RAOs. GRAs include no action, institutional actions, containment, removal, treatment, and disposal. Individually, these GRAs do not have to meet the remedial action objectives. The objectives will be met when the actions are combined into alternatives. The following GRAs were considered for Operable Unit 4.

- No Action - The no-action alternative is retained throughout the FS process as required by the NCP [40 CFR 300.430(e)(6)]. The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken. In the no-action alternative, the materials are considered to be left "as is", without the implementation of any institutional action or containment, removal, treatment, or other mitigating actions. The no-action alternative does not

provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and the no-action does not provide for access control actions taken to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

- Institutional Action - Institutional action applies various access controls and/or deed restrictions to reduce or eliminate direct exposure pathways. The volume, mobility, and toxicity of the contaminants is not reduced through the singular application of institutional actions.

- Containment - Another method of reducing the risk to the public and the environment is through waste containment, which reduces the contaminants' mobility. To reduce mobility, the contaminated media must be isolated from the primary transport mechanisms such as wind, erosion, surface water, groundwater, biological means, and mechanical means. Contaminated media may be isolated by installing surface and subsurface barriers that either block or divert any transport media from the contaminants.

- Removal - Technologies under the removal response action category are used to move waste or contaminated media from its present location to be treated and/or to be disposed elsewhere. Removal process options are combined with treatment and/or disposal process options to develop alternatives. Silo demolition process options are included in this response action.

- Treatment - Treatment response action includes both in situ and ex situ treatment process options. These process options are designed to reduce the toxicity, volume, or mobility of the contaminants present. Ex situ treatment process options are used with removal and disposal process options to develop alternatives.

- Disposal - Disposal technologies include waste transportation, on-site disposal, and off-site disposal. The disposal process options are used in concert with removal options and possibly treatment options to develop alternatives. Disposal technologies provide for the final deposition of the material.

2.5 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

Viable remedial action alternatives for Operable Unit 4 are developed by identifying remedial technologies, and viable process options within these technologies, that may be applied to the various contaminated media at the site. These media, which include soil, sludge, surface water, groundwater, perched water, structural material, and process residues, have been segmented into the three

previously identified subunits. The identification and screening of technologies and process options have been conducted in context with these subunits.

The technologies considered in selecting remedial action alternatives for these subunits include those identified in 40 CFR 300. Additional technologies were considered based on experience and information gained through remedial action planning and implementation at similar sites. In this section, the range of available technology types and process options were screened for applicability to the site in accordance with EPA guidance (EPA 1988a). Following the technology screening process, the following section presents an evaluation of the remaining process options to select representative process options to support the assembly of remedial action alternatives in Section 3.0.

2.5.1 Criteria for Identifying and Screening Technologies

Based on available information, media-specific remedial technologies and process options were identified for each of the GRAs. The technologies and associated process options were compiled by using information available in various EPA documents as well as other references. Each process option was screened for technical implementability. When no viable process option was left from a technology family, the technology was also screened. The screening process reduces the variety of possible process options for a given technology family to a smaller and more manageable number of options that were considered appropriate for the various media. In this step, both technologies and process options could be eliminated based on technical implementability criteria. Information' including site description and contaminant characterization and concentrations, was used to eliminate various technologies and process options that would not apply or could not be effectively implemented at the site.

Figure 2-2 summarizes the GRAs, remedial technologies, and associated process options considered for Operable Unit 4 wastes and media. Figure 2-2 further summarizes the applicability of the various process options to the Operable Unit 4 subunits and presents the results of the initial screening process. The following is a brief summary of the identification and screening of technologies and process options.

2.5.2 No-Action General Response Action

The no-action response does not provide additional remediation, maintenance, or security activities at the site to further minimize risk to public health and the environment. The no-action GRA is retained as a baseline for comparison to other remediation alternatives as required by the NCP. This GRA is

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SUBUNIT APPLICABILITY A	B	C	SCREENING COMMENTS
No Action	None	Not Applicable	No Action	X	X	X	Required for consideration by NCP
Institutional Action	Monitoring	Groundwater Monitoring	Installation of wells for monitoring groundwater	X	X	X	Potentially applicable
		Leachate Monitoring	Monitoring of leachate collection/detection system	X	X	X	Potentially applicable
		Radon Monitoring	Installation of radon monitoring devices	X	X	X	Low Levels of radium in Subunit C. Potentially Applicable
		Surface Water/Sediment Monitoring	Collection/analysis of surface water/sediment samples	X	X	X	Potentially applicable
	Access Control	Physical Barriers	Fencing, security, limited road access, etc.	X	X	X	Potentially applicable
		Administrative Controls	Restricted access only, posted signs, etc.	X	X	X	Potentially applicable
Containment	Subsurface Flow Control	Subsurface Drains	Gravity driven collection system	X	X	X	Potentially applicable
		Slurry Walls	A soil/bentonite grout wall emplacement	X	X	X	Potentially applicable
		Pumping Wells	Extraction/injection of water into ground	X	X	X	Potentially applicable
		Sheet Pilings	Steel/concrete forms joined and driven into ground	X	X	X	Potentially applicable
		Grout Curtains	Close-spaced grout injections isolate area	X	X	X	Potentially applicable
	Capping	Concrete-Based Cap	Concrete slab poured over area of concern	X	X	X	Potentially applicable
		Asphalt-Based Cap	Asphalt poured over area of concern	X	X	X	Potentially applicable
		Soil/Clay-Based Cap	Compacted soil or clay cover over area of concern	X	X	X	Potentially applicable
		Chemical Sealant Cap	Chemical stabilizers mixed with surface soils	X	X	X	Potentially applicable
		Multimedia Cap	Cap formed with various layers	X	X	X	Potentially applicable
		Void Space Grout	Fill dome void space with grout	X	X	-	Not feasible for empty silos
	Run-On/Runoff Control	Sedimentation Basin/ Sediment Trap	Temporary storage of runoff to allow settling/Traps to intercept soil particles in runoff	X	X	X	Potentially applicable
		Diversion/Collection	Surface water routing controls	X	X	X	Potentially applicable
		Grading	Topography modification for route control	X	X	X	Potentially applicable
		Revegetation	Vegetative cover provides surface stability	X	X	X	Potentially applicable
	Silo Renovation	Silo Rehabilitation	Apply gunite, paint, concrete, etc. to silo	-	-	X	No silos in Subunits A, B

"X" indicates process option to be retained for evaluation
"-" indicates process option not applicable for that subunit
Process option not retained for any subunit.

FIGURE 2-2

INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SUBUNIT APPLICABILITY A	B	C	SCREENING COMMENTS
Removal	Mechanical Removal	Loader/Dozer	Tractor- or wheel-mounted excavation vehicles	-	-	X	Not applicable due to material consistency and silo strength limitations
		Crane w/Clamshell System	Tractor-, wheel-, or skid-mounted hoisting system	X	-	X	Not feasible due to material consistency
		Conveyor System	Belt-type conveyor system excavates material	-	-	X	Not feasible due to material consistency, accessibility, and silo strength limitations
		Backhoe	Tractor- or wheel-mounted excavation vehicles	-	-	X	Not feasible due to material consistency, accessibility, and silo strength limitations
		Dragline System	Excavating tool pulled across material	-	-	X	Not feasible due to material consistency
	Hydraulic Removal	Slurry Pump w/ Jetting Ring	Dislodges and hydraulically removes material	X	X	X	Potentially applicable
	Pneumatic Removal	Pneuma/Oozer Dredging	In situ sludge pumping system	-	-	-	Not applicable because of material consistency
		Airlift Dredging	Expanding air pulls material behind it	-	-	-	Not applicable, requires depths > 20-30 ft
		Vacuum w/Cutterhead	Negative pressure displacement system	X	X	-	Not applicable due to material incompatability
	Silo Demolition	Controlled Blasting	Use of explosive agents to demolish structure	-	-	X	Only applicable to silo structures
		Impact Hammer	Percussion tools to break apart silo	-	-	X	Only applicable to silo structures
		Flame Cutting	Ignition of iron and aluminum oxides to cut structure/rebar	-	-	X	Only applicable to silo structures
		Thermite Reaction Lance	High-temperature flame cutting device to cut silo	-	-	X	Only applicable to silo structures
		Gas Torch	Torch used to cut structure/rebar	-	-	X	Only applicable to silo structures
		Hydraulic Splitter	High pressure water used to cut structure	-	-	X	Only applicable to silo structures
		Non-explosive Demolition Compounds	Expanding agents fracture structure	-	-	X	Only applicable to silo structures
		Circular Diamond or Carbide Saws	Diamond tipped or carbide saws to cut structural rebar	-	-	X	Only applicable to silo structures
		Diamond Rope Saw	Diamond-tipped rope saw to cut concrete/rebar	-	-	X	Only applicable to silo structures
		Diamond Chain Saw	Diamond-tipped chain saw to cut concrete/rebar	-	-	X	Only applicable to silo structures
		Abrasive Water Jet	Stream of abrasives to cut silo using a high-velocity water jet	-	-	X	Only applicable to silo structures
		Core Stitch Drilling	Drilling closely spaced holes resulting in failure of structure when force is applied	-	-	X	Only applicable to silo structures
		Wrecking Ball	Crane-mounted weight used to collapse structure	-	-	X	Only applicable to silo structures
Treatment	In Situ Treatment	Shallow-soil mixing	Chemical-, and/or fly ash-based stabilization	-	-	X	Silo strength limitations
		Vitrification	High voltage crystallization/glassification of solids	X	X	X	Potentially applicable
		Surcharging	Compaction of material by addition of soil cover	-	-	-	Limited waste compaction expected
		Soil Aeration	Inject air and collect volatiles	-	-	-	Not applicable to inorganics
		Steam Stripping	Inject steam to drive off volatiles	-	-	-	Not applicable to inorganics

"X" indicates process option to be retained for evaluation
"-" indicates process option not applicable for that subunit
Process option not retained for any subunit.

Figure 2-2
(Continued)

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GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	Subunit Applicability A	B	C	SCREENING COMMENTS
Treatment	Waste Stabilization	Asphalt-Based Stabilization	Asphalt mixed with soil and solidified	X	X	X	Potentially applicable
		Cement-Based Stabilization	Cement mixed with soil and solidified	X	X	X	Potentially applicable
		Thermoplastic Encapsulation	Polymers mixed with soil and solidified	X	X	X	Potentially applicable
		Vitrification	High voltage crystallization/glassification of solids	X	X	X	Potentially applicable
		Lime/Flyash Stabilization	Lime and fly ash mixed with soil	X	X	X	Potentially applicable
	Physical Treatment	Air Stripping	Volatile mass transfer process	-	-	-	Not applicable for inorganic materials
		Solid/Liquid Separation	Separation of solids and liquids	X	-	X	Not applicable due to low water content in material
		Oil/Water Separation	Gravity differential separates free oil and water	-	-	-	Not applicable, no free oil phase
		Polymerization	Combines monomers to form polymers	-	-	-	Not applicable, few polymerizable materials
		FEMP AWWT	Treatment at FEMP Advanced Wastewater Treatment System	X	X	X	Potentially applicable
		Soil Aeration	Air injectors remove volatile organics	-	-	-	Not applicable for inorganic materials
		Steam Stripping	Steam injection removes volatile organics	-	-	-	Not applicable for inorganic materials
	Chemical Treatment	Chemical Dechlorination	Reduces the amount of chlorinated compounds	-	-	-	Not applicable, few chlorinated compounds
		Oxidation/Ozonation/Photolysis	Organics destroyed by chemical oxidants	-	-	-	Not applicable for radionuclides
		Hydrolysis	Decomposition of compounds using water	-	-	-	Not applicable, material fully hydrolized
		Chemical Extraction	Impurities removed through solubility/affinity	X	X	X	Potentially applicable
		Reduction	Reduction of the ionic state of a compound	-	-	-	Not applicable, few reducable materials
	Thermal Treatment	Drying/Calcination	Removes water and decomposes carbonates	X	-	-	Silo 3 already calcined, does not treat radionuclides
		Incineration	Destroys hazardous organics and reduces volume	-	-	-	Not applicable for inorganic materials, radionuclides
		Thermal Desorption	Heating of a solid to drive off volatile organics	-	-	-	Not applicable for inorganic materials, radionuclides

"X" indicates process option to be retained for evaluation
"-" indicates process option not applicable for that subunit
Process option not retained for any subunit.

Figure 2-2
(Continued)

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GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SUBUNIT APPLICABILITY A	B	C	SCREENING COMMENTS
	Biological Treatment	Biodenitrification	Nitrates/nitrites reduced to molecular nitrogen	-	-	-	Not applicable due to lack of nitrates/nitrites
		Biological Detoxification	Microbial action degrades organics	-	-	-	Not applicable for radionuclides
		Land Farming	Microorganisms cultured in soil	-	-	-	Not applicable for radionuclides
	Decontamination and Decommissioning	Vacuum Scabbling	Pneumatically-driven piston, equipped with spikes used to chip away concrete and vacuumed up.	-	-	X	Only applicable to contaminated silo structures
		Pressure Washing	High pressure washer used to clean surface	-	-	X	Only applicable to contaminated silo structures
		Vacuum Grit-Blasting	Stream of abrasives propelled against surface to chip away concrete and vacuumed up	-	-	X	Only applicable to contaminated silo structures
		Acid Washing with Oxidizing Agents	Application of acid to dissolve concrete	-	-	X	Only applicable to contaminated silo structures
		Strippable Coatings	Application of material that cures to a thin solid coating and trapping contaminants in a polymer mix that may be stripped and disposed.	-	-	X	Only applicable to contaminated silo structures
Disposal	Waste Transportation	Rail Transport	Railroad transportation along available routes	X	X	X	Potentially applicable
		Truck Transport	Truck transportation along available routes	X	X	X	Potentially applicable
	On-Property Disposal	Engineered Disposal Facility	Engineered facility, capped when filled	X	X	X	Potentially applicable
		Above-Grade Vault	Above-ground disposal facility	X	X	X	Potentially applicable
		Lined/Unlined Pits/Trenches	Simple non-structural disposal units	-	-	-	Unacceptable for permanent disposal
	Off-Site Disposal	Nevada Test Site	Licensed government facility	X	X	X	Potentially applicable
		Permitted Commercial Disposal Site	Licensed commercial facility	-	-	X	Not applicable, cannot meet waste acceptance criteria
		New Facility Adjacent to FEMP	Engineered facility to be constructed	X	X	X	Potentially applicable
		New Facility w/in 300 Miles of FEMP	Engineered facility to be constructed	X	X	X	Potentially applicable
		Deep Geological Repository	Deep mined disposal facility	-	-	-	Not applicable, facility does not exist which accepts K-65 material

"X" indicates process option to be retained for evaluation
"-" indicates process option not applicable for that subunit
Process option not retained for any subunit.

Figure 2-2
(Continued)

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applicable to all subunits.

2.5.3 Institutional Action General Response Action

Institutional actions are applicable to all of the subunits and will include monitoring and access controls.

2.5.3.1 Monitoring Technologies

Monitoring would be conducted during the implementation of any selected remedial action alternative to assess short-term impacts to workers and the public. Additionally, sampling and/or monitoring would be employed following completion of remedial actions to demonstrate attainment of remedial action objectives and, as necessary, assess the continued performance of on-property waste disposal systems. Groundwater would be monitored through the sampling and analysis of existing and new well installations. In addition, disposal vault performance would be monitored through the existing and new leachate collection/detection systems (LC/DS), and the air would be monitored for radon emissions. Furthermore, surface water and sediment runoff would be monitored as needed. The following discussion presents the monitoring process options considered.

Groundwater Monitoring

Groundwater would be checked through existing and/or new monitoring wells to detect and monitor contaminant migration. Groundwater monitoring is applicable to Subunits A, B, and C and has been retained for evaluation.

Leachate Monitoring

Leachate would be monitored through existing systems such as the decant sump tank or a newly installed collection system. Leachate monitoring is applicable for Subunits A, B, and C and has been retained for evaluation.

Radon Monitoring

The air may be monitored for radon emissions near wastes containing significant quantities of radium. Subunit A and potentially Subunit B and C may require periodic monitoring of radon. Consequently, radon monitoring has been retained for further evaluation for Subunits A, B, and C.

Surface Water/Sediment Monitoring

Surface water and sediment monitoring is useful for determining the extent of surface contaminant migration due to runoff and emitted re-suspended contaminants. Accordingly, surface water/sediment monitoring has been retained for further evaluation for Subunits A, B, and C.

2.5.3.2 Access Control Technologies

Access controls would be implemented to regulate access to the site and any contaminated media. The technologies for access control technologies consider the potential implementation of active and passive controls. Active controls can consist of physical barriers such as fences, gates, and security forces, while passive controls include administrative controls such as ownership, access permits, and deed restrictions. The following discussion presents the access control process options.

Physical Barriers

Physical barriers limit the potential for inadvertent public or worker exposure to on-property contamination by restricting entry. Public access to the FEMP site is controlled by security forces and fencing. In addition, workers are restricted from contaminated areas within the Operable Unit 4 boundaries by access gates, internal fences, ropes, and signs. Accordingly, this process option will be retained for all subunits.

Administrative Controls

Administrative controls provide passive measures to limit potential of public and worker exposure to contamination on property. This option controls public exposure to on-property contamination by restricting access and use. This access control technology is applicable and will be retained for all subunits.

2.5.4 Containment General Response Action

Long-term containment consists of technologies that confine contaminated media at their current locations. These technologies limit the migration of contaminants and the associated potential for exposure, but they do not reduce contaminant toxicity or volume. These containment technologies include subsurface flow control, capping, run-on/runoff control, and silo renovation.

2.5.4.1 Subsurface Flow Control Technologies

Subsurface contamination can be isolated by lateral barriers such as subsurface drains, slurry walls, pumping wells, sheet pilings, or grout curtains. There are two purposes for these technologies: 1) collect and control leachate flow, and 2) control clean groundwater from coming in contact with

contaminated subsurface soils. The effectiveness of subsurface flow controls depends on the size of the affected area and the nature of the site-specific hydrogeological conditions. The following discussion presents the subsurface flow control process options considered.

Subsurface Drains

Subsurface drains include any type of buried conduit used to collect and convey groundwater or leachate by gravity flow. A subsurface drainage system often uses a perforated drain pipe or a gravel bed for conveying flow to a storage tank or sump. This process option was retained to potentially collect leachate from Subunits A, B, and C.

Slurry Walls

Slurry walls would isolate the subsurface soil contamination by diverting the groundwater around the contamination. Slurry walls are fixed, underground physical barriers that are formed by pumping slurry, usually a soil or cement, bentonite, and water mixture, into a trench as excavation proceeds, allowing the slurry to set while backfilling. The slurry is used primarily to maintain the trench during excavation. Slurry walls have been retained for additional evaluation for Subunit C due to the known subsurface soil contamination and for Subunits A and B in conjunction with other containment process options.

Pumping Wells

Pumping wells either extract or inject water to contain or remove a contamination plume or to adjust groundwater levels to prevent plume formation. They can also be used in conjunction with other groundwater controls to maximize efficiency. This process option has been retained for additional evaluation for Subunit C because it could prevent groundwater contact with contaminated subsurface soil and for Subunits A and B in conjunction with other containment process options.

Sheet Pilings

Sheet pilings are constructed by permanently driving webbed sections of sheet piling into the ground. Sections are joined before being driven into the ground and initially are not watertight. However, the joints soon fill with fine- to medium-grained soil particles, which generally block groundwater flow. Because of costs and unpredictable wall integrity, sheet pilings are seldom used except for temporary dewatering for construction, or as erosion protection where another barrier intersects flowing water. Sheet pilings have been retained for additional evaluation for Subunit C as a process option that could

isolate the subsurface soil contamination by diverting groundwater from the contamination source and for Subunits A and B in conjunction with other containment process options.

Grout Curtains

Grout curtains are fixed underground barriers formed by injecting grout, either particulate (such as portland cement) or chemical (such as sodium silicate), into the ground. Grout curtains have been retained for Subunit C for further study because they make it possible to divert groundwater from the contaminated subsurface soil, which helps prevent contaminant migration and for Subunits A and B in conjunction with other containment process options.

2.5.4.2 Capping Technologies

A contaminated area can be encapsulated by placing physical barriers on top (caps) of the waste. Capping of soil, sludge, and sediment could effectively limit airborne emissions and reduce precipitation-enhanced percolation and leaching. A stabilized surface fill would be required before cap placement. In situ capping of the silos in Subunits A and B would require filling void space in the individual silos to increase each silo's weight-bearing capacity. The following sections discuss the capping options that were considered.

Concrete-Based Cap

A single-layered cap composed of concrete can effectively control erosion and minimize generation of leachate from precipitation infiltration. Periodic application of special surface treatment may be required to maintain integrity. This process option has been retained for further evaluation for all subunits as a way to prevent or retard the contact of water with contaminated material.

Asphalt-Based Cap

This capping option is similar to the concrete-based cover except this technology uses a layer of asphalt to isolate the material. Again, periodic application of special surface treatment may be required to maintain integrity. The asphalt-based cover has been retained for additional evaluation for all subunits.

Soil-/Clay-Based Cap

A soil-/clay-based cap is a single layer cap that uses soil or clay with a lower permeability than the waste being capped to reduce or stop infiltration of precipitation. Although more susceptible to

cracking from freeze/thaw cycles, this option has been retained for all subunits for further evaluation since it is technically implementable.

Chemical Sealant Cap

The chemical sealant cap mixes a chemical binder with the upper soil layer. Cement, quicklime, or other grouting materials can be applied to the surface to create a seal that minimizes infiltration of precipitation and erosive transport of contaminated surface soils. This process option has been retained for all subunits for further evaluation.

Multimedia Cap

A multimedia cap incorporates the most effective attributes of other capping options by using more than one barrier material to form multiple layers over the contaminated media. This layered design offers the highest effectiveness for capping by using the properties of the cap components to reduce or stop infiltration and control erosion while simultaneously providing protection (vegetation and drainage layers) that protect against freeze/thaw damage, cracking, or other damaging actions. This capping option has been retained for all subunits for further evaluation.

Void Space Grout

The void space grout option involves filling the small void spaces in the silo domes with grout. This process option was retained for Subunits A and B because the void spaces over the contained wastes are relatively small. Completely filling the empty silos of Subunit C with grout may result in silo failure, given the structural condition of the silos. Therefore, this process option was not retained for this subunit.

2.5.4.3 Run-on/Runoff Control Technologies

Run-on/runoff controls are used to divert surface runoff around contaminated areas, thus minimizing the potential for contaminant resuspension. Graded contours, swales, and berms can effectively control surface water run-on/runoff and can limit contaminant migration. These measures have been effectively used on property (e.g., Operable Unit 1 - Waste Pit Area Runoff Control Project). Also, sediment traps such as siltation fences or bales may be used to intercept soil particles in runoff; however, their use requires active maintenance. Sedimentation basins or sediment traps could also be used in conjunction with surface diversions/controls for surface water control. The following discussion presents run-on/runoff control process options.

Sedimentation Basin/Sediment Trap

Sedimentation basins and sediment traps are used to control suspended solids entrained in surface flows. A sedimentation basin is usually constructed by placing an earthen dam across a waterway or natural depression or by excavation, or by a combination of both. Sediment traps include silt fences or bales that intercept and collect soil particles in runoff. This process option has been retained for additional evaluation for all subunits because of the short-term potential for contaminated runoff to occur during storm events.

Diversion/Collection

Essential to surface water management, surface diversion and collection includes the use of dams, dikes, berms, channels, waterways, terraces/benches, chutes, seepage ditches/basins, levees, and flood walls as temporary or permanent measures for effective surface water control. Diversion/collection may be used to prevent flooding, control erosion, or direct surface runoff and can effectively prevent the contact of surface runoff with contaminated water or waste material. Diversion/collection has been retained for further evaluation for all subunits as a means to control potential surface water runoff.

Grading

By reshaping the land surface through grading, both surface water infiltration and runoff are managed while controlling erosion. Spreading and compaction of soils are commonly used in conjunction with grading. This process option will be evaluated further for all subunits as a way to manage surface water infiltration and control runoff.

Revegetation

Revegetation is a cost-effective method to stabilize the surface, especially when preceded by capping and grading. Revegetation decreases erosion by wind and water and contributes to the development of a naturally fertile and stable surface environment. This process option has been retained for further evaluation for all subunits as a way to stabilize the surface of regraded land or capping of the subunits.

2.5.4.4 Silo Renovation

This process option renovates the silos to help contain the contaminated media. Long-term renovation processes include application of paint, foam, concrete, or emulsions. Such applications can effectively control releases from contaminated surfaces. An applicable option, silo renovation has

been retained for Subunit C for further evaluation in controlling releases from the contaminated surfaces. This process option does not apply to Subunits A or B because there are no silo structures associated with these subunits.

2.5.5 Removal General Response Action

Removal of contaminated material is used before ex situ treatment and/or disposal that could reduce contaminant toxicity, mobility, or volume. Removal measures can be applied to all affected Operable Unit 4 media, and the appropriate technology and process option depends on the physical properties of the medium.

The waste removal technology encompasses five mechanical removal process options, a single hydraulic removal process option, three pneumatic removal process options, and 13 silo demolition process options. The proposed removal process options for Subunits A and B allow the contents of Silos 1, 2, and 3 to be removed with or without the silo domes in place.

2.5.5.1 Mechanical Removal Technologies

Loader/Dozer

A tracked or wheeled front-end loader or dozer uses a front-mounted bucket to excavate and move material. This process option was not retained for Subunits A and B because supporting such a vehicle on Silos 1, 2, or 3, given their consistency, would be difficult. Also, there are concerns about the silo structure if the vehicle was placed on the berms surrounding Silos 1 and 2. This process option has been retained for Subunit C for removing the contaminated soil and debris from silo demolition.

Crane with Clamshell System

A clamshell suspended from a crane or other overhead structure could be used to remove the Subunit A residues or the berms, subsoil, and demolished silo structures of Subunit C. However, this process option has not been retained for Subunit B due to the clamshell's inability to remove the dry, powdery wastes without excessive fugitive dust emissions from Silo 3.

Conveyor System

A belt-type conveyor system with excavation buckets could be used to remove the berms and soil (Subunit C). The device would have to be placed on the berms for the Subunit A contents, which may be hazardous to the silo walls; therefore, this option was not retained for Subunit A. This device

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would have to be suspended from the silo structure to access the Subunit B contents, but due to the material consistency and accessibility of Silo 3 (Subunit B), this process option has not been retained for Subunit B. Consequently, this process option was only retained for the soil in Subunit C.

Backhoe

A tracked or wheeled backhoe could be used to remove soil and other material. For Subunit A, the device would have to be mounted on the berm to excavate the waste and may require structural modifications to the silos. For Subunit B, the backhoe would have to be placed on an elevated platform to access the wastes. The demolished silos and the berms and soil could be removed directly by the backhoe. As a result, this process option was not retained for Subunits A or B because of silo structural concerns and restricted access to the waste material, respectively. Consequently, the backhoe process option has been retained for Subunit C.

Dragline System

A dragline system is a crane-suspended excavation tool that is pulled across the surface of the media. This process option was not retained for Subunits A and B because it would not be effective with the sludge-like waste in Subunit A and the dry, powdery waste of Subunit B. The process option was retained for Subunit C for removal of the contaminated soil.

2.5.5.2 Hydraulic Removal Technology

The only hydraulic removal technology considered and retained for further evaluation would use a hydraulic mining pump, consisting of a slurry pump and a water jetting ring to remove any liquids in Silo 4 and the Subunit A and B waste as a slurry. This device could be supported from an overhead structure or used in conjunction with robotics. This process option is applicable to Subunits A, B, and C (Silo 4 water only).

2.5.5.3 Pneumatic Removal Technologies

Pneuma/Oozer Dredging

A pneuma/oozer dredging system consists of a compressed air-driven pump that displaces and removes the wastes. This device would be suspended from an overhead structure. This process option is not applicable to Subunits A, B, and C due to material consistency.

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Airlift Dredging

An airlift dredge uses expanding air introduced through a pipe that is driven into the waste to entrain the waste and force it upward. The dredge would then be suspended from an overhead structure. This process option has not been retained for Subunits A and B because the minimum depth for application is 6.1 to 9.1 m (20 to 30 ft). It also does not apply to Subunit C because of the nonheterogeneous solid materials that are not amenable to airlift dredging.

Vacuum with Cutterhead

A vacuum with a cutterhead could be used to loosen waste residue and displace it with negative pressure. This process option is applicable to Subunits A and B and will be retained for further evaluation because the waste consistency and accessibility are suitable. The vacuum with cutterhead option has been eliminated for Subunit C because Subunit C contains piping, soil, and concrete.

2.5.5.4 Silo Demolition Technology

Application of the various tools and techniques available in demolition depends on the physical and radiological conditions of the structure. The chosen technology should demolish the silos and other structures while maintaining control of the process, both radiologically and physically. The process should also minimize, as much as possible, the quantity of waste to be packaged for disposal. Various commercial products are available to demolish structures.

Before demolition, the inner silo walls may have to be decontaminated to remove gross contamination, to the extent practical, to minimize the contamination hazard during demolition. The generation of contaminated dust is a concern during demolition activities. Because Subunits A and B contain no structures, the demolition options are not applicable to those subunits. The following process options were considered for Subunit C.

Controlled Blasting

Controlled blasting can be used to demolish radioactively contaminated concrete when massive, reinforced concrete sections are encountered. The process consists of drilling holes in the concrete, loading them with explosives, and detonating them using a delayed firing technique. Delayed firing increases the fragmentation and controls the direction of material movement. The process is well suited for demolishing heavily reinforced concrete because, with the proper selection of blast parameters, a high degree of fragmentation may easily be achieved. There is an inherent danger in

blasting with regard to personnel safety and damage to nearby buildings. This process option is applicable to Subunit C.

Impact Hammer

Impact hammers are used on floors to remove small areas that are inaccessible by larger equipment. They also may be used to expose reinforcing rods after controlled blasting to permit cutting of the rods. The major advantage of impact hammers is their ability to operate in relatively small work areas. This process option will be considered for Subunit C.

Flame Cutting

Flame cutting of concrete consists of a thermite reaction process whereby a powdered mixture of iron and aluminum oxides in a pure oxygen jet is ignited. The temperature in the jet typically ranges from 1982 to 2482°C (3600 to 4500°F), which rapidly decomposes the concrete contacting the jet. Reinforcing rods in the concrete add iron, which sustains the flame and assists the reaction. The major disadvantage with flame cutting is that large amounts of dust, smoke, and heat are produced. This process option will be considered for Subunit C.

Thermite Reaction Lance

The thermite reaction lance is a high-temperature flame cutting device that cuts irregularly shaped materials. This equipment consists of a combination of steel, aluminum, and magnesium wires packed inside an iron pipe through which a flow of oxygen gas is maintained. During cutting, the lance must be hand-held, and the operator must be equipped with fireproof protective clothing and a respirator. This process option is applicable for Subunit C.

Gas Torch

A gas torch could be used to cut both concrete and steel and would create little, if any, dust. Because the silo might collapse, this procedure should be performed remotely. This process option was retained for Subunit C.

Hydraulic Splitter

A hydraulic splitter can be used to cut both concrete and steel. This would generate little dust but the water used would have to be collected and possibly treated. This process option is applicable for Subunit C.

Nonexplosive Demolition Compounds

The compound can be mixed with water and placed in holes that were drilled into the concrete along a fracture line of predetermined burden, spacing, and depth. Within 20 hours, pressure would develop to more than 31,027 kiloPascals (kPa) [4500 pounds per square inch (psi)], much greater than the tensile strength of most concrete. Cracks would form and propagate along the fracture line. The fractured burden may then be removed with a pavement breaker, backhoe, or bucket loader. The steel would have to be cut with a torch or other cutting device. Nonexplosive demolition compounds are applicable for Subunit C.

Circular Diamond or Carbide Saws

Circular diamond or carbide saws are used to minimize disturbance of the surrounding material. Large diamond or carbide-tipped saws are ordinarily used to cut concrete walls and floors. These saws can cut through reinforcing bars, although the bars tend to damage the blade. This process option is retained for Subunit C.

Diamond Rope Saw

Diamond rope saws are used to minimize the creation of airborne contaminants and vibration to surrounding structures. The diamond rope saw is a smooth cutting technology capable of much deeper cuts than the diamond or carbide-tipped saws. Diamond rope saws can be used to cut concrete up to 6 m (20 ft) thick.

The rope is fed through previously drilled holes. The ends are then joined securely and wrapped around a hydraulically driven flywheel. A small amount of water is added to the cut line for lubrication, cooling, and dust control. The diamond rope sawing equipment, including saw stand and hydraulics, should be placed as far from the actual work as necessary for personnel and equipment protection. This process option would also create little, if any, dust due to the water used for dust control; however, a collection system would be required for the water produced. The process option is retained for further consideration for Subunit C.

Diamond Chain Saw

A diamond chain saw consists of a saw that is equipped with a diamond-tipped chain. This device is powered with hydraulics and is capable of cutting through concrete and steel reinforcement. It uses a

stream of water for cooling and dust control. A diamond chain saw is light-weight and is easily managed by a single person. Diamond chain saws were retained for Subunit C.

Abrasive Water Jet

In the abrasive water jet process, a small diameter, high-velocity water jet and a stream of solid abrasives are introduced from separate feedports into a specially shaped abrasive jet nozzle. The water jet's momentum is transferred to the abrasives. Garnet sand is the abrasive most commonly used for cutting. When steel grit is used, it can be separated magnetically and reused. The major disadvantage with the abrasive water jet is the large volume of dirty and contaminated water it produces. Also, the system has its inherent dangers to personnel with the high pressure abrasives. Use of abrasive water jets was retained for Subunit C.

Core-Stitch Drilling

Core-stitch drilling is available for nonreinforced concrete, especially when surroundings should not be disturbed. The technique consists of drilling holes in the concrete. The center-line of the holes is located to correspond to the desired breaking plane in the concrete. The hole pitch is such that there is very little concrete left between the adjoining holes. A force is then applied to split the concrete along the line of the holes. This process option is applicable to Subunit C.

Wrecking Ball

A wrecking ball suspended from a crane would be effective in demolishing the silos, but a gas torch or other cutting device would be necessary to cut the steel wire and the reinforcement in the concrete. Wrecking balls are considered applicable for Subunit C.

2.5.6 Treatment General Response Action

This response action contains both in situ and ex situ treatment technologies. Ex situ treatment technologies discussed are waste stabilization, physical treatment, chemical treatment, thermal treatment, and decontamination and decommissioning.

2.5.6.1 In Situ Treatment Technologies

These technologies are applicable to Subunits A and B and the soils in Subunit C. They are not applicable for the nonsoil wastes in Subunit C because these materials are not amenable to in situ waste treatment options. These process options may be combined with containment process options to form alternatives. The following discussion presents in situ treatment process options.

Shallow Soil Mixing

This process would add cement, flyash, and bentonite to soil or waste materials and blend the mixture with augers lowered into the material. Stabilization will cause the volume of the material to increase. Silo berms may need to be raised for the silo support or the silo may need to be structurally modified to maintain silo integrity. Ex situ stabilization is much more applicable since the existing silos could not retain the stabilized material. This process option has not been retained for Subunits A and B; however, it has been retained for further evaluation for stabilization of the soils in Subunit C.

In Situ Vitrification

This process option would heat the silo wastes and/or soils by applying electrical energy until a molten mass is formed. Upon cooling, a monolithic glass waste form is achieved. Electrodes, through which a large current would pass, would be lowered into the waste in a closely spaced grid pattern. This process would continue until the waste formed a stable glass matrix. This process option, an innovative technology, has been retained for Subunits A, B, and C for further evaluation.

Surcharging

This process option induces densification and subsidence of waste by mounding or overburdening the material in place with a large quantity of soil for an extended time period. The overburden compacts the media and reduces the voids, while simultaneously evacuating liquids from the media. These liquids can then be collected for treatment. Surcharging has been eliminated for Subunits A, B, and C because very little waste compaction is expected or needed prior to in place containment. For alternatives involving removal, there is no merit in compacting the material in place.

Soil Aeration

Soil aeration is used to remove volatile contaminants from soil or a soil-like material by contacting the waste matrix with air and collecting the entrained volatiles. This process option has not been retained for any of the subunits because it cannot remove the inorganics or radionuclides present in the silo residues and because the concentrations of volatiles contained in the residues are low.

Steam Stripping

Steam stripping is used to evaporate volatile contaminants from an aqueous waste stream by injecting steam into the waste matrix and collecting the resultant volatile-contaminated water. This process option has been eliminated for all subunits because it cannot treat the inorganics or radionuclides present.

2.5.6.2 Waste Stabilization Technologies

Waste stabilization techniques immobilize the contaminants in a matrix to reduce or eliminate leachability and impart structural rigidity to the waste form. The waste stabilization process options are asphalt-based stabilization, cement-based stabilization, thermoplastic encapsulation, vitrification, and lime/flyash stabilization. The process options considered for the stabilization technology are discussed in the following text.

Asphalt-Based Stabilization

The waste or soil is blended with molten asphalt in a heated mixer and extruded into a container for disposal. The asphalt encapsulates the contaminants in the matrix. The contaminants do not react chemically with the encapsulating material. This process option has been retained for Subunits A, B, and C for evaluation since both the waste materials and soil can be stabilized by asphalt.

Cement-Based Stabilization

The waste or soil is mixed with water and cement-based reagents in a mixer or pug mill and poured into containers for curing before disposal. The waste is incorporated into the rigid matrix of the hardened concrete. This method physically or chemically stabilizes the waste, depending on waste characteristics. However, most wastes are not chemically bound and therefore are subject to leaching. This process option has been retained for Subunits A, B, and C for evaluation since waste materials and soils can be stabilized by cement.

Thermoplastic Encapsulation

The waste or soil is mixed with an organic monomer and an initiating agent or a catalyst. This polymerized waste is then poured into a container, allowed to cure, and then placed into a disposal facility. Thermoplastic encapsulation has frequently been used to stabilize heavy metal waste. This process option has been retained for Subunits A, B, and C for evaluation.

Vitrification

The waste material or soil is mixed with vitrification reagents (i.e., alumina, silica, sodium) in a surge hopper and fed into a glass smelter for vitrification. The glassified waste form is cast into steel containers and cooled for final disposal. Leaching is usually minimal after this treatment process. Vitrification has been tested at numerous DOE facilities including Savannah River and Oak Ridge. This process option has been retained for Subunits A, B, and C for evaluation.

Lime/Flyash Stabilization

The waste or soil is mixed with lime and flyash in a cement mixer or pug mill and poured into disposal containers for curing. With proper additives, this option has been used on a variety of waste. The site flyash piles could be used for the flyash. This process option has been retained for Subunits A, B, and C for evaluation.

2.5.6.3 Physical Treatment Technologies

This technology contains physical treatment process options that provide varying levels of treatment. Many of these process options are simply pretreatment steps for other treatment process options such as those for chemical treatment and waste stabilization. They are summarized in the following text.

Air Stripping

Air stripping removes volatile contaminants from aqueous waste streams by introducing air countercurrently to the waste stream to strip volatiles from the waste. This process option was not retained for any subunits because it does not effectively remove the inorganics present and because the levels of volatiles found in the subunit aqueous waste streams are relatively low.

Solid/Liquid Separation

This process option is a primary pretreatment step for other treatment process options that require specific solid/liquid ratios. Solid/liquid separation schemes typically use filtration (solids removal) and/or dewatering systems. This process option has been retained for Subunit A for evaluation due to the sludge-like consistency of the waste residues. The options for dewatering Subunit A material include belt filter press, vacuum, and centrifuge, among others. Solid/liquid separation was screened out for Subunit B because these materials are solid with no known liquid. This process option is applicable to Subunit C; the options would include gravity filtration, pressure filtration, or precipitation.

Oil/Water Separation

Oil/water separation consists of removing a free oil phase from the carrier wastewater through a specific gravity differential. This process option will not be retained because there is no free oil phase present in any of the subunits in Operable Unit 4.

Polymerization

Polymerization uses catalysts to form polymers from a monomer or a low-order polymer of a particular compound. Because there are few polymerizable compounds present in any of the subunits, this process option has not been retained.

FEMP Advanced Wastewater Treatment Facility

The FEMP Advanced Wastewater Treatment (AWWT) facility is being built on the FEMP site and will be available for treating wastewater, including perched water encountered during remediation and any liquids in Silo 4. This system will utilize metals precipitation, ion exchange, and other treatment techniques to treat influent so that the effluent will meet all discharge criteria.

The treatment system will consist of two parallel treatment systems. Phase I will treat 700 gpm of contaminated storm water runoff from the FEMP storm water retention basin. When capacity is available, the treatment system will also treat uranium-contaminated groundwater to be extracted from the South Groundwater Contamination Plume prior to its discharge to the Great Miami River. The South Plume is located just south of the FEMP in a portion of the Great Miami Buried Valley Aquifer. Phase II will treat 400 gpm of wastewater from cleanup and other activities at the site. This consists of approximately 200 gpm existing wastewater flows and 200 gpm future remediation flows. The AWWT is designed to reduce uranium in the FEMP's wastewater discharges to less than the proposed Safe Drinking Water Standard of 20 parts per billion (ppb).

Each phase consists of the following major treatment steps:

- Flow Equalization and pH adjustment to 11.5
- TRU/Clear addition and clarification for bulk removal of radionuclides and heavy metals. TRU/Clear is targeted at removal of radionuclides other than uranium; however, uranium will also be removed. System will have the capability to use alternate coagulants if TRU/Clear is not required.
- Clarifier effluent is directed to multitube filtration (solids collected from the clarifiers and filtration will be directed to Plant 8 for filtration)
- Filtered wastewater will pass through carbon filters for removal of any organic compounds
- pH adjustment to 8.0 using sulfuric acid (optimum for ion exchange)
- Ion exchange for uranium removal (Dowex 21-K)

- Final pH adjustment to within NPDES limits (6.5 - 9.0)
- Final filtration

Metals precipitation is one of several methods that uses chemicals or other additives to remove/extract contaminants from a waste stream. One metals precipitation process that was developed for the precipitation of radionuclides and metals is the TRU/Clear process. This process uses potassium ferrate as an inorganic coagulant to remove radionuclides and other priority pollutants from wastewaters.

Ion exchange is the process whereby hazardous/radioactive ions are removed from a solution by being exchanged with harmless ions held by the ion exchange material. The ion exchange material is typically a resin with ionic functional groups attached. The use of the FEMP AWWT facility as a process option applies to all subunits that may generate wastewater, and therefore, has been retained for Subunits A, B, and C for evaluation.

Soil Aeration

Soil aeration removes volatile contaminants from soil or a soil-like material by injecting the waste matrix with air and collecting the entrained volatiles. This process option has not been retained for any of the subunits due to the relatively low levels of volatile organics found in the waste residues and the ineffectiveness of this process option in removing inorganics or radionuclides.

Steam Stripping

Steam stripping is used to evaporate volatile contaminants from an aqueous waste stream by injecting steam into the waste matrix and collecting the resultant volatile-contaminated water. This process option has not been retained for any of the subunits due to the relatively low levels of volatile organics found in the waste liquids and the inability of this process option to remove inorganics or radionuclides.

2.5.6.4 Chemical Treatment Technologies

Several chemical treatment process options are available for treating contaminated soil, sludge, water, and structural material. These process options are typically implemented following removal of the contaminated media.

Dechlorination

Dechlorination involves the addition of a sodium reagent to strip chlorine atoms from chlorinated compounds. This process option has not been retained for any of the subunits because there are few chlorinated compounds found in the Operable Unit 4 wastes.

Oxidation/Ozonation/Photolysis

This process option represents those techniques commonly used to oxidize or prepare contaminants in a waste stream for oxidation. Photolysis uses UV radiation to make a compound more amenable to oxidation. Ozonation is the use of ozone, a chemically unstable molecule, to oxidize a compound. Oxidation is that chemical process by which the oxidation state of a compound is raised to change the solubility, stability, and/or separability of a compound. This process option has not been retained for any subunits because it cannot treat the radionuclide constituents found in the subunits. The Subunit A and B residue contaminants are already in oxidized forms.

Hydrolysis

Hydrolysis is the process of breaking a bond in a molecule (which is ordinarily not water soluble) so that it will go into ionic solution with water. This process option has not been retained for Subunits A and B because the residues in all of these subunits are fully hydrolyzed. This process option is not applicable to Subunit C because of the physical nature of the soil and debris.

Chemical Extraction

Chemical extraction is the process by which a solute is extracted from a solid. A liquid solvent is used to effect the transfer of the solute, which in turn is recovered from the solvent by evaporation or distillation. In an effort to minimize the volume of contaminated soils requiring disposal, the FEMP site is investigating soil washing as part of the Operable Unit 5 RI/FS. The goal of this chemical extraction is to extract contaminants (particularly uranium) from the soil, thereby creating an extractant stream which contains the contaminants and clean soil which may be returned to the environment. Chemical extraction is a viable process option for the Subunits A and B wastes and the soils within Subunit C.

Reduction

Reduction is the chemical process by which the oxidation state of a compound is reduced to change the solubility, stability, and/or separability of a compound. This process option was eliminated for all

subunits because there are few reducible compounds in the Operable Unit 4 wastes and because reduction may result in more toxic contaminants.

2.5.6.5 Thermal Treatment Technologies

This technology proposes several treatment process options that will thermally treat the wastes through drying/calcination, incineration, and thermal desorption. Process options are summarized in the following text.

Drying/Calcination

Drying and calcination are weight/volume reduction techniques that use heat to remove bound water from sludges or solids. Calcination can remove water by hydration due to the higher temperatures involved. These process options have been retained for Subunit A because they can be used in conjunction with other treatment technologies (i.e., vitrification). Because Subunit B contains little or no water and the Silo 3 contents were calcined before being placed in the silo, these process options have not been retained for Subunit B. Drying/calcination was also eliminated for Subunit C because it is inappropriate to the treatment of the inorganic or radionuclide contaminants found in the soils, structures, and debris.

Incineration

Waste material can be incinerated by rotary kiln, fluidized bed, slagging, and liquid injection incinerators. Rotary kiln and fluidized bed incineration are typically used to destroy organic contaminants. Rotary kilns are refractory-lined rotating cylinders positioned at a slight incline. Waste is introduced at the high end, and ash is collected from the bottom end. Flue gasses pass through a secondary chamber and control equipment before exiting to the atmosphere. Fluidized bed incinerators contain a bed of sized granular refractory material in a refractory-lined vessel. Waste is injected onto the bed and incinerated as air is forced up through the bed at a velocity sufficient to fluidize the burning material. This process option has not been retained for any of the subunits because it does not treat the inorganic or radionuclide contaminants present.

Thermal Desorption

Thermal desorption is a process by which the waste solids are sufficiently heated to volatilize organic compounds absorbed on the material. This process option has not been retained for further evaluation because it does not treat the inorganic or radionuclide contaminants. The relatively low

concentrations of volatiles present in the waste preclude consideration of treating all waste with this option.

2.5.6.6 Biological Treatment Technologies

Several biological treatment process options are available for treating contaminated soil, waste material, water, and structural material are available for consideration. Biological treatment process options use living organisms such as bacteria or fungi to detoxify or immobilize contaminants in waste. These process options are applied primarily to convert organic contaminants into nontoxic products. Bioremediation has also been used to degrade inorganic contaminants such as nitrates, and to detoxify or immobilize certain metals by changing their oxidation state.

Effective bioremediation technologies often require the use of amending agents and nutrients such as sewage sludge, hay, or manure for the remediation of solid material and a soluble organic compound such as glucose for the remediation of aqueous or slurry waste. The addition or control of oxygen, temperature, and pH are also commonly required. Use of microbes already present at the waste site is preferable to introducing other microbes that must be acclimated to site conditions. In bioremediation processes, limitations to microbial activity (e.g., nutrient deficiencies or improper oxygenation or temperature control) are identified and corrected to stimulate or accelerate naturally occurring processes. The following discussion presents potential bioremediation process options.

Biodenitrification

Biodenitrification is a microbial process by which nitrates and nitrites are reduced to molecular nitrogen. The nitrate/nitrite replaces the molecular oxygen in bioassimilation. This process option has been eliminated for all of the subunits because none of the subunits contain significant quantities of nitrates.

Biological Detoxification

This process utilizes biological processes to detoxify a waste stream by destroying the organic constituents. The processes are typically some form of aerobic respiration. This process option has not been retained for any of the subunits due to the insignificant quantities of organic constituents and the inability of this process option to treat inorganics and radionuclides.

Land Farming

This process uses a microbial process to treat biodegradable contaminated soils or soil-like wastes. The wastes are spread to a thickness of 0.3 to 0.61 m (1 to 2 ft) over the land and mixed with the microorganisms and nutrients. The mixture is regularly wetted and mixed with a tiller to maintain the proper growth environment. This process option has not been retained for any subunits because the inorganics and radionuclides are usually concentrated in the soil and may migrate through the subsurface. Typically, no treatment occurs.

2.5.6.7 Decontamination and Decommissioning Technologies

These decontamination and decommissioning (D&D) techniques apply only to the contaminated structural media in Subunit C. This technology does not apply to Subunits A and B because these subunits have no structures for D&D. Decontamination and decommissioning will remove gross contamination from the Silos 1, 2, and 3 walls. Because Silo 4 has not stored any residues, there is no contamination and it will not require decontamination. Because it is not contaminated, Silo 4 provides for a unique opportunity to demonstrate D&D technologies in a clean setting prior to the implementation of the technologies on Silos 1, 2, and 3. Application of the various tools and techniques available in D&D depends on the physical and radiological conditions of the structure. The chosen technology must decontaminate the silos and other structures while maintaining control of the process, both radiologically and physically. The process should also minimize, as much as possible, the quantity of waste to be packaged for disposal. The D&D process options considered include vacuum scabbling, pressure washer, vacuum grit-blasting, acid washing, and strippable coatings.

Vacuum Scabbling

Scabbling removes the surface contamination by chipping away small amounts of the top layer of material (usually concrete), using a pneumatically-driven piston equipped with spikes that strike the surface and break away the concrete. A vacuum device can be used in conjunction with the scabbler to capture the generated dust and debris. This process is best suited for flat surfaces. Vacuum scabbling has been retained for evaluation for Subunit C.

Pressure Washing

High-pressure washing water can be used to decontaminate radioactively contaminated surfaces. The washing action and impaction of water removes loose surface contamination and dissolves soluble

contaminants to an aqueous phase. The wash water would require treatment and disposal. This technique is often used in areas where the contaminated surface is difficult to reach; therefore, this process option has been retained for Subunit C.

Vacuum Grit-Blasting

Vacuum grit-blasting is one of the most widely used decontamination techniques. A stream of abrasive grit material is propelled against the contaminated surface, and the resulting dust/particles are vacuumed away in a vacuum collar surrounding the abrasive cleaning head. This process option has been retained for Subunit C for removal of the contaminated surface material.

Acid Washing with Oxidizing Agents

Acid washing decontaminates concrete surfaces by removing surface contamination during generalized destruction of the concrete surface. The acid reacts chemically with the concrete matrix, thereby removing a thin layer of concrete along with the surface contamination. The acid can be applied either manually (brush or roller) or by spray. The dissolved concrete and associated contamination must be rinsed from the surface and collected for treatment and disposal or reuse. A waste treatment system for spent acid solutions is required. This process option could be applied for the silos and has been retained for Subunit C for removing a thin layer of the surface contamination.

Strippable Coatings

Strippable coatings remove loose contaminants from large surface areas by trapping the contaminants in a polymer matrix for removal and disposal. Strippable coatings are available as liquids that may be applied to surfaces by brushing or rolling. After application, these coatings are allowed to cure to a thin, solid coating that may be stripped from the surface and disposed of as a waste. Strippable coatings have been retained for further evaluation for Subunit C as a way to remove surface contamination.

2.5.7 Disposal Technologies

Several disposal technologies may be used following removal as part of the remedial action. Disposal technologies include both on-property and off-site disposal, either of which would require transportation using rail, truck, or a combination of the two. A discussion of the process options associated with the waste disposal technologies follows.

2.5.7.1 Waste Transportation

Specific federal requirements for the off-site transport of chemically hazardous and/or radioactive material have been identified to address factors such as packaging and labeling. Many states, including Ohio, also have transportation requirements and many require advance notice for shipments of radioactive material.

The residues and waste generated will be packaged in DOT specification containers and shipped exclusive use to assure proper handling of the radioactive materials. 7A Type A containers or Strong Tight Containers may be used for the residues generated during Operable Unit 4 remediation. 7A Type A containers will be used for the residues with a higher level of radioactivity (i.e., K-65 residues, cold metal oxides, and Decant Sump sludges). Soils, concrete, and other media may be packaged into 7A Type A containers and/or Strong Tight Containers, depending on their activities at the time of generation. The basis for selecting 7A Type A containers for packaging is that the silos residues meet the definition of Low Specific Activity material under 49 CFR 173.403(n). Activity levels for some contaminated media may be low enough to allow the use of Strong Tight Containers.

For the purposes of this document, it is assumed that 7A Type A containers will be used for transporting and storage of all hazardous materials generated in the remedial alternatives. The containers will be boxes with outer dimensions of approximately 1.2 m x 1.2 m x 1.2 m (4 ft x 4 ft x 4 ft). These boxes will be designed to limit the activity readings on the outer container within DOT limits. The boxes will be configured on the vehicle to assure readings on the outside of the truck or train and exposure are within these limitations.

The process options for waste transportation include both truck and rail transport. Both of these process options will be retained for further evaluation for all subunits.

Rail Transport

The FEMP site can readily support rail transportation by using existing on-property rail spurs. Some off-site disposal options, such as the permitted commercial disposal site, have facilities with the capability of receiving the waste by rail. However, transportation to NTS may be facilitated by a combination of truck and rail transport. Waste shipped by rail to NTS would go through the Las Vegas, Nevada terminal. To assure exclusive use, the boxes would be placed within an ISO (similar to a sealand in size) and placed on a flat bed rail car. At the Las Vegas terminal, the ISO would be removed from the train, without losing exclusive use status and placed on flatbed trucks where they

would be transported to NTS. The Las Vegas Terminal is a new facility which has been constructed to handle the transfer of hazardous materials, including radioactive material for the NTS. Although rail transport has a lower percentage of accidents per trip, the volume of material hauled is also many times higher. Rail transport is, however, more cost effective (approximately 25% lower) than truck.

Truck Transport

Truck transport can offer portal-to-portal service with the road system available at the FEMP site. The primary disadvantages with this process option are the relatively undeveloped and heavily travelled roads near the FEMP site and the higher cost to the public as compared to rail transport.

2.5.7.2 On-Property Disposal Technology

The on-property disposal technology consists of various land-based engineered process options designed to restrict contaminant migration, thereby reducing the threat to potential receptors.

Disposal options evaluated herein are limited to contaminated solids. Any perched water encountered during remediation or the liquids in Silo 4 would be transferred to a wastewater treatment plant at the site. The resultant treated water would be managed in accordance with the NPDES permit issued by the State of Ohio as identified in the ARARs for Operable Unit 4. Hence, the discussion of disposal generally focuses on soils, waste, and structural material.

The following sections discuss the land based process options for on-property disposal facilities.

Engineered Disposal Facility

An above-grade engineered disposal cell has been employed in the United States to dispose of low level radioactive waste. Engineered cells are constructed to satisfy the design requirements appropriate to the type of waste they would contain. The radioactive waste associated with Operable Unit 4 is classified as by-product material, as defined in Section 11(e)2 of the Atomic Energy Act; such material is typically disposed in accordance with the requirements of 40 CFR 192. In a cell engineered for this type of waste, e.g., waste contaminated with low concentrations of naturally occurring radionuclides (uranium, thorium, radium, and their radioactive decay products), the waste is placed on an impermeable liner which includes a leachate collection system to impede the percolation of free water from the cell into the ground. The waste is then covered with a radon barrier to limit radon emissions from the cell, a drain layer, a frost protection layer, and an erosion protection barrier to limit erosion, water infiltration, frost penetration, and biotic intrusion.

A number of designs for engineered disposal facilities are presently being employed throughout the United States for the disposal of low level radioactive wastes. One representative design has been adapted for purposes of this FS to represent this disposal process option. The adopted concept for an engineered disposal facility includes an on-grade reinforced concrete pad designed specifically for holding containerized, stabilized waste. The waste would then be covered by a multimedia cap designed to minimize water infiltration and prevent intrusion. An LC/DS is an integral part of the design. For those wastes requiring protection from inadvertent human/animal intrusion, such as those in Subunit A, a barrier of concrete or other relatively impermeable material can be incorporated into the design. This process option has been retained for all subunits.

Above-Grade Disposal Vault

Concrete vaults are typically used to dispose of containerized waste. Although vaults are structurally stable, they can be more permeable than clay and, as a result, disposal of leachable material within a vault would require an additional low-permeability lining of clay or other material to contain the waste. Compared with an engineered cell, incorporating design changes in a vault during planning and construction (e.g., to increase or decrease the size) is more difficult and could result in schedule delays. In addition, maneuverability within the vault during waste placement activities would be constrained by the structure.

The vault would be constructed of concrete and would be divided into individual cells. The vault slab and walls would act as a base for supporting the double liner system. Upon completion of material emplacement in the vault, a multimedia cap and appropriate drainage controls would be placed over the vault. This on-property disposal facility would also be equipped with an LC/DS. This process option has been retained for evaluation for all subunits.

Lined/Unlined Pits/Trenches

Unlined pits and trenches are not acceptable as permanent waste disposal facilities under current regulatory requirements. The process option of unlined pits and trenches was, therefore, eliminated from consideration.

Properly designed lined pits/trenches are equivalent to landfill disposal units under RCRA. These units have been employed throughout the industry for the disposal of hazardous wastes and to a lesser degree low level radioactive wastes. These disposal options typically involve excavation into native soils with the installation of a natural and synthetic multimedia lining system equipped with a LC/DS.

Following emplacement of the wastes, the disposal cell is covered with a multi-layer capping system to minimize water infiltration. Landfills require the installation of a groundwater monitoring network.

An in-ground landfill design offers no significant advantages over the above grade engineered disposal facility or disposal vault. Lacking noticeable advantages and the increased concern generated by this technology for the protection of the underlying aquifer, this process option was eliminated from further consideration for all subunits.

2.5.7.3 Off-Site Disposal Technology

Nonradioactive contaminated process chemicals could be disposed off site at a commercial facility. Nonradioactive material determined to be hazardous under RCRA would be shipped to a RCRA-permitted treatment, storage, and disposal facility (TSDF) and would require meeting land disposal restrictions (LDRs). Nonhazardous, non-radiologically contaminated waste may be disposed in a sanitary, demolition, or solid waste landfill. Related requirements are presented in Appendix F.

The implementability of land disposal at an off-site facility is affected by the availability of disposal sites for the Operable Unit 4 waste. No commercial facilities are currently permitted to accept 11(e)2 by-product material for disposal. One facility, located near Clive in Tooele County, Utah, is authorized to accept naturally occurring radioactive material. The operator of the permitted commercial disposal site has applied to the U.S. Nuclear Regulatory Commission (NRC) for a license to dispose of 11(e)2 by-product material, but such permission has not yet been received. However, because it is possible that this facility could receive permission to dispose of this material in the future, it has been evaluated as a potential off-site disposal facility.

Other off-site disposal options are currently limited to facilities that are owned and operated by DOE or newly constructed facilities. As identified in DOE Order 5820.2A, large quantities of 11(e)2 by-product material should normally be disposed in the state in which it is generated. Disposal facilities for low-level radioactive waste are currently located at major DOE installations such as the Hanford site near Richland, Washington; the Idaho National Engineering Laboratory near Idaho Falls, Idaho; the Savannah River Site near Aiken, South Carolina; and the Nevada Test Site (NTS) near Las Vegas, Nevada. However, no current DOE disposal facilities exist in the State of Ohio or in the surrounding states. The NTS was evaluated for potential off-site disposal as a reasonable, representative DOE facility, along with two newly constructed facilities.

It is anticipated that some level of opposition by local citizens around the off-site facilities may occur. Resolution of these concerns could result in delays in obtaining required approvals from the disposal facility, thereby requiring temporary storage of the residues at the FEMP for a period of time. Additionally, in order to fully utilize waste minimization technologies pertaining to soil and debris being examined and potentially constructed under Operable Units 3 and 5, interim storage of these materials may be required for alternatives examining both on-site and off-site disposal. In order to safely store the material, an interim storage facility may need to be constructed. This facility would be designed to safely store the residues for an interim period, perhaps years, until treatment or shipment occurs. The potential requirement for interim storage applies to all subunits and, thus, is not specifically considered further in the development, screening, or evaluation of remedial alternatives.

Off-Site Disposal at the Nevada Test Site

This process option calls for the disposal of the waste at an existing government facility located in an arid western environment. This facility is currently operating and accepting many types of DOE waste. Preliminary assessment of the Operable Unit 4 wastes indicated they either currently or with treatment would meet the NTS waste acceptance criteria. The wastes can be transported to the facility by truck or rail as discussed previously. This process option has been retained for all subunits.

Off-Site Disposal at the Permitted Commercial Disposal Site

This process option calls for the disposal of the wastes at an existing commercial facility located in an arid western environment. This facility is currently operating and accepting low-level radioactive and mixed waste that meets the LDR standards for disposal at the facility. The wastes can be transported by truck or rail. The licensing restrictions embodied in the waste acceptance criteria for the permitted commercial disposal site limit the ability of the facility to receive wastes above certain radionuclide specific activity concentrations. Specifically, the permitted commercial disposal site waste acceptance criteria prohibit the receipt of waste exceeding 2000 pCi/g and 15,000 pCi/g for Ra-226 and Th-230, respectively. The mean activity concentration of Ra-226 and Th-230 in Silo 1 and 2 exceeds these levels at 310,400 pCi/g and 55,300 pCi/g respectively. Similarly, the mean activity concentration of Ra-226 and Th-230 in Silo 3 residues exceeds these levels at 2900 pCi/g and 51,200 pCi/g, respectively. Even considering the dilution effects of any additives to support cement-based solidification, these residues could not meet both of these limitations. The process option of off-site disposal at the permitted commercial disposal site therefore has been eliminated for Subunits

A and B. The process option was retained for Subunit C. However, the implementability of such an alternative would be affected by existing DOE policy (DOE Order 5820.2A) precluding disposal of DOE wastes at non-DOE disposal facilities.

Off-Site Disposal at a Facility Constructed Adjacent to the FEMP Site

This process option calls for the disposal of the wastes at a hypothetical facility assumed to be constructed adjacent to the FEMP site and with a common boundary to the FEMP site. This process option involves the siting of a new facility at a location adjacent to the FEMP which could provide improved geologic siting conditions. It should be noted that no such sites have currently been investigated or identified for consideration. The facility would have waste acceptance criteria consistent with those established for the on-property disposal facility. The wastes can be transported by truck or rail. This process option has been retained for all subunits.

Off-Site Disposal at a Facility Constructed Within 483 Kilometers (300 Miles) of the FEMP Site

This process option calls for the disposal of the wastes at a proposed facility to be constructed within a 483-km (300-mi) radius of the site. This facility, a federally owned regional disposal site, would be built in an area with desirable demographic and geologic conditions and would be shared by several regional DOE facilities. This facility is assumed to have waste acceptance criteria consistent with the on-property disposal facility. The wastes can be transported by truck or rail. This process option has been retained for all subunits.

Deep Geological Repository

This process option calls for the disposal of the wastes with alpha-emitting radioisotopes of greater than 100 nanoCi/g activity in a mined geologic repository. This process option considers only those wastes deemed inappropriate for aboveground or shallow land disposal and would only be considered if available land disposal technologies are determined to inadequately protect human health and the environment. Such a disposal facility would offer isolation and protection of the wastes due to deep earth disposal and natural barriers. Presently, there is not a mined or deep geologic repository licensed to receive the treated Silos 1 and 2 contents. The Waste Isolation Pilot Plant (WIPP) in New Mexico is slated to receive only Defense Department transuranic waste and has limited capacity. Given that the K-65 material does not meet WIPP's waste acceptance criteria and that a new mined repository is not likely to be sited, constructed, and approved in time to receive the K-65 material under the current remediation schedule, this process option has been screened from further consideration for all subunits based on poor implementability.

2.6 EVALUATION OF TECHNOLOGIES AND PROCESS OPTIONS

Specific application of these technology types and process options to Operable Unit 4 subunits was evaluated to select representative options from similar options. The purpose of the evaluation is to obtain a reasonable number of options to combine in alternatives (Section 3). Options not carried forward can be reexamined by the designer as they are considered available for further consideration. The process options were evaluated based on effectiveness, implementability, and cost.

The evaluation was only relative to similar process options and did not compare process options between technologies.

2.6.1 Criteria for Evaluating Technologies and Process Options

The process options were evaluated using effectiveness, implementability, and cost as the criteria. These criteria were applied only to the process options and the purpose that they were intended to satisfy; they were not applied to the operable unit as a whole. The evaluation process primarily focuses on effectiveness factors with less emphasis on the implementability and cost evaluations. A description of each evaluation criteria follows.

2.6.1.1 Effectiveness Evaluation

The various process options identified under each technology type in Section 2.5 were evaluated for effectiveness based on the following:

- The potential effectiveness of the process option for meeting the purpose of the technology
- The potential impacts to human health and the environment during the construction and implementation phase
- The reliability of the process option as it relates to the constituents of concern and conditions within the Operable Unit 4 boundary

2.6.1.2 Implementability Evaluation

The implementability evaluation includes both technical and administrative feasibility of implementing a process option. Examples of administrative feasibility include the availability of skilled workers to implement the process option; the ability to obtain permits for off-site actions; and the availability and capacity of TSDFs.

2.6.1.3 Cost Evaluation

Each process option was evaluated as to whether costs were high, medium, or low relative to other process options of the same technology type.

2.6.2 No-Action General Response Action

The no-action GRA was retained for development into an alternative as required by CERCLA. Under the no-action GRA, no additional actions will be taken at Operable Unit 4. It is assumed that the silos would eventually fail releasing their contents. Additionally, DOE would release the site for other unrestricted uses. The evaluation of this GRA follows.

- Effectiveness: This GRA is not effective. It provides no protection of human health and does nothing to reduce the toxicity, mobility, or volume of contaminants present. The potential for exposures to wildlife, trespassers, on-property workers, and off-site residents would increase over time as contaminants continued to be released to groundwater, surface water, soil, or air. Potential impacts to human health and the environment associated with no further action at Operable Unit 4 are discussed in Appendix D.

- Implementability: No technical or other issues exist that would affect implementation, but it would be difficult to gain public acceptance.

- Cost: There are no costs associated with this alternative.

2.6.3 Institutional Action General Response Action

The technologies considered for the institutional action GRA include monitoring and access control. Table 2-9 summarizes the results of the process options evaluation. A narrative discussion follows.

2.6.3.1 Monitoring Technology

Process options evaluated for the monitoring technology include:

- Groundwater monitoring
- Leachate collection/monitoring
- Radon monitoring
- Surface water/sediment monitoring

Groundwater Monitoring

Groundwater monitoring is a process option for Subunits A, B, and C as follows:

- Effectiveness: Monitoring wells effective in determining contaminant migration and in evaluating the effectiveness of other remedial measures. The potential impact on

TABLE 2-9

SUMMARY OF EVALUATION ANALYSIS FOR INSTITUTIONAL ACTION PROCESS OPTIONS

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
Monitoring	Groundwater Monitoring	A, B, C	Monitoring groundwater wells are effective in determining migration and evaluating effectiveness.	Readily implementable	Moderate
	Leachate Monitoring	A, B, C	Effective in detecting water infiltration.	Readily implementable	Low
	Radon Monitoring	A, B, C	A viable option for measuring the effectiveness of implementing other process options.	Readily implementable	Low
	Surface Water/Sediment Monitoring	A, B, C	Can be effective for determining migration and evaluating effectiveness of other process options.	Readily implementable	Low
Access Control	Physical Barriers	A, B, C	Can mitigate potential public exposure on site by restricting access.	Readily implementable	Low
	Administrative Controls/Deed Restrictions	A, B, C	Can be effective in reducing contact between contaminants and receptors.	Readily implementable	Low

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

human health and the environment during the construction and implementation phase of this option is negligible. The only additional exposure by contaminated groundwater monitoring is to sampling and analytical personnel.

- Implementability: A large number of monitoring wells currently exist at and near the FEMP site. Additional wells can be installed quickly, and required equipment and services are readily available.

- Cost: Capital costs would only include the installation of additional monitoring wells. Major operations and maintenance (O&M) costs include well maintenance, sampling and analysis, data validation, database management, and payments to landowners. Overall, costs would be moderate.

The groundwater monitoring process option has been carried forward into the development of alternatives for Subunits A, B, and C.

Leachate Collection/Monitoring

Leachate monitoring is a process option for Subunits A, B, and C.

- Effectiveness: Leachate monitoring is effective in detecting water that has infiltrated and passed through containment systems or waste sites. Leachate monitoring has negligible impact on human health and the environment.

- Implementability: Leachate monitoring just requires taking samples of collected leachate and analyzing the samples. Equipment and services are readily available.

- Cost: The costs would include sampling and analyses. Overall, costs would be low.

Leachate monitoring has been carried forward to the development of alternatives for Subunits A, B, and C.

Radon Monitoring

Radon monitoring is evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: Radon monitoring is a mandate requirement of the FFCA for the control and abatement of radon emissions. Radon monitoring is also an effective means of measuring the success of remedial actions. The impact on human health and the environment during the construction and implementation of this process option is negligible.

- Implementability: The required equipment is readily available, and depending on the type of radon monitoring systems (passive, continuous, or filter), most systems can be easily implemented.

- Cost: Capital costs for most monitoring systems are relatively inexpensive as are O&M costs, which include periodic monitoring and maintenance. Overall, costs would be low.

Radon monitoring has been carried forward into the development of alternatives for Subunits A, B, and C.

Surface Water/Sediment Monitoring

The surface water/sediment monitoring process option is evaluated for Subunits A, B, and C:

- Effectiveness: Surface water/sediment monitoring can be very effective for determining surface water contaminant migration and monitoring the performance of remedial actions.

- Implementability: Surface water/sediment monitoring is easily implemented and requires no specialized training or equipment.

- Cost: Costs for this process option would be very low. Laboratory analytical costs would constitute the largest part of the cost. Overall, costs would be low.

The surface water/sediment monitoring process option has been carried forward to the development of alternatives for Subunits A, B, and C.

2.6.3.2 Access Control Technology

Access control process options were considered for all the subunits. Process options evaluated for access control technology include:

- Physical barriers
- Administrative controls/deed restrictions

Physical Barriers

Use of physical barriers was evaluated as a process option for all the subunits as follows:

- Effectiveness: Physical barriers do mitigate potential exposure to contamination on property by restricting entry. Physical barriers are typically used in conjunction with other remedial actions.

- Implementability: Barriers can be constructed quickly and safely, without disturbing the operation of existing facilities and the environment.

- Cost: The capital costs would be low because barriers are relatively inexpensive to install, depending on the level of security required. Also, O&M costs would be low because once the barrier is installed, little maintenance is be required. The overall costs would be low.

The option of physical barriers has been carried forward to the development of alternatives for all subunits.

Administrative Controls

Administrative controls were evaluated as a process option for all the subunits as follows:

- Effectiveness: Administrative controls can be highly effective in reducing contact between contaminants and receptors but often cannot be relied on as the sole method of remediation.

- Implementability: Administrative controls are easy to implement and are standard requirements at hazardous waste management facilities.

- Cost: Capital costs would be higher for administrative controls than for passive controls, and depending on the controls chosen, the O&M costs would be low. The overall costs would be low.

The option of administrative controls/deed restrictions has been carried forward to the development of alternatives for all subunits.

2.6.4 Containment General Response Action

The following technologies were considered for the containment GRA:

- Subsurface flow control
- Capping
- Run-on/runoff control
- Silo renovation

Table 2-10 summarizes the results of the process options evaluation. A narrative discussion follows.

2.6.4.1 Subsurface Flow Control Technology

Subsurface flow control was determined to be a remedial technology potentially applicable for Subunits A, B, and C. Process options retained for evaluation for subsurface flow control include:

- Subsurface drains
- Slurry walls
- Pumping wells

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TABLE 2-10

SUMMARY OF EVALUATION ANALYSIS FOR CONTAINMENT PROCESS OPTIONS

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
Subsurface Flow Control	Subsurface Drains	A, B, C	Less effective if installed under existing waste, Would still mitigate leachate release to subsurface.	Moderately difficult to implement	Moderate
	Slurry Walls	A, B, C	Most effective in controlling lateral migration and flow but do not eliminate the radioactive contaminants of the contained waste. Potential impact to human health and the environment is minimal.	Moderately difficult to implement	Moderate
	Pumping Wells	A, B, C	Moderately effective in controlling subsurface flow and diffusion and effectiveness is maintained only as long as pumping continues.	Moderately difficult to implement	High
	Sheet Pilings	A, B, C	Effective in controlling lateral migration and flow but not as effective as slurry walls.	Readily implementable	Moderate
	Grout Curtains	A, B, C	Less effective in controlling lateral diffusion and flow than slurry walls.	Difficult to implement	High
Capping	Concrete-Based Cap	A, B, C	Effective for erosion control and minimizing leachate generation; as an intrusion barrier will be more effective than asphalt cap. Susceptible to weathering and cracking.	Readily implementable	High
	Asphalt-Based Cap	A, B, C	Effective for erosion control and minimizing leachate generation. Serves as an intrusion barrier but very susceptible to weathering and cracking.	Readily implementable	Moderate

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

TABLE 2-10
(Continued)

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
	Soil-Clay-Based Cap	A, B, C	Less effective for erosion control and minimizing leachate generation. Not very effective as an intrusion barrier. Very susceptible to weathering.	Readily implementable	Low
	Chemical Sealant Cap	A, B, C	Moderately effective for erosion control and minimizing leachate generation if maintained. Not as durable as concrete, asphalt, or clay caps.	Moderately difficult to implement	Moderate
	Multimedia Cap	A, B, C	Highly effective in preventing contaminant migration. It minimizes leachate generation, promotes surface drainage, prevents erosion and sediment transport of waste, and acts as an effective intrusion barrier.	Readily implementable	Moderate
	Void Space Grout	A, B	Effective in radon reduction and subsidence control but does not treat or remove the waste.	Readily implementable	Low
Run-On/Runoff Control	Sedimentation Basin/Sediment Trap	A, B, C	Effective for the removal of suspended solids. Unable to retain surface runoff.	Readily implementable	Low
	Diversion/Collection	A, B, C	Effective in preventing flooding, controlling erosion, and directing surface when used with other process technologies.	Readily implementable	Moderate
	Grading	A, B, C	Highly effective in controlling site drainage and minimizing infiltration of water into contaminated areas. Some form of grading will be necessary for the development of all alternatives.	Readily implementable	Moderate

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

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TABLE 2-10
(Continued)

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
	Revegetation	A, B, C	Effective in controlling erosion. No apparent impact to human health and the environment. It stabilizes the surface of waste disposal facilities.	Readily implementable	Low
Silo Renovation	Silo Rehabilitation	C	Effective in controlling surface contamination for the short term. Soil and subsoil contamination still exists and long-term effectiveness is very poor.	Readily implementable	Low

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

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- Sheet pilings
- Grout curtains

Subsurface Drains

Leachate collection/control through subsurface drains was evaluated for Subunits A, B, and C.

- Effectiveness: The effectiveness of drains to control leachate is dependent on their design. They are not as effective if installed on an existing disposal/storage unit as if installed prior to waste placement. However, they can still mitigate leachate release into the subsurface.

- Implementability: Installing drains near or under existing disposal/storage units can be moderately difficult, but achievable. There are minimal administrative issues.

- Cost: Capital costs are fairly low but there are moderate O&M costs. Overall costs are therefore rated moderate.

Subsurface drains for leachate collection will be carried forward to the development of alternatives for Subunits A, B, and C.

Slurry Walls

Slurry walls were evaluated as a groundwater flow control process option for Subunits A, B, and C as follows:

- Effectiveness: These structures are effective as a barrier to confine contaminated groundwater that might otherwise flow from the site, or to divert the flow of groundwater away from the contaminated media. Slurry walls do not eliminate the radioactive contaminants of the enclosed waste, but inhibit the release of these contaminants through lateral migration. This technology is subject to several limiting criteria, such as type of waste to be contained, site geology, and construction. The potential impact to human health and the environment in the implementation of this structure is considered minimal.

- Implementability: Slurry walls are moderately difficult to install but can be constructed without disturbing the function or operation of existing facilities. Deep slurry walls could be difficult to install and would require deep trenching.

- Cost: Costs of construction equipment for trench construction, cost of grout, and removal of the contaminated material contribute to the expense of this process. Given the contaminants, periodic maintenance of slurry walls is not required if design considerations include selection of the most appropriate slurry mixture. Overall, costs would be moderate when compared to other control technologies.

Slurry walls will represent groundwater flow control processes and have been carried forward to the development of alternatives for Subunits A, B, and C.

Pumping Wells

Pumping wells were evaluated as a groundwater flow control process option for Subunits A, B, and C as follows:

- Effectiveness: Pumping wells are moderately effective in controlling the lateral diffusion and flow of a contaminated plume, thereby restricting contaminant migration in the soil and groundwater. This process option is proven to be reliable and minimal impact should occur on human health. Effectiveness is maintained only as long as pumping operations continue.

- Implementability: Equipment and services for this process option are readily available. The groundwater can be pumped to the FEMP AWWT facility and treated before discharge to the Great Miami River through the NPDES. However, it is moderately difficult to keep the system operating as necessary to achieve the desired effects.

- Cost: The capital costs include equipment and installation and would be moderate. Pumps, screens, casings, and pipeline must be maintained to ensure proper water flow from the extraction well; also, maintenance is required to prevent loss of the well that would result in contaminant escape. Long-term costs for the pumping system would be very high. Additional costs for treating the pumped groundwater would be considered low because the pumped groundwater would only be a small portion of the total volume of water treated by the FEMP AWWT facility. Overall, costs would be considered high.

Pumping wells have not been carried forward to alternative development for any subunits due to the moderate effectiveness rating and high operating costs. Slurry walls will represent the groundwater control technology.

Sheet Pilings

Sheet pilings were evaluated as a groundwater flow control process option for Subunits A, B, and C as follows:

- Effectiveness: Sheet pilings function similar to slurry walls in confining contaminated groundwater or diverting groundwater flow away from contaminated media. Sheet pilings are not as effective as slurry walls in diverting the groundwater flow because the joints of the sheets allow for leakage.

- Implementability: Sheet pilings are installed from the surface using a pile driver. This process option would be readily implementable because the Operable Unit 4 subsurface conditions offer little or no obstructions.

- Cost: The capital cost for the sheet pilings would be high compared to slurry walls. The maintenance of the sheet pilings would be low. Therefore, the overall costs would be moderate.

Sheet pilings have not been carried forward to alternative development in favor of slurry walls because of the low effectiveness when compared to slurry walls and the moderate capital cost.

Grout Curtains

Grout curtains were evaluated as a groundwater flow control process option for Subunits A, B, and C as follows:

- Effectiveness: This process option is less effective in retarding groundwater flow than a slurry wall. The incremental nature of the installation process for the grout curtains results in more gaps in the barrier than that for a slurry wall. This process option is moderately effective.

- Implementability: This process requires extensive drilling and equipment for pressure injecting grout directly into the soil. Depending on the subsurface conditions, this process option could be difficult to implement.

- Cost: Cost of grout curtains can be three times as costly as a slurry wall. The O&M costs would include inspection, groundwater monitoring, and possibly repairs. Overall, costs would be high on a comparative basis.

Grout curtains have not been carried forward to alternative development in favor of slurry walls as a result of the moderate effectiveness and implementation difficulty.

2.6.4.2 Capping Process Options

Capping was determined to be a viable remedial technology for all subunits for long-term containment. Process options evaluated for capping include:

- Concrete-based cap
- Asphalt-based cap
- Soil-/clay-based cap
- Chemical sealant cap
- Multimedia cap
- Void space grout

Concrete-Based Cap

The concrete-based cap was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: A concrete-based cover is a moderately effective material used for building a single-layered cap. If properly constructed, the cap will control erosion and minimize leachate generation. However, it is susceptible to weathering and cracking. As an intrusion barrier, concrete will provide a greater degree of protection as compared to a single-layered asphalt cap.

- Implementability: A single-layered cap using concrete is readily built and requires the standard construction equipment. The concrete vendors near the FEMP site could readily support the demand for large volumes of concrete.

- Cost: For a single-layered concrete cap, the capital costs for raw construction materials would be approximately 30 to 35 percent more than a single-layered asphalt cap. The O&M costs of a single-layered concrete cap should be minimal. Overall, costs would be high.

The concrete-based capping option is not carried forward for the development of alternatives because it is not as effective as a multimedia cap.

Asphalt-Based Cap

The asphalt-based cap was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: An asphalt-based cover is a moderately effective material used for building a single-layered cap. Properly constructed, the cap will control erosion and minimize leachate generation. As an intrusion barrier, it will minimize direct contact between receptors and waste. Due to the year-round climate variations at the FEMP site, an asphalt-based cap could be subjected to considerable expansion and contraction forces that cause cracking in the asphalt layer. Although the effects of expansion and contraction can be lessened through additives and mesh-like membranes, significant maintenance is required and increases with time. It is less reliable than a multimedia cap.

- Implementability: A single-layered asphalt cap is readily constructed and requires standard construction equipment. Availability of the required asphalt quantity and favorable weather conditions are the primary considerations for construction. Local asphalt contractors are available and could support this effort.

- Cost: A single-layered asphalt cap would be moderate in cost compared with a multimedia cap. Fewer types of construction equipment and materials would be required. As the exposed surface would be asphalt, no mowing and maintenance would be required as with the vegetative layer of a multimedia cap. Special surface treatment would be required periodically and would increase in quantity and frequency with age. Overall, costs would be moderate.

The asphalt-based cap is not carried forward for any subunit for the development of alternatives because it is not as effective as the multimedia cap.

Soil-/Clay-Based Cap

The soil-/clay-based cap was evaluated as a capping option for Subunits A, B, and C as follows:

- Effectiveness: For single-layered caps, natural soil/clay is not recommended due to its high susceptibility to cracking and weathering attributed to the freeze/thaw and shrink/swell cycles of the FEMP's climate. Infiltration through cracks will facilitate leaching. Cement or asphalt are more effective materials for single-layered caps. As an intrusion barrier, natural soil-/clay would be ranked as low. Effectiveness for this process option is low.

- Implementability: A single-layered soil/clay based cap could be easily constructed with only very basic construction equipment required. Availability of natural soil/clay, with a lower permeability than emplaced waste, is the primary construction consideration.

- Cost: The natural soil/clay single-layered cap is the most economical in both equipment and material costs as compared to single-layered caps using asphalt or concrete and multimedia caps. The O&M costs of a natural soil/clay cover would be low due to the nature of the materials used in maintaining cap integrity. Maintenance and inspection depend on weather conditions and may be more frequent than a single-layered cap using asphalt, concrete, or the vegetative layer of a multimedia cap. Overall, costs would be low.

The soil-/clay-based cap is not carried forward for any subunit due to its low effectiveness.

Chemical Sealant Cap

Chemical sealant was evaluated as a capping process option for Subunits A, B, and C as follows:

- Effectiveness: Chemical sealants can form a moderately effective seal on the surface of a waste form. The seal is not as durable as concrete, asphalt, or even clay. Chemical sealant ranks low as an intrusion barrier.

- Implementability: Chemical sealants have not been used as extensively as other capping options evaluated. The companies and trained personnel required to implement this process option are not as available as for the other process options. Overall, this process option was rated as moderately difficult to implement.

- Cost: The cost of implementing this process option is rated as moderate. The operating costs for this process option would be low, but the maintenance costs for a chemical cap is expected to be moderate.

Chemical sealant has not been carried forward for any subunit because of its moderate effectiveness and because it is moderately difficult to implement.

Multimedia Cap

The multimedia cap was evaluated as a capping process option for Subunits A, B, and C as follows:

- Effectiveness: A multimedia cap is a highly effective method of preventing contaminant migration. A well-constructed cap significantly reduces infiltration into waste, thereby minimizing leachate generation. It promotes surface drainage and prevents erosion and sediment transport of waste. It also acts as an intrusion barrier to prevent direct contact between receptors and waste.

- Implementability: Multimedia caps are readily constructed and require only standard construction equipment. Availability of construction materials, such as suitable clays, is the primary construction consideration.

- Cost: A multimedia cap involves significantly more capital equipment costs than other types of caps. The O&M costs for multimedia caps are higher than concrete caps because the exposed surface is a vegetative layer that requires mowing and maintenance. Overall, costs are rated moderate.

The multimedia cap is carried forward as the representative capping option to the development of alternatives for Subunits A, B, and C due to its high effectiveness.

Void Space Grout

Void space grout was evaluated as a process option to be used in conjunction with a capping technology for Subunits A and B. The void space grout was evaluated as follows:

- Effectiveness: This technology would use a grout to fill the void in the silos and would effectively control subsidence and reduce radon production; however, it does not treat or remove the waste. Void space grouting would be required before placing a cap over Silos 1 and 2 to increase stability of the silo domes.

- Implementability: Void space grout is readily implemented, the equipment and materials required are easily obtained, and similar activities have been implemented at the site (bentonite addition).

- Cost: This option would incur very low capital costs for the necessary equipment and materials. The O&M costs for this option could also be very low or none at all. The overall cost for this process option would be low.

The void space grout process option has been carried forward to alternative development as a support process option for the Subunits A and B capping technology.

2.6.4.3 Run-On/Runoff Control Technology

Run-on/runoff control technology was determined to be a remedial technology applicable for all of the subunits. Process options evaluated for run-on/runoff control include:

- Sedimentation basin/sediment trap
- Diversion/collection

- Grading
- Revegetation

Sedimentation Basin/Sediment Trap

The sedimentation basin/sediment trap was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: Sedimentation basins and sediment traps can effectively remove suspended solids; however, sediment traps are not effective for retaining surface runoff. The effluent concentration of suspended solids is regulated by local and/or federal government authorities. This process option provides a reliable method for removing suspended solids from a runoff waste stream, provided the particles will settle.

- Implementability: To implement this process option, flow characteristics are required, fill material must be properly prepared, and emergency spillway of the sedimentation basin should be stabilized with temporary vegetation. Storage requirements of material must be considered when constructing the sedimentation basin. These requirements vary from state to state. Also, in many states, the sediment can accumulate to a specific limit within the sedimentation basin. However, this process option has been implemented at virtually every construction site and has been proven to be easily implementable.

- Cost: The costs for sedimentation basins vary with size, location, and construction method. Installation includes costs for equipment, materials, and construction. The sedimentation basin for the Operable Unit 4 Study Area is economical; it carries low O&M costs. Overall, costs are considered relatively low.

The sedimentation basin and sediment trap have not been considered in the alternative development for any subunits due to its inability to retain surface runoff. However, it may be reconsidered by the designer for stormwater flow control if needed.

Diversion/Collection

Diversion/collection was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: This surface water control method is used to prevent flooding, control erosion, and direct surface runoff. When used in conjunction with other remedial action technologies, this technology can be effective. Diversion of storm water runoff will reduce the amount of leachate produced.

- Implementability: This method can be easily and readily implemented using readily available equipment and materials and local contractors. Implementation of this method seldom poses significant risks to worker health and safety. Most excavation and grading equipment is available on property.

- Cost: Generally, cost of diversion and collection techniques usually is not high with the installation cost dependent on the site topography and geology. Low maintenance costs are common to almost all diversion and collection methods. Overall, costs are considered moderate.

Diversion/collection has been carried forward to the development of alternatives for Subunits A, B, and C.

Grading

Grading was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: Grading is a highly effective method of promoting and controlling site drainage and minimizing infiltration of water into contaminated areas. Grading can be used with in situ remediation alternatives as well as removal, treatment, and disposal alternatives. Some form of site grading will be used with any remediation alternative. Short-term fugitive dust emissions are the only concern to construction workers.

- Implementability: Grading can be easily implemented at the site and does not require specialized equipment. The techniques used in grading operations are well established and widely used. Personnel and equipment can usually be obtained locally.

- Cost: Capital costs would be moderate. Required equipment can be either purchased or leased. Periodic monitoring of the graded surface is necessary, and due to possible surface settling, smoothing operations may be required for several years. Also, O&M costs include annual inspections, mowing, erosion control, and drainage maintenance. Overall, costs are considered moderate.

Grading has been carried forward to the development of alternatives for Subunits A, B, and C.

Revegetation

Revegetation was evaluated as a process option for Subunits A, B, and C as follows:

- Effectiveness: Revegetation effectively establishes a vegetative cover that stabilizes the surface of waste disposal sites. This technique decreases erosion by wind and precipitation. No apparent impact to human health and the environment occurs from using this technique.

- Implementability: This process option is considered readily implementable due to the minimal equipment requirement. Planning involves the selection of suitable plant species, seed bed preparation, seeding/planting, mulching, fertilization, and maintenance.

- Cost: Relative to other technologies, revegetation is an inexpensive stabilization process. Periodic maintenance such as lining, fertilizing, mowing, replanting, and grading eroded slopes are O&M costs associated with this remedial technique. Overall, costs would be low.

Revegetation has been carried forward to the development of alternatives for Subunits A, B, and C.

2.6.4.4 Silo Renovation Technology

Silo Rehabilitation Process Option

Silo renovation has been retained for evaluation for Subunit C. The evaluation of the silo rehabilitation process option is summarized as follows:

- Effectiveness: Silo rehabilitation is moderately effective for containing contamination to the silo walls term through the application of paint, foam, concrete, or emulsions. Although it may hinder migration, this process option alone will not reduce the toxicity or volume of the contaminated material and, therefore, its long-term effectiveness is very poor. However, it cannot effectively treat the subsoils, berm soils, decant sump tank, or process piping.

- Implementability: This process option is moderately implementable. The materials and equipment required are readily available, but special precaution must be taken to protect site personnel from the materials being handled and exposure to contamination during implementation.

- Cost: Costs include labor and materials and would be low.

Silo renovation has not been retained for Subunit C because there is no intent on the part of DOE to renovate the silos for any future use. DOE is committed to removing the silos (if waste removal options are selected for Subunits A and B) as part of FEMP cleanup activities.

2.6.5 Removal General Response Action

The following technologies have been retained for the removal GRA:

- Mechanical removal
- Hydraulic removal
- Pneumatic removal
- Silo demolition

Table 2-11 summarizes the results of the process options evaluation for the removal general response action. A narrative discussion follows.

TABLE 2-11

SUMMARY OF EVALUATION ANALYSIS FOR REMOVAL PROCESS OPTIONS

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
Mechanical Removal	Loader/Dozer	C	Very effective in removing soil and debris.	Readily implementable	Low
	Crane w/Clamshell System	A, C	Effective in removing sludges/soils, but provides little protection to personnel from contaminated material. Effective for Subunit C soils; not viable for Subunit A due to health and safety concerns.	Readily implementable	Low
	Conveyor System	C	Moderate effectiveness for removing solid materials but requires another method for loading material onto conveyor system.	Moderately implementable	Moderate
	Backhoe	C	Very effective in removing soil and debris.	Readily implementable	Low
	Dragline System	C	Effective in removing soil and debris but less effective than a backhoe or loader/dozer due to the larger area required for operation.	Readily implementable	Moderate
Hydraulic Removal	Slurry Pump with Jetting Ring	A, B, C	Effective in removing sludge-like material with accessibility problems. Not as effective for material consistency in Subunit B.	Readily Implementable	Moderate
Pneumatic Removal	Vacuum with Cutterhead	A, B	Most effective with dry material and not effective on materials with high moisture content (Subunit A).	Moderately difficult to implement	Moderate
Silo Demolition	Controlled Blasting	C	Very effective for concrete demolition but hazards exist due to the use of explosives and fugitive dust emissions.	Readily implementable	Moderate

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

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TABLE 2-11
(Continued)

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
	Impact Hammer	C	Effective for removing small portions of concrete at a very slow removal rate. Dangers in controlling dust.	Readily implementable	Low
	Flame Cutting	C	Effective in cutting thick structures but creates large amounts of dust, smoke, and heat. Also has inherent operating dangers.	Moderately implementable	High
	Thermite Reaction Lance	C	Effective on almost any material and is suitable for irregular surfaces. Cuts rapidly but creates a large amount of dust, smoke, and heat.	Moderately difficult to implement	Moderate
	Gas Torch	C	Effective but represents a flame hazard while also creating large amounts of dust, smoke, and heat.	Readily implementable	Moderate
	Hydraulic Splitter	C	Not effective on steel-reinforced concrete.	Readily implementable	Moderate
	Nonexplosive Demolition Compounds	C	Only moderately effective on steel-reinforced concrete. Drilling holes in silos would weaken structures and pose a safety issue.	Readily implementable	Low
	Circular Diamond or Carbide Saw	C	Moderately effective for cutting thick concrete and steel-reinforced concrete. The dust produced is controlled with a water spray.	Readily implementable	Low
	Diamond Rope Saw	C	Very effective on reinforced concrete. It is lightweight and easy to handle.	Moderately implementable	Moderate
	Diamond Chain Saw	C	Very effective on steel-reinforced concrete. It is lightweight and easy to handle.	Readily implementable	Low

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

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TABLE 2-11
(Continued)

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
	Abrasive Water Jet	C	Effective on steel-reinforced concrete but has inherent dangers with the high pressures involved. Also creates large volumes of contaminated water.	Moderately difficult to implement	Moderate
	Core-Stitch Drilling	C	Only moderately effective on steel-reinforced concrete. Would have to be combined with another demolition process.	Moderately implementable	Low
	Wrecking Ball	C	Effective in demolishing the silos but would create large amounts of contaminated dust.	Readily implementable	Moderate

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

2.6.5.1 Mechanical Removal Technology

The process options being evaluated for the mechanical removal technology include:

- Loader/dozer
- Crane with clamshell system
- Conveyor system
- Backhoe
- Dragline system

Loader/Dozer

Use of a wheeled or tracked front-end loader or dozer was evaluated under the mechanical removal technology for Subunit C as follows:

- Effectiveness: This process option is very effective in removing soil and debris for treatment or for waste packaging. There is the potential for dust suspension that would require the use of dust controls.

- Implementability: Front-end loaders and dozers are widely used for earth-moving activities and can be readily obtained. This process option is readily implementable.

- Cost: Capital costs would be low and would only include equipment cost. The O&M costs would be low and include equipment repair. Overall, costs would be low.

The loader/dozer has been carried forward for alternative development for Subunit C because it effectively removes contaminated soil and debris and rates high in implementability.

Crane with Clamshell System

The crane and clamshell system was evaluated as a mechanical removal technology for Subunits A and C. The evaluation of this system is summarized as follows:

- Effectiveness: This system is used for material excavation and in rehandling materials. The health and safety of workers are of concern because of the minimal personnel protection provided. Fugitive dust emissions may result in environmental exposure to the contaminated residues. The crane and clamshell system would be ineffective for removing water such as the rainwater that infiltrated Silo 4.

- Implementability: The use of the clamshell to remove the Subunit A residues would require removing the silo domes and using a secondary containment device. It rates low in implementability for Subunit A residues. The silo domes serve as primary containment structures for the silo residues. Control of radon emissions would be difficult once the bentonite caps are disturbed. This system is readily implemented for

Subunit C residues because the equipment is easily obtained and the waste is accessible.

- Cost: Capital costs would include only the equipment cost. The O&M costs include labor and possibly equipment repair costs. Overall, costs are low.

The crane with clamshell has been retained for alternative development for Subunit C due to its high implementability for soils. This process option has not been retained for Subunit A because of its low implementability for residues.

Conveyor System

A belt-type conveyor system was evaluated as a process option under the mechanical removal technology for Subunit C. The evaluation of the conveyor process is summarized as follows:

- Effectiveness: This process option could be used for moving the soils and debris. Personnel may be exposed to fugitive dust emissions. Overall, effectiveness is rated moderate.

- Implementability: Conveyor equipment is readily available but would require another means of loading material onto the conveyor system. Implementability is considered moderate.

- Cost: Costs would include equipment and labor. Overall, costs are considered moderate.

Due to its moderate effectiveness, implementability, and cost, the belt-type conveyor system has not been carried forward for alternative development for any subunit.

Backhoe

Use of a wheeled or tracked backhoe was evaluated for the mechanical removal technology for Subunit C. This evaluation is summarized as follows:

- Effectiveness: This process option would be very effective in removing soils and debris for treatment or disposal. There is the potential for dust suspension that could spread contamination. Dust control measures may be needed.

- Implementability: The backhoe option is readily implemented and the equipment is easily obtained.

- Cost: Capital costs would be low and would only include equipment cost. The O&M costs would be low and include equipment repair. Overall, costs would be low.

The backhoe has been retained for alternative development for Subunit C because of its effectiveness in removing contaminated soil and debris. This option is also attractive because it is easily implemented and has low capital and O&M costs.

Dragline System

A dragline system was evaluated for Subunit C as follows:

- Effectiveness: A dragline system could be effective in removing the soils and debris; however, it probably would require excavating a larger area than necessary due to the nature of its operation.

- Implementability: A dragline system would be readily implemented.

- Cost: Capital costs would be moderate and include only the equipment cost. The O&M costs would be low and include labor and equipment repair. Overall, costs are considered moderate.

The dragline system has not been carried forward for alternative development for any subunits because its costs are higher than the other removal process options. Also, it would be less effective than a backhoe or loader/bulldozer because it requires a larger area for operation.

2.6.5.2 Hydraulic Removal Technology

The slurry pump with jetting ring process option was retained for evaluation for Subunits A, B, and C. The evaluation of this option is summarized as follows:

- Effectiveness: This option is highly effective in pumping liquids with varying solids content ranging from slurries to sludges. This process option would work well on the moist, sludge-like residues of Subunit A. The interaction of the water with the dry metal oxides, however, may make it difficult to pump the material in Subunit B.

- Implementability: Equipment is readily available and does not require highly trained personnel. There is potential for significant radon releases when the bentonite cover is breached in the silos.

- Cost: Capital costs vary depending on the options and type of power source. The O&M costs would consist of operator, labor, and fuel costs. Overall, costs are considered moderate.

The slurry pump with jetting ring has been carried forward for alternative development for Subunit A, but not for Subunit B. Subunit B residues are more effectively removed by another removal technology due to its low water content. Subunit C can use the slurry pump to remove any water but a jetting ring would not be required.

2.6.5.3 Pneumatic Removal Technology

The only process option retained for evaluation for pneumatic removal technology is a vacuum with a cutterhead. This process option is applicable for treating Subunits A and B. The evaluation of the vacuum with cutterhead is summarized as follows:

- Effectiveness: The primary limitations on the effectiveness of pneumatic removal systems are the limited production rates when pumping materials with high moisture contents. This process option is more amenable to the dry material of Subunit B.

- Implementability: Pneumatic removal systems are readily available for many applications. Additional support systems may be required when removing wastes with high moisture contents. There is the potential for significant radon releases when the bentonite cover is breached in the silos. This process option is moderately difficult to implement.

- Cost: Capital costs for pneumatic removal systems are moderate and require a work platform, compressors, pumps, and intake and discharge lines. O&M costs for pneumatic removal systems are moderate. Overall, costs are considered moderate.

The vacuum with cutterhead process option has been carried forward to alternative development for Subunit B but will not be carried forward for Subunit A due to the reduced effectiveness on materials with a high moisture content.

2.6.5.4 Silo Demolition Technology

Process options retained for the evaluation of silo demolition technology for Subunit C include:

- Controlled blasting
- Impact hammer
- Flame cutting
- Thermite reaction lance
- Gas torch
- Hydraulic splitter
- Nonexplosive demolition agents
- Circular diamond or carbide saws
- Diamond rope saw
- Diamond chain saw
- Abrasive water jet
- Core-stitch drilling
- Wrecking ball

Controlled Blasting

Controlled blasting was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Controlled blasting is very effective for concrete demolition, provided noise and shock in adjoining areas are not of concern. It is well suited to heavily reinforced concrete because a high degree of fragmentation is possible with the proper selection of blast parameters. Also, very high removal rates are possible. There are inherent dangers in controlling blasting with regard to personnel safety and nearby building damage. Also, total dust control is difficult to achieve. Airborne release of contamination is likely.

- Implementability: Controlled blasting is easily implemented and the necessary equipment is readily available.

- Cost: The costs for controlled blasting range from low to moderately high. Capital costs comprise the major portion of the total cost. Overall, costs are considered moderate.

The substantial hazards due to the use of explosives and the generated dust render this process option unacceptable for use with any of the silo structures. Consequently, controlled blasting has not been carried forward for development of alternatives. Its usefulness may be reassessed by the designer.

Impact Hammer

The impact hammer was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Impact hammers or "jackhammers" are very useful for working in small areas. They are effective for removing portions of concrete without disturbing the surroundings; however, they have a very slow removal rate. There are inherent dangers in controlling dust and direct worker exposure to contaminated dust when working with contaminated materials.

- Implementability: The use of impact hammers is easily implemented and the equipment necessary is readily available.

- Cost: Costs for the impact hammer process option would be very low with low capital and O&M costs.

Because of the extremely slow removal rate and the amount of airborne dust created, the impact hammer is not being carried forward for the development of alternatives. It is being represented by other process options and may be reconsidered by the designer.

Flame Cutting

Flame cutting was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Flame cutting makes it possible to cut extremely thick structures and may be used when no vibrations are allowed. The major disadvantages are that during cutting, large amounts of dust, smoke, and heat are produced. Also, there are dangers inherent to the personnel operating the equipment and those near the equipment.

- Implementability: Flame cutting is moderately implementable because of equipment and operator availability.

- Cost: Costs for flame cutting would be moderate to high.

Due to the inherent risk to the workers and the environment, flame cutting has not been carried forward to the development of alternatives. It is being represented by other process options and may be reconsidered by the designer.

Thermite Reaction Lance

Thermite reaction lance is another silo demolition process option evaluated for Subunit C. The evaluation of this process option follows:

- Effectiveness: The thermite reaction lance can rapidly cut almost any material present at the silos and is also suitable for irregular surfaces. In less than six minutes, the lance can burn a hole 5.1 cm (2 in.) in diameter through reinforced concrete that is 1.1 m (3-ft, 6-in.) thick.

- Implementability: The thermite reaction lance is moderately difficult to implement. During use, large amounts of dust, smoke, and heat are produced. A control envelope and ventilation must be provided.

- Cost: The costs for this process option would be moderate and depends on the geometry of the cuts.

Due to the smoke and dust problems associated with this equipment, the thermite reaction lance has not been carried forward as a process option for the development of alternatives. It is being represented by other process options and may be reconsidered by the designer.

Gas Torch

The gas torch was retained for evaluation as a silo demolition process option for Subunit C. The evaluation of the gas torch is summarized as follows:

- Effectiveness: The gas torch uses a flame with temperatures ranging from 1980 to 2480°C (3600 to 4500°F) to effectively cut the concrete and steel reinforcement. The cutting does generate large amounts of dust, smoke, and heat, which could be removed using a flexible duct, pre-filters, and high efficiency particulate air (HEPA) filters. The intense flame represents a flame hazard.

- Implementability: The technology and personnel for the gas torch process option are readily available. This process option is readily implementable.

- Cost: The capital costs for this process option include the cost of the remotely controlled torch and monitoring frame. The capital costs would be moderate. The operating costs would include the cost of the gas fuel for the torch and periodic replacement of the torch tips. The O&M costs for this process option were rated as moderate. Overall, costs are considered moderate.

The gas torch has not been carried forward to development of alternatives due to the smoke, flame, and dust problems associated with this process option. It is being represented by other process options and may be reconsidered by the designer.

Hydraulic Splitter

The hydraulic splitter was evaluated as a silo demolition process option for Subunit C as follows:

- Effectiveness: A hydraulic splitter effectively demolishes concrete by expanding a wedge in predrilled holes along predetermined fault lines, thus causing the concrete to fracture. The amount of steel reinforcing in the silos will reduce the effectiveness of the splitter to cause fracture and the ability to predict the fracture path. Overall, this process option was rated with a low effectiveness for steel-reinforced concrete.

- Implementability: The resources required to implement this process option are readily available. The hole drilling and the operation of the hydraulic splitter can be operated manually or remotely.

- Cost: The costs of the hydraulic splitter process option would range from moderate to high, depending on the amount of automation desired. For evaluation purposes the capital costs for this process option were rated as high. Overall, costs are considered moderate.

The hydraulic splitter process option has not been carried forward to alternative development because it is not effective on steel-reinforced concrete. It may be reconsidered by the designer.

Nonexplosive Demolition Agents

The use of nonexplosive demolition agents was evaluated as a process option for silo demolition, which applies to Subunit C. The evaluation of nonexplosive demolition agent is summarized as follows:

- Effectiveness: Nonexplosive demolition agents are moderately effective in crumbling unreinforced concrete but they are not as effective on reinforced concrete.

- Implementability: The use of nonexplosive demolition agents on the silo would be readily implementable but would require drilling thousands of holes in the silo walls and dome. This would weaken the structure and present safety problems.

- Cost: The capital costs of this process option were rated as low. The capital costs include the drilling rig and application tools. The O&M costs of this process option were rated as low. Overall, costs for nonexplosive demolition systems are considered low.

Nonexplosive demolition agents were not carried forward for the development of alternatives because of the low implementability and moderate effectiveness on reinforced concrete. It may be reconsidered by the designer.

Circular Diamond or Carbide Saws

Circular diamond or carbide saws were retained for evaluation as possible silo demolition options for Subunit C. The evaluation of these process options follows:

- Effectiveness: Circular diamond or carbide saws are moderately effective. They may be used to cut thick concrete walls or floors and, also, can cut through reinforcing bars, although the bars tend to break off diamonds from the blade. The dust produced is controlled with a water spray.

- Implementability: This process option is easily implemented and requires no specialized equipment or personnel. A collection system for the water used for dust control would be required but can be readily installed.

- Cost: The capital costs are low and include purchasing the saws and installing a water collection system. The O&M costs would also be low and include periodic chain replacement and fuel purchases. Overall, costs of this process option would be low.

Circular diamond or carbide saws have not been carried forward to the development of alternatives because of the moderate effectiveness. The diamond rope saw is more effective and has a faster concrete removal rate and will represent demolition response options.

Diamond Rope Saw

The diamond rope saw was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Diamond rope saws are capable of cutting concrete up to 6.1 m (20 ft) thick. The resulting cuts are made much more quickly than those made with the diamond-tipped circular saw or carbide saw. The diamond rope saw can cut at any elevation and in any direction. The diamond rope saw mechanism, including saw stand

and hydraulics, can be placed as far away from the actual work as necessary for personnel and equipment protection. It is highly effective for cutting concrete.

- Implementability: This process option is moderately implementable. The major disadvantage is that there is a significant setup time between cuts. Also, the rope saw is specifically configured for the project requirements such as thickness of the cut, type of aggregate in concrete, and the amount of reinforcement in the concrete.

- Cost: The costs are considered moderate. Initial capital costs include the equipment, and O&M costs mainly consist of replacing the rope saw and maintaining the equipment.

The diamond rope saw has been retained for alternative development for Subunit C.

Diamond Chain Saw

The diamond chain saw was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: The diamond chain saw effectively cuts concrete and steel reinforcement to depths of 38 cm (15 in.). Dust protection needs to be controlled.

- Implementability: The diamond chain saw is easy to implement. Portable power units are readily available as are vehicles capable of powering the chain saw. The saw is lightweight and can be handled by a single worker.

- Cost: The capital and O&M costs for this process option are low. O&M costs include replacing the diamond-tipped chain and labor. Overall, costs are considered low.

The diamond chain saw has been retained for alternative development for Subunit C.

Abrasive Water Jet

The abrasive water jet was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: The abrasive water jet is effective in cutting reinforced concrete. A shroud and vacuum system can be used to contain the waste with more than 90 percent efficiency. Hazards to personnel result from the high pressure associated with this process option.

- Implementability: The abrasive water jet is moderately difficult to implement with regard to other process options under consideration. A collection system is required for the large volume of dirty and contaminated water produced by the water jet.

- Cost: The costs for this process option are considered moderate. Initial capital costs would include purchase of equipment and the installation of a collection system. The O&M costs include recycling or purchasing the abrasives used for cutting.

The abrasive water jet process option has not been carried forward to alternative development because of the inherent dangers associated with the high pressures required. This option offers no advantages over other demolition process options under consideration but may be reconsidered by the designer.

Core-Stitch Drilling

Core-stitch drilling was retained for evaluation as a possible silo demolition option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Core-stitch drilling is moderately effective because the concrete is reinforced. This process option would have to be combined with another process to cut the steel reinforcement before concrete removal.

- Implementability: The implementability for this process option is moderate. It requires drilling a very large number of holes to establish a fracture plane.

- Cost: The capital costs for core-stitch drilling include purchasing the equipment. These costs, along with the O&M costs, would be low. Overall, costs are considered low.

Core-stitch drilling has not been carried forward for the development of alternatives because it is only moderately effective. However, it may be reconsidered by the designer.

Wrecking Ball

The wrecking ball was retained for evaluation as a silo demolition process option for Subunit C. The evaluation of a wrecking ball is summarized as follows:

- Effectiveness: A wrecking ball would be effective in demolishing the silo but would produce large amounts of dust.

- Implementability: Implementing this process option would require a crane with a wrecking ball and a qualified operator, both of which are readily available.

- Cost: The costs of mobilizing the crane and operator to the site would be moderate. The operating costs for this process option would include the cost of operating the crane, health and safety oversight, and health physics monitoring. Overall, costs are considered moderate.

The wrecking ball has been eliminated from alternative development because of the hazards associated with dust produced from the operation.

2.6.6 Treatment General Response Action

The following treatment technologies have been evaluated:

- In Situ Treatment
- Waste Stabilization
- Physical Treatment
- Chemical Treatment
- Thermal Treatment
- Decontamination and Decommissioning

Table 2-12 summarizes the results of the process options evaluation for the removal general response action. A narrative discussion follows.

2.6.6.1 In Situ Treatment Process Options

In situ treatment was determined to be a viable remedial technology for Subunits A, B, and C. Process options retained for in situ treatment include:

- Shallow soil mixing
- In situ vitrification

Shallow Soil Mixing

Shallow soil mixing was evaluated as an in situ treatment process option for Subunit C as follows:

- Effectiveness: This process is an effective way to stabilize in situ soils subject to erosion. Transport of surficial site soil to downstream locations will be limited by this technology (i.e., this technology facilitates a chemical or physical reduction of the mobility of hazardous constituents). This process option is effective if the contaminated material is completely stabilized. Leachate generation and contaminant mobility would be greatly reduced. Shallow soil mixing will not treat deeper subsurface soils.

- Implementability: Interference with below-grade structures such as the decant sump tank and process piping makes implementation more difficult. Complete stabilization must be verified. Implementability is rated as very difficult.

- Cost: Common construction machinery is required, such as backhoe, pullshovel, pumps, or front-end loader. Minimal maintenance is required due to weathering influences. Overall, costs are considered moderate.

Shallow soil mixing will not be carried forward to alternative development for Subunit C due to the difficulty in implementation.

TABLE 2-12

SUMMARY OF EVALUATION ANALYSIS FOR TREATMENT PROCESS OPTIONS

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
In Situ Treatment	Shallow Soil Mixing	C	Effective in limiting the transport of surficial contaminants through controlling erosion and limiting migration.	Very difficult to implement	Moderate
	In Situ Vitrification	A, B, C	Effective in destroying organics and immobilizing inorganics and radionuclides.	Difficult to implement	High
Waste Stabilization	Asphalt-Based Stabilization	A, B, C	Creates solid block with low permeability but does not reduce potential leaching. Safety concerns from organic vapor and dust generation.	Moderately difficult to implement	Moderate
	Cement-Based Stabilization	A, B, C	Moderately effective in treating wastes. The solidified matrix reduces exposed surface area and leachate generation. Most suitable for immobilizing metals. Large volume increase.	Moderately difficult to implement	Moderate
	Thermoplastic Encapsulation	A, B, C	Effective in stabilizing soluble, toxic materials, but not proven on large-scale projects. Waste and the matrix may not be compatible.	Difficult to implement	High
	Vitrification	A, B, C	Very effective in stabilizing wastes. Considered an innovative technology and BDAT for high-level nuclear waste. The noncrystalline solid is very effective for reducing the leachability. Volume reduction also occurs.	Difficult to implement	High
	Lime/Flyash Stabilization	A, B, C	As effective as cement stabilization but concerns exist with stability of final matrix. Volume increase will occur.	Moderately difficult to implement	Moderate

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

TABLE 2-12
(Continued)

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
Physical Treatment	Solid/Liquid Separation	A, C	Effective.	Readily implemented	Moderate
	FEMP AWWT	A, B, C	Metals precipitation is effective for separation when used with a series of filtering options. Ion exchange is effective on specific ions. Generally used as a final treatment in a series of filtering options.	Readily implementable	Low
Chemical Treatment	Chemical Extraction	A, B, C	Effective in removing heavy metals; not a stand-alone treatment, but requires pretreatment such as neutralization or precipitation. Large quantities of acids are required, introducing an additional waste stream. This process also requires posttreatment for stabilizing the primary waste streams before disposal. Not effective in removing contaminants below levels in Operable Unit 4 soils.	Difficult to implement	High
Thermal Treatment	Drying/Calcination	A	Not effective for remediation alone; does not treat radionuclides alone. Provides suitable pretreatment where liquid/solid ratio must be reduced before treatment.	Moderately implementable	Moderate
Decontamination and Decommissioning	Vacuum Scabbling	C	Effective for removing surface contamination only and will reduce fugitive dust emissions.	Readily implementable	Moderate

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

TABLE 2-12
(Continued)

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
	Pressure Washing	C	Low effectiveness due to inability to remove subsurface contamination; only able to cleanse the surface. Ordinarily used as a pretreatment to remove loosely adhered contamination. Many safety risks associated with high pressure and high temperature operations.	Readily implementable	Low
	Vacuum Grit Blasting	C	Not effective for removing contaminants on the surface or subsurface.	Readily implementable	Moderate
	Acid Washing	C	Moderately effective for removing contaminated concrete. Effectiveness varies with depth. Requires special precautions and training. It also produces an additional waste stream for treatment.	Difficult to implement	High
	Strippable Coatings	C	Not effective for removing subsurface contamination	Readily implementable	Moderate

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

In Situ Vitrification

Vitrification was evaluated as an in situ treatment process option for Subunits A, B, and C. The evaluation of in situ vitrification is summarized as follows:

- Effectiveness: This technology destroys the hazardous organics and immobilizes the hazardous material in a reduced, nonleachable, vitreous mass. The vitrified material would possess good mechanical integrity and would have long-term stability. Vitrification of radioactive wastes has been proven in various pilot and demonstration projects with various degrees of success and is an emerging technology. This process option results in a better stabilized waste product than shallow soil mixing and better overall performance.

- Implementability: This process is a very energy intensive operation that requires trained personnel and more sophisticated equipment. However, in situ vitrification is still in the development phase. Tests to date have shown difficulty in implementation, especially due to significant off-gases and inconsistent density of the material. However, significant difficulty in implementation and verification of the extent and sufficiency of this process in a specific in situ application is difficult. Implementability is low for this process option.

- Cost: In situ vitrification has a high capital cost because it involves the design and construction of a localized facility using specialized equipment including an off-gas treatment system. This process will require highly trained professionals and has a high energy demand. Once the process is completed, no maintenance will be required; however, demolition and disposal costs will be incurred. The overall costs are considered high.

In situ vitrification has not been carried forward to alternative development for Subunits A, B, and C due to the required depths and the difficulty of implementation and high costs. Ex situ treatment process options will be selected as representative treatment options.

2.6.6.2 Waste Stabilization Technology

Process options evaluated for waste stabilization technology include:

- Asphalt-based stabilization
- Cement-based stabilization
- Thermoplastic encapsulation
- Vitrification
- Lime/flyash stabilization

Asphalt-Based Stabilization

Asphalt-based stabilization was evaluated as a process option for Subunits A, B, and C as follows.

- Effectiveness: As with other stabilization technologies, this asphalt-based technology creates a solid block of waste with relatively low permeability. Safety concerns are

primarily related to protecting on-site personnel from organic vapor and/or fugitive dust generation. Environmental considerations include air, water, and land resources. This process option is moderately effective.

- Implementability: This technology requires complex, specialized mixing equipment and a trained operations staff to ensure safe, consistent operations. Compared to cement-based stabilization systems, the power consumption for this process option is quite high. This process option is moderately difficult to implement.

- Cost: Complex, specialized mixing equipment, extruders, and safety equipment are required. Operation staff, power consumption, and equipment repair are concerns for this technology. Overall, costs are considered moderate.

Asphalt-based stabilization will be represented by cement-based stabilizations, which have fairly similar evaluations.

Cement-Based Stabilization

Cement-based stabilization was evaluated as a process option for Subunits A, B, and C as follows.

- Effectiveness: Cement-based stabilization is moderately effective in treating wastes. The wastes are mechanically locked within a solidified matrix that significantly reduces the leachate generation. Safety concerns include organic vapors and dust generation. This process option is most suitable for immobilizing inorganic metals and is less effective for use in wastes with organics.

- Implementability: Cement-based stabilization is moderately difficult to implement. Major advantages include the readily available equipment and materials. Disadvantages are the increased volume and weight for disposal once the waste is stabilized.

- Cost: Cost for cement-based stabilization is rated moderate. The process would require construction of waste handling, mixing, and curing facilities. The equipment for cement-based stabilization is readily available. The O&M costs are expected to be moderate for cement-based stabilization. The operation will require additional materials (cement) and maintenance of the mechanical equipment, which must operate in a fairly caustic environment. Costs would be moderate when compared to other process options.

Cement-based stabilization has been carried forward to alternative development for Subunits A and B. This process option has not been carried forward for Subunit C because the increase in waste volumes for the slightly contaminated soils is not cost-effective.

Thermoplastic Encapsulation

Thermoplastic encapsulation was evaluated as a stabilization process option applicable for Subunits A, B, and C. The evaluation of thermoplastic encapsulation is summarized as follows:

- Effectiveness: This process option is useful in stabilizing very soluble, toxic materials. In using this technology, compatibility of the waste and the matrix must be given major consideration. Thermoplastic encapsulation has not been proven on a large scale but has been widely used in nuclear waste disposal. This process option is highly effective on a small scale but its effectiveness is questionable on a large scale.

- Implementability: To implement this technology, treatability studies would be needed. Complex, specialized mixing equipment and a trained operations staff to ensure safe, consistent operations would be required for this process option. This process option is difficult to implement.

- Cost: This process option requires specialized equipment and materials, which can be expensive. The O&M costs associated with this process include labor and repair costs, and disposal costs following the process. Overall, costs are considered high.

The high costs, difficulty implementability, and uncertain effectiveness precludes this process option from being selected as a representative process option.

Vitrification

Vitrification was considered for evaluation as a stabilization process option for Subunits A, B, and C. The evaluation of vitrification is summarized as follows:

- Effectiveness: Vitrification is highly effective in stabilizing certain wastes. The vitrification process involves combining the waste with a molten glass at a temperature of 1350°C (2462°F). The resulting noncrystalline solid has an extremely low leach rate for most wastes. Considered an innovative technology, EPA determined that vitrification is the best demonstrated available technology (BDAT) for high-level nuclear waste. This process option is most suitable for immobilizing inorganic metals and radionuclides and is very effective for certain materials. However, its long-term effectiveness is unknown.

- Implementability: Vitrification is a relatively new technology without readily available equipment. The long lead times associated with the procurement of equipment should be considered in the schedule because this process option is innovative and vendors are not readily available. The process also requires high energy demands and trained personnel who are not readily available. An off-gas treatment system is also needed. This process option is difficult to implement.

- Cost: Capital costs for vitrification would be high. The process would require construction of a waste handling, processing, and curing facility and, as a relatively new technology, it will require special design and specifications. The O&M costs would be high. The system also requires a relatively extensive off-gas collection and cleaning system that must be maintained during processing. Overall, costs are considered high.

This process option is considered effective for immobilizing metals in a glass matrix. Waste configuration can be controlled to minimize the surface area subject to leachate.. Volume reduction of

the waste will reduce disposal costs. Vitrification has been carried forward to alternative development for Subunits A and B. Vitrification of Subunit C soils may occur if pilot studies indicate the soils are an effective additive to the waste. Otherwise, Subunit C materials have sufficiently low levels of contamination to make vitrification of soils not cost-effective.

Lime/Flyash Stabilization

Lime/flyash stabilization was evaluated as a stabilization process option for Subunits A, B, and C as follows.

- Effectiveness: Although lime/flyash stabilization is often as effective as cement stabilization, this technology is not as effective on a wide range of waste matrixes as cement stabilization. Additionally, there is concern over the long-term stability of the final material and the potential for dust emissions. Treatability studies are important to ensure the compatibility of this process option to the waste matrix.

- Implementability: Lime/flyash stabilization is equivalent to cement-based stabilization with respect to implementability. The equipment is conventional and readily available as with cement-based stabilization. This process option is rated as moderately difficult to implement.

- Cost: Capital costs for lime/flyash stabilization are essentially the same as those for cement-based stabilization. The process would require construction of waste handling, mixing, curing, and bulk handling facilities. The capital costs for this process option are moderate. The lime/flyash process option would also require bulk quantities of lime and flyash, maintenance of the mechanical equipment, and storage containers for the stabilized waste. Overall, costs are considered moderate.

This process option can be as effective as cement-based stabilization; however, there are concerns over the long-term stability of the waste matrix. For this reason, lime/flyash stabilization has not been carried forward for alternative development for Subunits A, B, and C.

2.6.6.3 Physical Treatment Technology

Process options evaluated for physical treatment technology include:

- Solid/liquid separation
- FEMP AWWT facility

Solid/Liquid Separation

Solid/liquid separation was evaluated as a physical treatment process option for Subunits A and C as follows:

- Effectiveness: Solid/liquid separation options are effective, both for a dewatering purpose and for a solid removal process.

- Implementability: The equipment for solid/liquid separation is conventional and is manufactured and stocked by many companies. The personnel required to operate this equipment are readily available. This process option is considered readily implementable.

- Cost: Typical equipment used for solid/liquid separation include belt filter presses, centrifuges, filters, settling tanks or ponds, clarifiers, or hydrocyclones. Although the costs associated with each type of equipment vary, this process option was rated moderate for capital costs. Operating costs for this process option include the energy for pumping slurries or liquids and replacement of any filtering media. Maintenance would include the typical requirements for a pump and piping system. Overall, the O&M costs for the solid/liquid separation process option were rated as moderate. Overall, costs are considered moderate.

Solid/liquid separation through dewatering has been carried forward as an alternative development for Subunit A. The FEMP AWWT will be carried forward as the representative process option for treating any water from Subunit C, since it will be built for other uses. The identification for a specific dewatering option will be a design decision.

FEMP Advanced Wastewater Treatment System

Treatment using the AWWT facility at the FEMP site was evaluated for encountered perched groundwater and other liquids generated during the remediation of Subunits A, B, and C. This facility will use a combination of wastewater treatment options to treat the FEMP site wastes. Metals precipitation and ion exchange are two process options used to treat FEMP site wastewaters that contain inorganic metals and radionuclides, such as those that will be found in Operable Unit 4 wastewaters.

The evaluation of metals precipitation is summarized as follows:

- Effectiveness: Metals precipitation uses additives to wastewaters to aid in the precipitation process. This process option, used with a series of filtering options, is effective on a wide range of aqueous wastes. It has been rated as an effective process option.

- Implementability: Metals precipitation system for treating the quantity of water required for the treatment process would consist of adding potassium ferrate to remove radionuclides and metals studies would be helpful for optimizing the precipitation process for a specific waste stream. This process option would be moderately implementable. However, since the AWWT will already be present for alternative development, adding liquids to the system will be easy.

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- Cost: The cost of metals precipitation depends on the quality of the water being received by the system, the desired quality of the water to be discharged from the system and the flow rate of water required by the process. It is expected that the capital costs for this process option would be moderate. The O&M costs are expected to be moderate. The overall costs to Operable Unit 4 alternatives however, are expected to be low since the capital costs will already have been incurred.

The evaluation of selective ion exchange is summarized as follows:

- Effectiveness: As with the other physical treatment processes, selective ion removal requires, as a minimum, a filtering pretreatment and is effective on aqueous wastes containing specific ions.

- Implementability: To select the proper resin for a selective ion removal system, tests would be performed with actual samples of the water to be treated to ensure that no components are present (either ionic or nonionic) that would interfere with the resins selectivity. Ion exchange equipment is manufactured and stocked by many companies. This process option is considered moderately implementable. However, since the AWWT will already be present for alternative development, adding liquids to the system will be easy.

- Cost: The resin for selective ion removal can be very expensive depending on the ions to be removed and the interference from the other components in the stream to be processed. Therefore, the capital costs for this process option were rated as high. Because resins need to be replaced periodically, the O&M costs for this process option are rated as high. The overall costs to Operable Unit 4 alternatives, however, are expected to be low since the capital costs will already have been incurred.

The FEMP AWWT facility has been retained for development of alternatives for all of the subunits because it will be constructed on-line and will be readily available to receive wastewater from Operable Unit 4 remedial actions.

2.6.6.4 Chemical Treatment Technology

The only process option retained for evaluation for chemical treatment was chemical extraction. This process option was evaluated for Subunits A, B, and C as follows:

- Effectiveness: Chemical extraction is a separation technique that utilizes a liquid solvent to remove a solute from a solid mixture. This process option effectively removes heavy metals but is not a stand-alone treatment and requires pretreatment such as neutralization or precipitation. In addition, this process option requires posttreatment stabilization of the two primary waste streams. In the case of soil washing, current studies indicate that the contaminant levels in Operable Unit 4 soils are below levels considered achievable using the soil washing technology.

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- Implementability: Depending on the application, this process option is relatively complicated and requires the effective and optional operation of multiple processes to achieve the desired results. This process option is rated difficult to implement.

- Cost: The costs of a chemical extraction system would be high due to the cost of the material handling equipment, process equipment, reagents, and labor.

Chemical extraction has been carried forward to alternative development for Subunit A because of the relative benefit obtained in generating a small volume of highly contaminated waste and a much larger volume of lesser contaminated waste. Disposal costs may ultimately be less expensive with this process option. Chemical extraction was not retained for Subunit B because of a probable low effectiveness. The expense of this process option due to the limited quantity of soil in Operable Unit 4 caused it to not be carried forward for Subunit C. It should be noted that chemical extraction and other technologies are currently being examined under Operable Unit 5 to address the large quantity of site-wide soils at the FEMP potentially requiring remedial action. In the event such treatment facilities become available at FEMP or elsewhere, consideration will be given to employing these facilities as a waste minimization initiative for addressing Operable Unit 4 contaminated soils.

2.6.6.5 Thermal Treatment Technology

The only process option evaluated for thermal treatment is drying/calcination for Subunit A. This evaluation is summarized as follows:

- Effectiveness: Calcines can be used to heat treat and dry the Silos 1 and 2 material while at the same time, reducing the metal oxides and burning off any organic impurities. Calcination does not treat radionuclides and is therefore not an effective process option. However, calcination does provide suitable pretreatment for other treatment technologies where the liquid/solid mixture must be reduced before treatment.

- Implementability: Calcines are readily available from a number of manufacturers so there would be no significant delay in constructing a system. Because a calciner emits air emissions, some type of scrubbing system or HEPA filtration for the off-gas would be required. Overall, this process option is rated as moderately implementable.

- Cost: The capital costs for the calciner would include the cost of the calciner, the required air quality equipment, and the material handling equipment. These costs are estimated to be moderate. The energy required to calcine the Operable Unit 4 material would constitute the major operating cost. Maintenance costs would include maintenance on the calciner, the material handling equipment, and the emissions control system. Overall, costs are rated as moderate.

Drying/calcination has not been carried forward to alternative development as a process option for Subunit A because of its low rating for effectiveness; however, it may be considered as a pretreatment

option for another technology (i.e., cement stabilization or vitrification) by the designer, if appropriate.

2.6.6.6 Decontamination and Decommissioning Technology

Process options being evaluated for D&D include:

- Vacuum scabbling
- Pressure washing
- Vacuum grit blasting
- Acid washing with oxidizing agents
- Strippable coatings

Vacuum Scabbling

The scabbling process option was evaluated for Subunit C as follows:

- Effectiveness: Scabbling physically removes contamination from a wall or floor by using a piston equipped with spikes to chip away small amounts of the top layer of concrete or plaster. This option is effective and can be used in conjunction with a vacuum system to reduce dusting and collection of the material.

- Implementability: The system can be operated remotely, requires no special worker training, and the equipment is readily available. This process option was rated as readily implementable. However, dust is generated and it either must be controlled or the workers protected.

- Cost: The cost for the scabbling equipment with provisions for remote operation and the vacuum collection system was rated as moderate. The O&M costs for this process option rated as moderate. Overall, costs are considered moderate.

Scabbling has been carried forward to alternative development for Subunit C as a decontamination process option.

Pressure Washing

Pressure washing was evaluated as a possible D&D process option for Subunit C. The evaluation of this process option follows:

- Effectiveness: Pressure washing techniques effectively remove loose surface contamination but cannot remove subsurface contamination. Large volumes of water are required; yet, dust is not produced. Pressure washing is ordinarily used as a pretreatment step prior to the use of other methods of removing embedded contamination.

- Implementability: Pressure washing is easily implemented. Water is nonhazardous and does not require special handling by personnel. Spraying and pumping equipment are

inexpensive and readily available. Relatively few personnel and training are required. A disadvantage is the safety risks associated with high-pressure and high temperature operations. In addition, the wastewater will require collection (line the floor) treatment before disposal. The water can be removed with standard pumping equipment.

- Cost: Overall, costs would be extremely low. Water is inexpensive in comparison to other solvents. Capital costs include the purchase of pumping and spraying equipment.

Pressure washing has been retained for the development of alternatives for Subunit C as a pretreatment step to remove loosely adhered contamination.

Vacuum Grit Blasting

Vacuum grit blasting is another D&D process option that was retained for evaluation for Subunit C. The evaluation follows:

- Effectiveness: This option is not effective for removing contaminants strongly adhered to the surface or within the subsurface. This process option is typically used for limited areas of contamination.

- Implementability: Grit blasting is easily implemented. It requires no specialized equipment and little training for personnel is needed. Two waste disposal systems are required because contaminated material is broken into two waste streams via a cyclone separator. There is the potential for dust generation.

- Cost: Costs are typically higher than those for pressure washing for both equipment and maintenance. Overall, costs are moderate.

The vacuum grit blasting has not been carried forward to the development of alternatives for any subunits because of its low effectiveness and because of the large surface areas of the silo structures.

Acid Washing with Oxidizing Agents

Acid washing with oxidizing agents was retained for evaluation as a potential process option for the D&D technology. The evaluation of this process option for Subunit C as follows:

- Effectiveness: This process option is moderately effective for dissolving/removing contaminated concrete. The effectiveness varies with depth because subsurface contamination could require several applications.

- Implementability: Acid washing requires special precautions and training to protect workers handling the chemicals. A liner is placed on the floor to collect the water. As a result, this process option is difficult to implement. In addition, the process results in a waste stream that must be collected and treated before disposal.

- Cost: The costs for acid washing could be high due to the required treatment of the waste stream and precautionary measures required by the worker. Overall, costs are considered high.

Because of its difficult implementability, high cost, and danger to personnel, acid washing has been eliminated from the development of alternatives.

Strippable Coatings

Strippable coatings were also retained as a process option for the D&D remedial technology. The evaluation of this process option for Subunit C follows:

- Effectiveness: This process option is not effective for removing contamination below the treatment surface. However, dust emissions and waste production are minimized.
- Implementability: Strippable coatings are easily implemented. Extensive training and equipment are not required for implementation.
- Cost: The costs of strippable coatings are considered moderate primarily due to labor and materials.

Because this option cannot remove subsurface contamination, strippable coatings will not be carried forward to the development of alternatives for any subunits.

2.6.7 Disposal General Response Action

The following disposal technologies have been evaluated:

- Waste Transportation
- On-Property Disposal
- Off-Site Disposal

Table 2-13 summarizes the results of the process options evaluation.

2.6.7.1 Waste Transportation Technology

Waste transportation options retained for evaluation are rail transport and truck transport. The evaluation of these options is presented in the following sections.

Rail Transport

The evaluation of rail transport is summarized as follows:

TABLE 2-13

SUMMARY OF EVALUATION ANALYSIS FOR DISPOSAL PROCESS OPTIONS

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
Waste Transportation	Rail Transport	A, B, C	Effective form of transportation because of the reduced risk to human life. Rail spurs may need to be upgraded.	Readily implementable	Low
	Truck Transport	A, B, C	Effective but less reliable than rail transportation. Truck transportation is required for on-property disposal.	Readily implementable	Moderate
On-Property Disposal	Engineered Disposal Facility	A, B, C	Effective by providing isolation from the groundwater and isolating waste from surface environment. Also provides intrusion barrier.	Moderately difficult to implement	High
	Above-Grade Vault	A, B, C	Effective disposal of highly hazardous or radioactive waste forms. Provides long-term waste immobilization and environmental protection.	Moderately difficult to implement	High
Off-Site Disposal	Nevada Test Site	A, B, C	Very effective disposal of stabilized or solid Operable Unit 4 waste.	Moderately difficult	Moderate
	Permitted Commerical Disposal Site	C	Very effective disposal of stabilized or solid waste from Subunit C.	Difficult	High
	New Facility Adjacent to FEMP	A, B, C	Less effective disposal than the permitted commercial disposal site or NTS because the site would be above or adjacent to Great Miami Aquifer and near a large population area.	Difficult	High

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

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TABLE 2-13
(Continued)

Remedial Technology	Process Option	Applicable Subunit	Effectiveness	Implementability	Cost
	New Facility Within 300 Miles of FEMP	A, B, C	Less effective disposal than the permitted commercial disposal site or NTS but slightly better than the new facility adjacent to the FEMP site because it would not have to be above the Great Miami Aquifer.	Difficult	High

Note: A, B, C - Double underline indicates process option was retained for alternative development for that subunit.

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- Effectiveness: The rail transport process option is an effective option for off-site transportation. By transporting waste by rail, large tonnages of waste can be hauled at one time. On a per trip basis, there are less accidents by rail than by truck. However, should a rail accident occur, there are much larger quantities of contaminants exposed to the public.

- Implementability: Rail transport is readily implementable because rail transport at the FEMP site can be accommodated by the existing on-site rail spur. However, the rail transport process option is susceptible to route availability and coordination with state and local agencies along the route.

- Cost: The rail transport process option is expected to be moderately costly because of the following requirements: upgrading of the on-site rail spur and the need to build or upgrade loading and unloading waste handling facilities. The O&M costs are expected to be low for the rail transport process option because of the limited need for machinery, equipment, and maintenance items. In addition, historical records indicate that railway components have a relatively long life span and require little maintenance as compared to other transportation systems. Overall, costs are considered low.

Rail transportation has been retained for the development of alternatives for all subunits.

Truck Transport

The evaluation of truck transport is summarized as follows:

- Effectiveness: Truck transport is effective for short distances but is not as effective as rail transport for the distances required for the off-site disposal option at NTS and perhaps even the 483 km (300 mi) disposal option, depending on the availability of rail spurs. Truck transport would be effective but less reliable than rail transport. Truck transportation would be required for on-property disposal.

- Implementability: Truck transport would be easily implemented at the site.

- Cost: The capital costs associated with this process option would include the construction of access roads. The overall capital costs would be moderate. Operation costs include the fees charged by the trucking company for each trip, and the salaries of the employees who load the trucks. Maintenance costs include the maintenance of the access road and the loading terminal. Overall, costs are considered moderate.

Truck transportation has been retained for the development of alternatives for all subunits.

2.6.7.2 On-Property Disposal Technology

On-property disposal is a remedial technology that may be applied for Subunits A, B, and C. Process options retained for evaluation include:

- Engineered disposal facility

- Above-grade disposal vault

Engineered Disposal Facility

The engineered disposal facility was evaluated as an on-property disposal option for Subunits A, B, and C. The evaluation of an engineered disposal facility is summarized as follows:

- Effectiveness: A properly designed engineered disposal facility will dispose of the waste effectively by isolating the waste from the groundwater and the surface environment. A compacted concrete intrusion barrier will reduce inadvertent human contact.

- Implementability: This process option consists of covering/capping waste that has been placed on a stable structural pad with an underlying leachate collection system. Once designed, the construction and implementation of the engineered disposal facility should occur without delay. This process option would be moderately difficult to implement.

- Cost: The engineered disposal facility will be constructed of concrete designed for permanent waste disposal as well as an intrusion barrier made of compacted concrete. These concrete layers will contribute to the high cost as will the detailed construction of the vegetative layers, drainage layer, and the clay layers of the cap. Furthermore, the facility will consist of a cap with leachate collection system that will also inflate the cost. The O&M costs are expected to be moderate. The costs are primarily associated with mowing, cap inspection, and groundwater monitoring. Overall, costs are considered high.

The characteristics of the engineered disposal facility are essentially the same as the above-ground disposal vault except that the latter encapsulates the disposed material in a concrete vault. Because of this, coupled with the fact that neither on-property disposal option emerges as clearly superior, the vault was selected as the representative process option, and the Engineered Disposal Facility was not retained for any subunits.

Above-Grade Disposal Vault

The above-grade disposal vault was evaluated as an on-property disposal option for Subunits A, B, and C as follows:

- Effectiveness: The vault concept permits disposal of unsorted, highly hazardous/ radioactive (mixed) waste forms. This structure provides effective isolation of waste from both the surface and subsurface environment. All designs are structured to withstand environmental and structural stresses and to provide long-term waste immobilization and environmental protection.

- Implementability: The vault is constructed directly on grade with a liner system and leachate collection system and requires a cap that can be placed over the closed

structure. Once designed, the construction and implementation of the vaults should occur without delay. This facility is considered moderately difficult to implement.

- Cost: This vault structure will consist of a liner system, a leachate collection system, and a structural support slab (depending on particular design). Furthermore, the facility will consist of a cap that will also inflate the cost. This disposal technology requires regularly scheduled monitoring and a facility maintenance program throughout some specified postclosure period. Overall, costs are considered high.

Because neither of the on-property disposal options clearly emerges as superior and the above-grade disposal vault provides additional containment via a concrete vault, the above-grade disposal vault was retained for alternative development for Subunits A, B, and C.

2.6.7.3 Off-Site Disposal Technology

Process options being evaluated for off-site disposal technology include:

- NTS
- Permitted commercial disposal site
- New facility adjacent to the FEMP site
- New facility within 483 km (300 mi) of the FEMP site

Nevada Test Site

NTS was retained for evaluation as an off-site disposal process option for Subunits A, B, and C. This evaluation is summarized as follows:

- Effectiveness: NTS is currently in operation and should be able to accept Operable Unit 4 media. NTS was rated as very effective for storage of stabilized or solid Operable Unit 4 media.

- Implementability: NTS is more than 3219 km (2000 mi) from the FEMP site. This process option would be moderately difficult to implement since treatment may be required to meet waste acceptance criteria. The FEMP site also has an approved NTS waste shipment and certification program that is periodically audited by NTS. Efforts have been initiated to amend the current program to include Operable Unit 4 materials.

- Cost: The capital costs would include the disposal fee, which is rated as moderate. There would be no O&M costs with this process option. Overall, costs are considered moderate.

The NTS process option has been carried forward to alternative development for Subunits A, B, and C.

Permitted Commercial Disposal Site

The permitted commercial disposal site was retained for evaluation as an off-site disposal process option for Subunit C. This evaluation is summarized as follows:

- Effectiveness: The permitted commercial disposal site is currently in operation and should be capable of accepting waste from Subunit C following receipt of the necessary approvals for the site to receive 11(e)2 wastes. Wastes from Subunit C exceeding acceptance criteria (i. e., concrete in contact with residues) would be required to be segregated and handled consistent with Subunit A.

- Implementability: Similar to the NTS process option, the representative permitted commercial disposal site is a relatively long distance from the FEMP site. Additionally, a variance from DOE Order 5280.2A restricting DOE radioactive wastes from disposal at a commercial facility would be needed. This option is considered administratively difficult to implement.

- Cost: The disposal costs for this process option are essentially three times higher than those for the NTS. There would be no O&M costs with this process option. Overall, costs are rated high.

The permitted commercial disposal site has been carried forward to alternative development for Subunit C.

New Facility Adjacent to the FEMP Site

A new disposal facility adjacent to the FEMP site was retained for evaluation as an off-site disposal process option for Subunits A, B, and C. This evaluation is summarized as follows:

- Effectiveness: The construction of an off-site disposal facility adjacent to the FEMP site was rated as less effective than NTS or the permitted commercial disposal site process options because the site would either be above or adjacent to the Great Miami Aquifer and near a large population area.

- Implementability: This facility would have to be sited, property purchased, permits obtained, and construction completed before disposal of any Operable Unit 4 media. This process option was rated as less implementable than NTS or the permitted commercial disposal site process options.

- Cost: Capital costs for this process option were rated as high and include: the purchase of property, the design, and the construction of the disposal facility. The O&M costs for this process option would be approximately the same as for the new facility adjacent to the FEMP site process option.

This process option will not be carried forward to alternative development for any of the subunits because this process option is essentially identical to the on-property engineered disposal facility, but has a lower rating for effectiveness, implementability, and cost.

New Facility Within 483 Kilometers (300 Miles) of FEMP

The new facility within 483 km (300 mi) of the FEMP site was evaluated as an off-site disposal option for Subunits A, B, and C. This evaluation is summarized below:

- Effectiveness: This process option was considered only slightly better than the adjacent disposal facility because a site could be chosen to ensure that its location is not on top of an aquifer or in an area of high population.

- Implementability: As with the adjacent disposal facility, this facility would have to be sited, property purchased, permits obtained, and construction completed before any disposal of Operable Unit 4 subunit wastes. This process option was rated less implementable than NTS or the permitted commercial disposal site process options.

- Cost: Capital costs for this process option were rated as high and include: the purchase of property, the design, and the construction of the disposal facility. The O&M costs for this process option would be approximately the same as for the new facility adjacent to the FEMP site process option.

This process option will be carried forward to alternative development for Subunits A, B, and C.

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3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 INTRODUCTION

This section presents the development and screening of remedial alternatives assembled from combinations of technologies and associated process options evaluated in Section 2.0. Section 3.2 presents the development and description of a range of alternatives based on the GRAs discussed in Section 2.0. Section 3.3 presents the initial screening of alternatives evaluated against the three broad criteria of effectiveness, implementability, and cost. Section 3.4 summarizes the initial screening of alternatives. Figure 3-1 illustrates the elements of the FS process that are addressed in Section 3.0.

The purpose of the FS and the overall remedy selection process is to implement remedial actions that eliminate, reduce, or control risks to human health and the environment (40 CFR 300). The national program goal for the FS process, as defined in the NCP, is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. The criteria for identifying potentially applicable technologies to achieve these goals are provided in EPA guidance (EPA 1988a) and in the NCP (EPA 1990). A strong statutory preference for remedies that will result in a permanent and significant decrease in toxicity, mobility, or volume and provide long-term protection is identified in Section 121 of CERCLA, as amended. The primary requirements for the final remedy are that it be both protective of human health and the environment and comply with ARARs; hence, alternative screening focuses on these criteria.

In addition to the above objectives, the NCP defines certain expectations in developing and screening remedial action alternatives.

- The expectation to use treatment to address the principal threats posed by a site, wherever practical
- The expectation to use engineering controls, such as containment, for waste that poses a relatively low long-term threat and for which treatment is impractical
- The expectation to use a combination of methods, as appropriate, to achieve protection of human health and the environment. In appropriate site situations, treatment of principal threats will be combined with engineering controls (such as containment) and institutional actions for treatment residuals and untreated waste
- The expectation to use institutional actions, such as water controls and deed restrictions, to supplement engineering controls for short- and long-term management to prevent or limit exposures to hazardous substances, pollutants, or contaminants

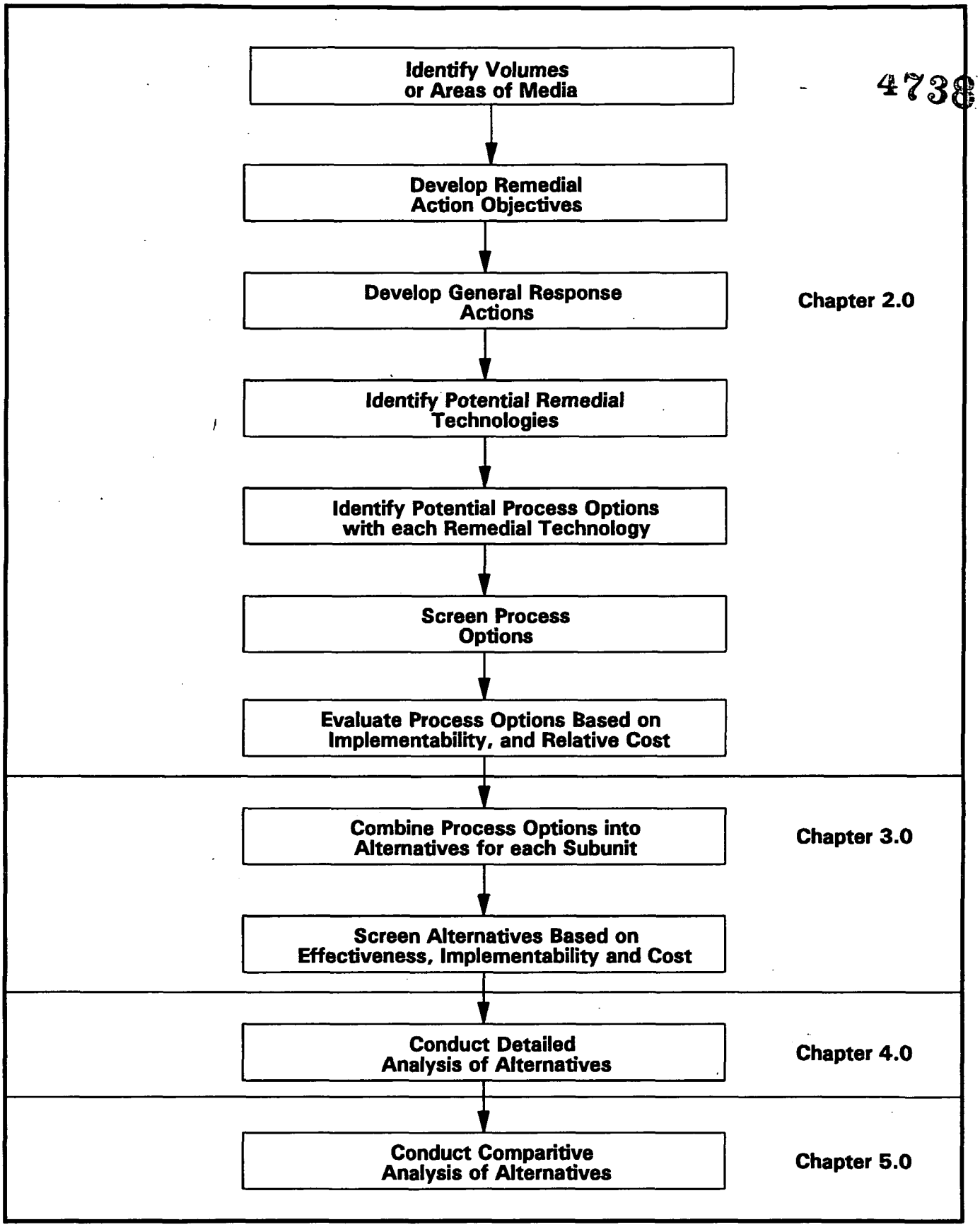

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FIGURE 3-1
ELEMENTS OF THE FS PROCESS

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- The expectation to consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies

- The expectation to return environmental media such as groundwater to their beneficial uses, wherever practical, within a time frame that is reasonable given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practical, EPA expects to prevent further migration of the plume, prevent exposures to contaminated groundwater, and evaluate further risk reduction.

These expectations have been applied in the development and screening of alternatives which follow.

Section 2.0 identifies the Operable Unit 4 subunits for which GRAs, and subsequently remedial alternatives, are being developed and assembled. They are repeated here for reference.

- Subunit A: Silos 1 and 2 contents and the sludge in the decant sump tank

- Subunit B: Silo 3 contents

- Subunit C: Silos 1, 2, 3, and 4 structures, the berms, the silo subsoil, the surface soil, the existing RTS, the K-65 Drum Handling Building pad, standing water within Silo 4 (if any), the decant sump tank and the liquid within, the process piping and trenches, and any rubble or debris (i.e., D&D of waste treatment facility) generated consequential to the implementation of remedial actions for all Operable Unit 4 subunits.

3.2 DEVELOPMENT OF PRELIMINARY ALTERNATIVES

3.2.1 Criteria for Developing Preliminary Alternatives

The EPA has established an approach for developing remedial action alternatives that are appropriate to the specific conditions at the FEMP site. In this approach, the scope, characteristics, and complexity of the site are considered in developing a range of alternatives that would be protective of human health and the environment. Protection can be achieved by eliminating, reducing, and/or controlling risks posed by each pathway at a site. The assembled alternatives differ from those proposed in the ISA Report in that several off-site disposal process options have been added.

3.2.2 Factors Common to All Subunits

For the Operable Unit 4 subunits, certain common strategies will be applied to address contaminated media and materials or to assemble technologies and process options into alternatives. These common factors are discussed in this section.

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3.2.2.1 On-Property Disposal Facility

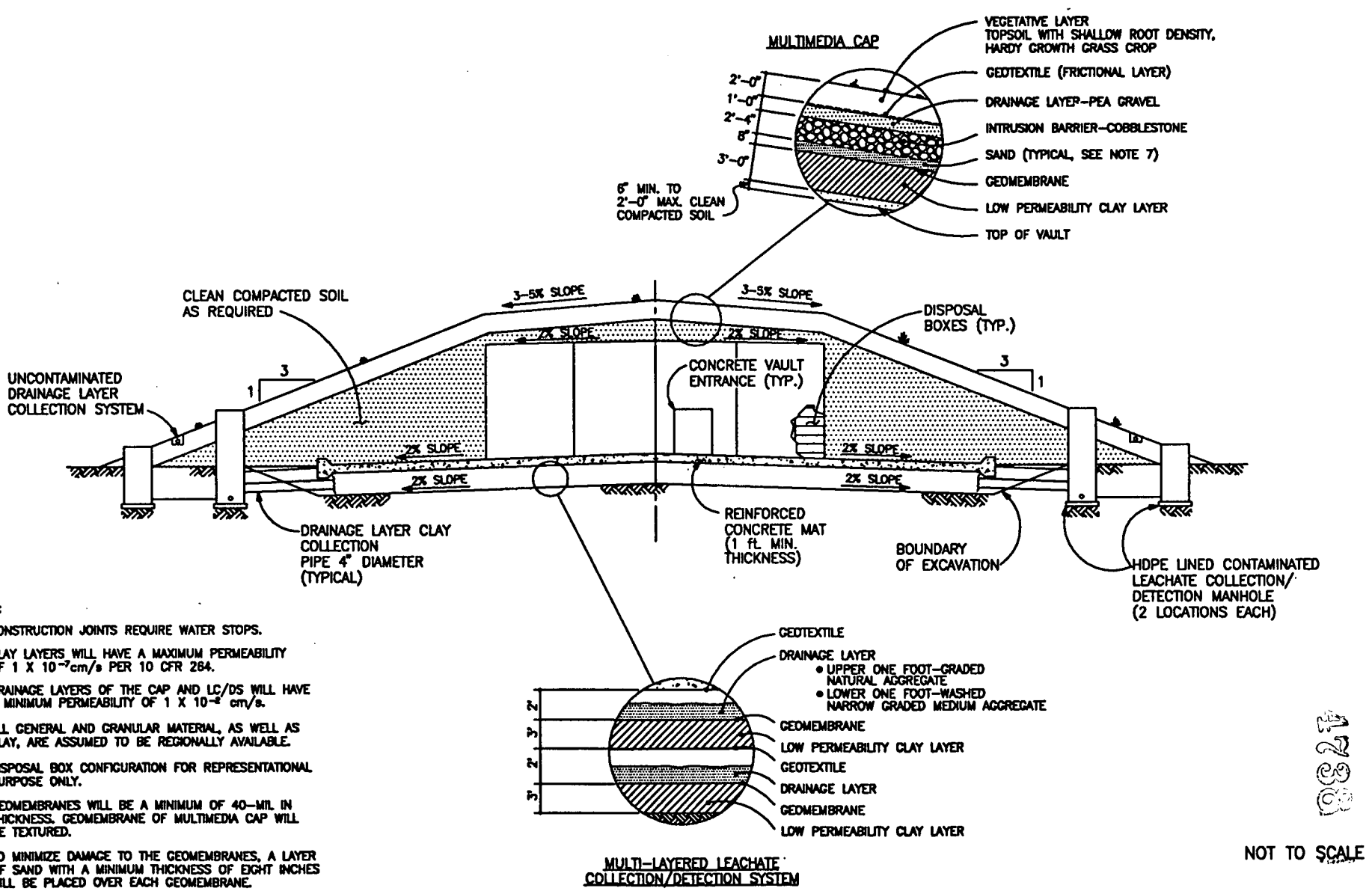
A series of alternatives for each of the subunits involve the construction of an above-grade disposal system. As previously discussed in Section 2.6.7.2, the above-grade disposal vault was selected as the representative process option for the on-site disposal of Operable Unit 4 waste. Figure 3-2 provides a conceptual cross-section of the disposal vault concept. The preliminary cross-section is subject to change on the basis of the decision regarding the type and quantity of waste proposed for on-site disposal, and to the requirements provided through detailed design engineering. The above-grade disposal vault has been preliminary sited on the northern part of the FEMP property as depicted in Figure 3-3. The final location of any required on-site disposal system may be modified pending receipt of on-going geological site characterization data and detailed evaluation of federal and state ARAR/TBCs.

The representative disposal concept involves the placement of containerized waste in a concrete vault. The concrete vault is located at-grade with an underlying multilayered lining system. The vaults would be constructed on a reinforced concrete mat with a perimeter curbing system. The leachate collection system (Figure 3-2) will be composed of alternating composite soil liners and drainage layers to minimize the potential release of contaminated leachate to the Great Miami Aquifer.

The liner system would employ compacted clays with maximum permeability of 1×10^{-7} cm/sec. These layers are envisioned to be a minimum thickness of 0.9m (3 ft). Between the soil liners, drainage layers will be installed to intercept any leachate that may be generated. The drainage layers are envisioned to be a minimum thickness of 0.6 m (2 ft.). A geotextile membrane will be placed on the upper surface of each drainage layer to inhibit the migration of fines from the overlying material.

During placement of the aggregate, a perforated piping will be installed within the aggregate to collect and direct any leachate to a series of manholes. Likewise, any leachate not captured by the perforated piping that reaches the sand layer will travel along the slope of the cap to the manholes. The leachate will then be pumped from the manholes for treatment at the FEMP site AWWT facility.

A multimedia cap constructed of five distinct layers of media is envisioned to provide final closure of the vaults. The upper layer of the cap will be a vegetative layer consisting of topsoil with a hardy, shallow root grass cover. This layer will be noncompacted and have minimum thickness of 0.6 m (2 ft) to support plant growth. The vegetative layer will inhibit erosion and allow runoff during storm



NOTES:

1. CONSTRUCTION JOINTS REQUIRE WATER STOPS.
2. CLAY LAYERS WILL HAVE A MAXIMUM PERMEABILITY OF 1 X 10^{-7}cm/s PER 10 CFR 264.
3. DRAINAGE LAYERS OF THE CAP AND LC/DS WILL HAVE A MINIMUM PERMEABILITY OF 1 X 10^{-4} cm/s.
4. ALL GENERAL AND GRANULAR MATERIAL, AS WELL AS CLAY, ARE ASSUMED TO BE REGIONALLY AVAILABLE.
5. DISPOSAL BOX CONFIGURATION FOR REPRESENTATIONAL PURPOSE ONLY.
6. GEOMEMBRANES WILL BE A MINIMUM OF 40–MIL IN THICKNESS. GEOMEMBRANE OF MULTIMEDIA CAP WILL BE TEXTURED.
7. TO MINIMIZE DAMAGE TO THE GEOMEMBRANES, A LAYER OF SAND WITH A MINIMUM THICKNESS OF EIGHT INCHES WILL BE PLACED OVER EACH GEOMEMBRANE.

FIGURE 3-2. ABOVE GRADE DISPOSAL VAULTS

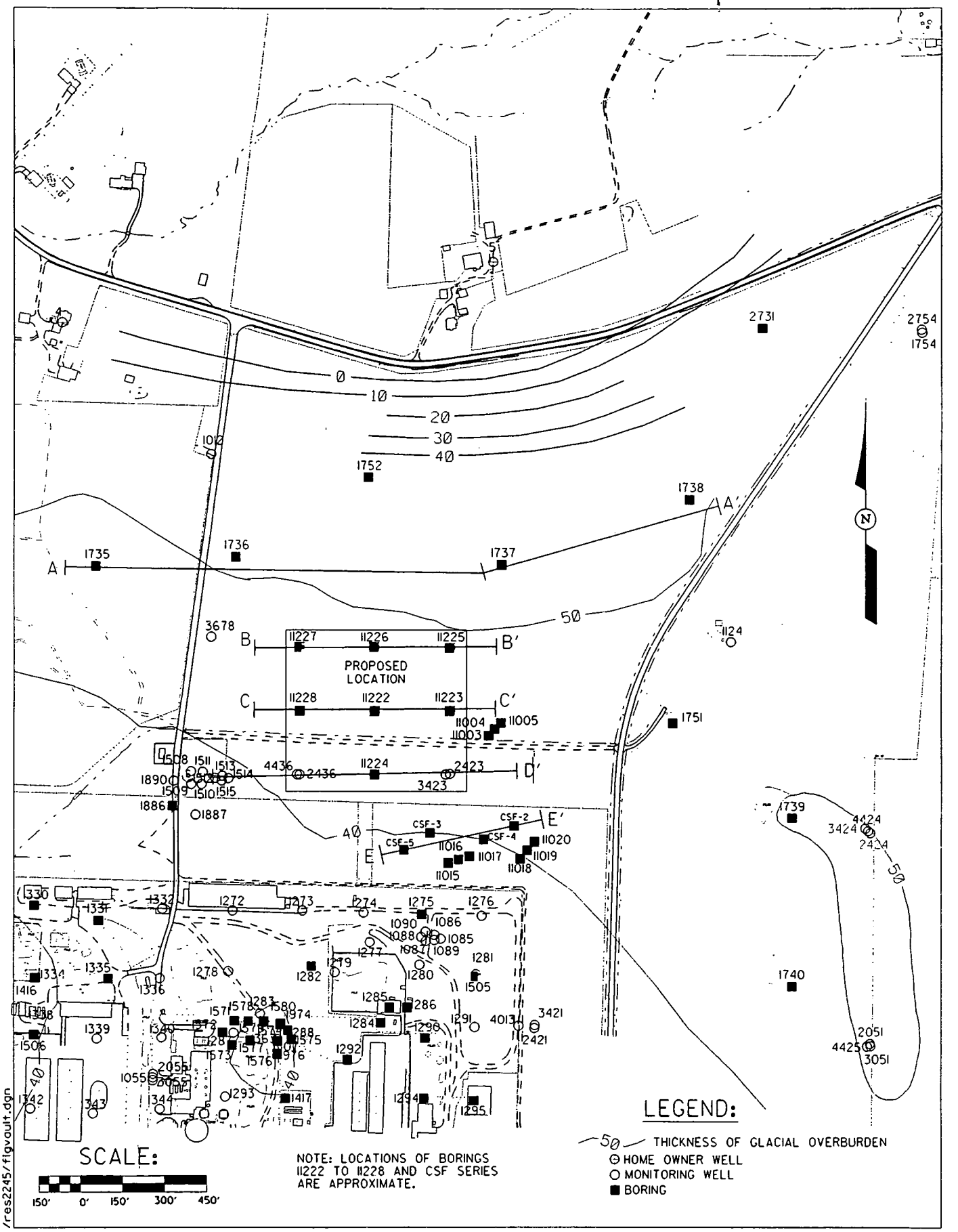


FIGURE 3-3 LOCATION OF PROPOSED ABOVE GRADE DISPOSAL VAULT

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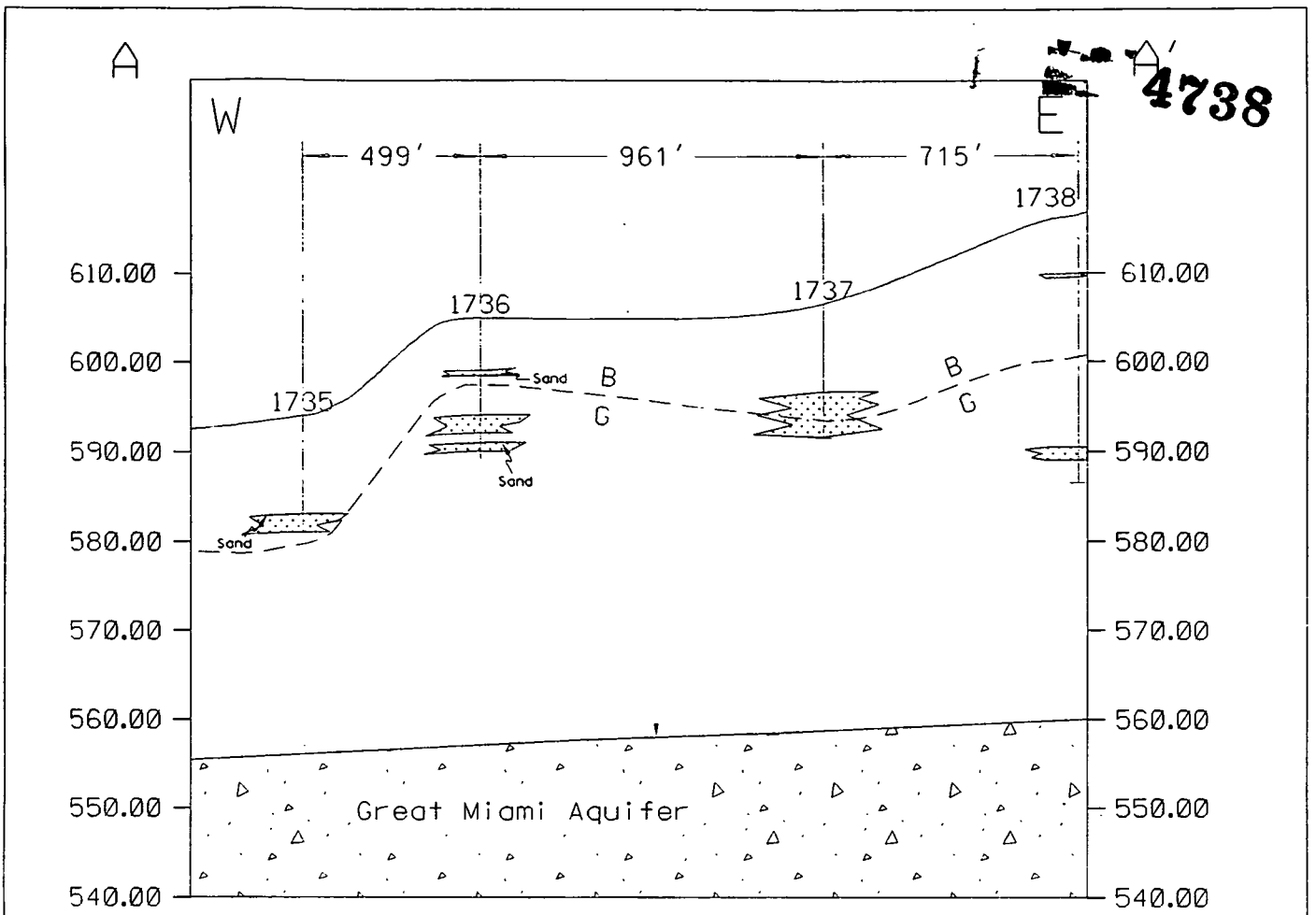
events. A drainage layer will be located beneath the vegetative layer to intercept infiltrating precipitation. The layer will consist of compacted pea gravel, which will provide a minimum permeability of 1 x 10^{-2} cm/sec. A geotextile membrane will be placed between the vegetative layer and the top surface of the drainage layer to prevent the migration of fines from the vegetative layer to the drainage layer.

A layer of cobblestone with a minimum thickness of 0.7 m (2.3 ft) will be beneath the drainage layer to serve as an inadvertent intrusion barrier against both human and burrowing animals. Beneath the cobblestone will be a composite liner to impede downward moisture movement from the drainage layer. The soil of this layer will be natural, compacted clay with a maximum permeability of 1 x 10^{-7} cm/sec. The layer will be 0.9 m (3 ft) thick to ensure the isolation of the disposal containers. A geomembrane at least 40 mil in thickness will be placed over the surface of the clay, which is smooth-rolled to ensure good hydraulic contact and thus improving the performance of the clay. To minimize slippage of the overlying layers due to interfacial shearing characteristics, the geomembrane will be textured. Similar to the composite soil liners, a layer of sand will be place over the geomembrane to minimize damage during construction.

The foundation of the multimedia cap will be clean, compact soil. This layer will be a minimum of 0.15 m (6 in.) to a maximum of 0.6 m (2 ft) in thickness above the vaults. All general granular material, as well as clay, are regionally available.

The proposed site for the on-site disposal system was selected on the basis of available information on the local geologic conditions and upon knowledge of the previous use of the area. No facility operations are known to have occurred in the area and no known housing units are believed to have been located in the area based upon pre-construction photos for the facility.

The proposed area (Figure 3-3) can generally be characterized as having approximately 40 feet of glacial overburden over the sand and gravel deposits constituting the Great Miami Aquifer (GMA). Figures 3-4 through 3-8 represent geologic cross sections from locations within or adjacent to the proposed siting area. The locations of the cross sections are depicted in Figure 3-3. Figure 3-9 provides a conceptual view of the on-site disposal vault superimposed upon a cross-section D-D' from the siting area.



LEGEND:

- CLAY
- SILT
- SAND
- SAND & GRAVEL
- B / G — BASE OF WEATHERED HORIZON

NOTE:

SCALE IS APPROXIMATE, VERTICAL EXAGGERATION APPROXIMATELY 25 TO 1.

PRELIMINARY

SCALE 20 0 FEET

RES2245 B FIG3-4.DGN CRU-4 FERMCO/GIS SEPT 1993

FIGURE 3-4 GEOLOGIC CROSS SECTION A-A'

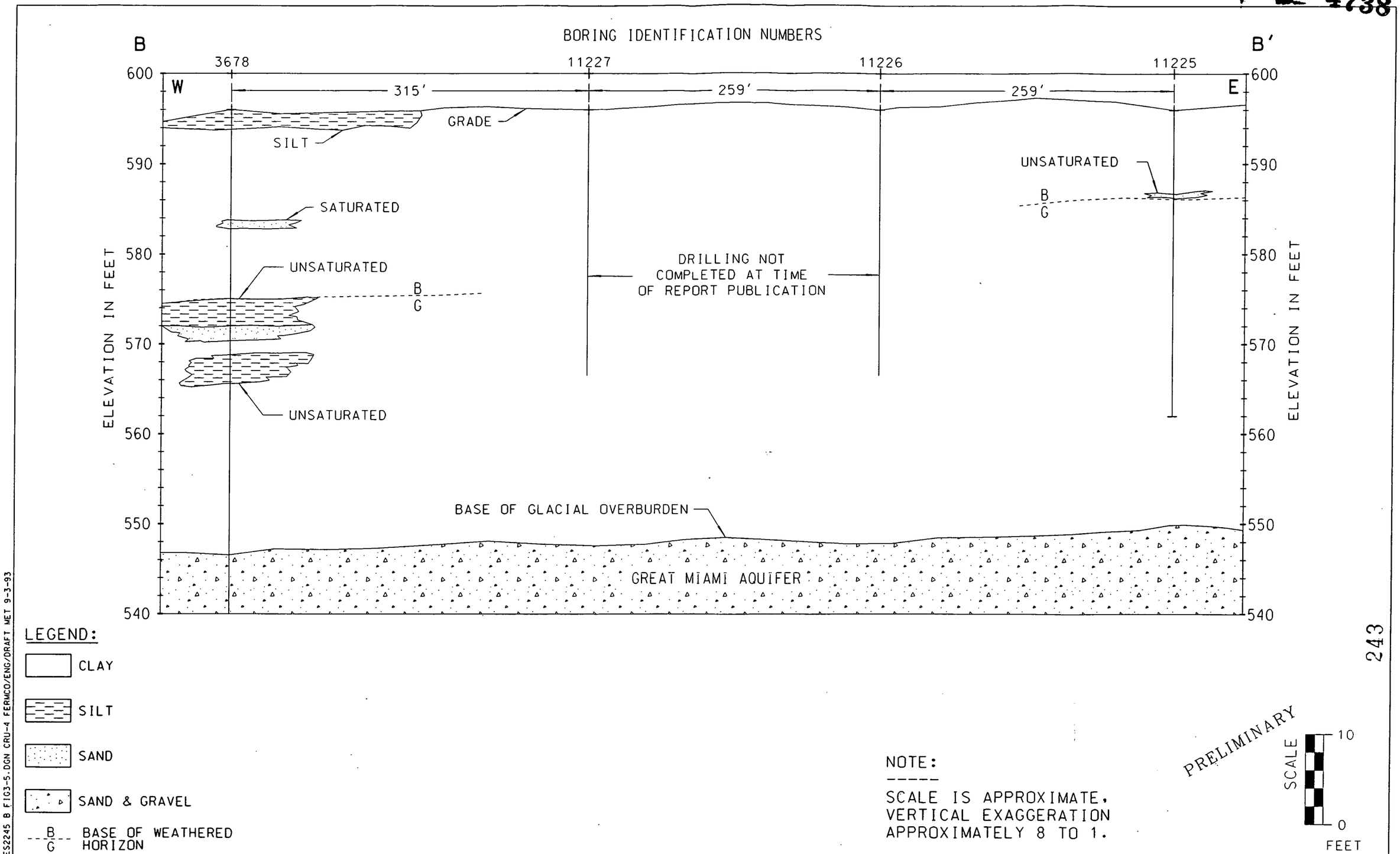
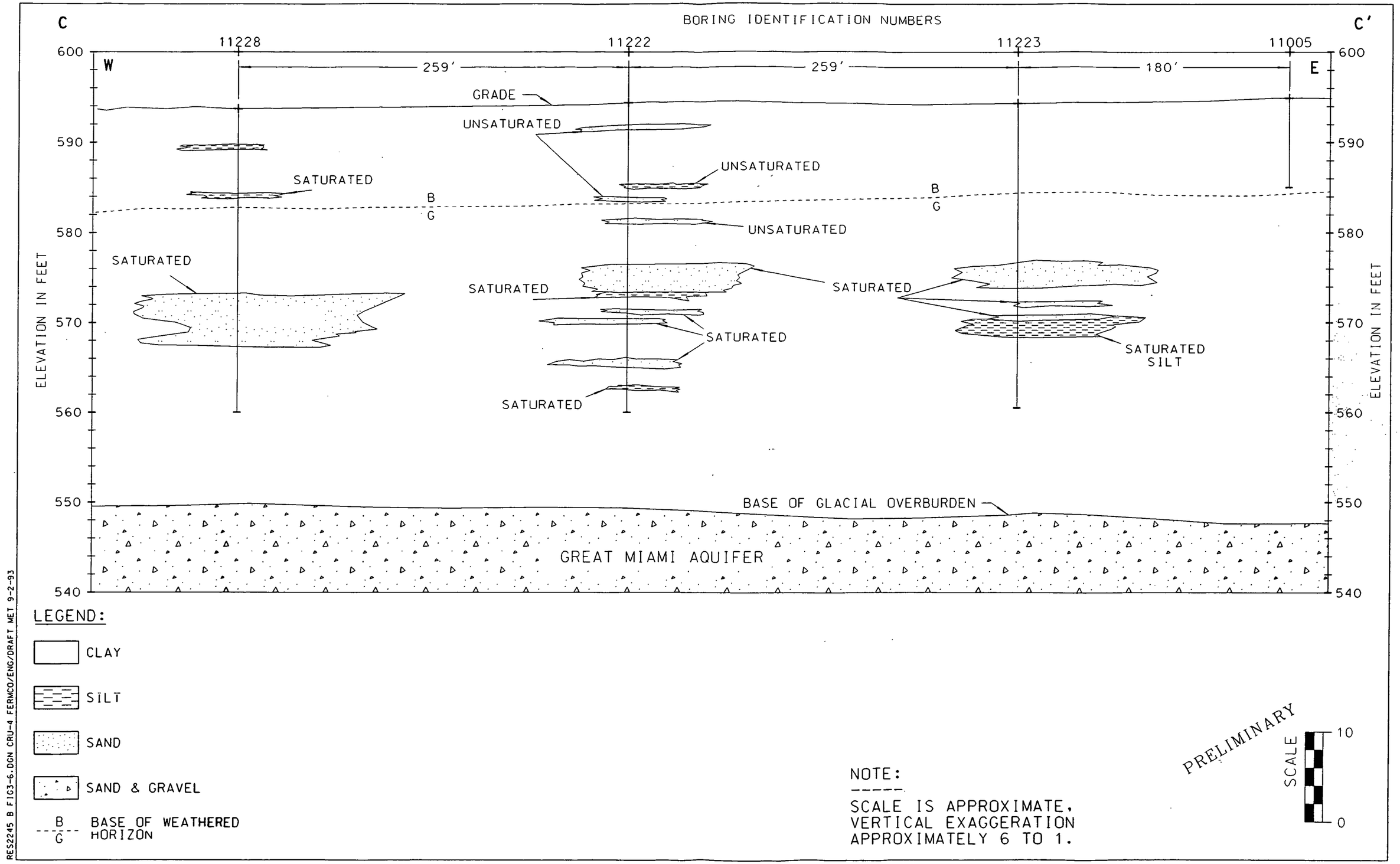


FIGURE 3-5 GEOLOGIC CROSS SECTION B-B'



RES2245 B FIG3-6.DGN CRU-4 FERMCO/ENG/DRAFT MET 9-2-93

FIGURE 3-6 GEOLOGIC CROSS SECTION C-C'

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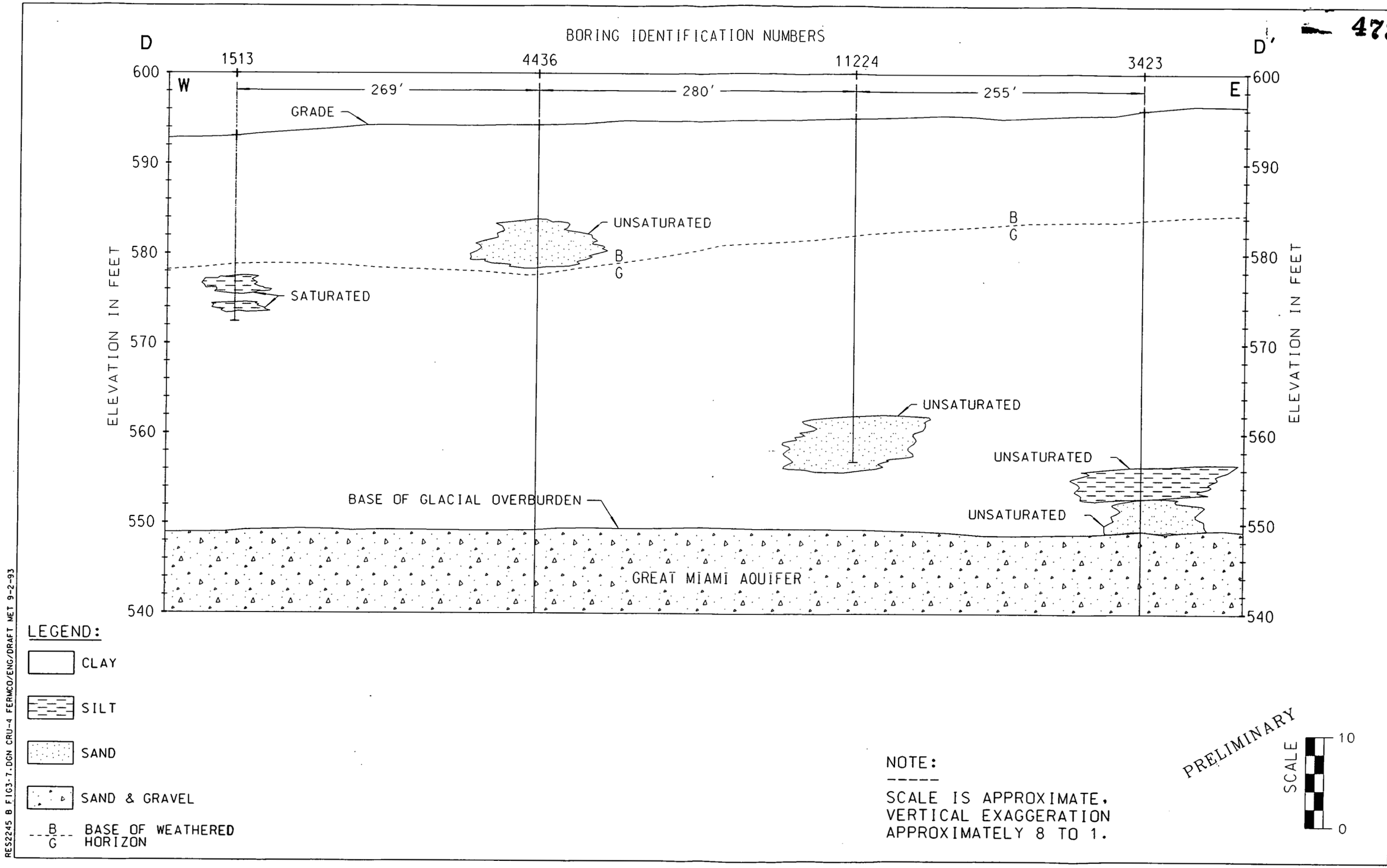
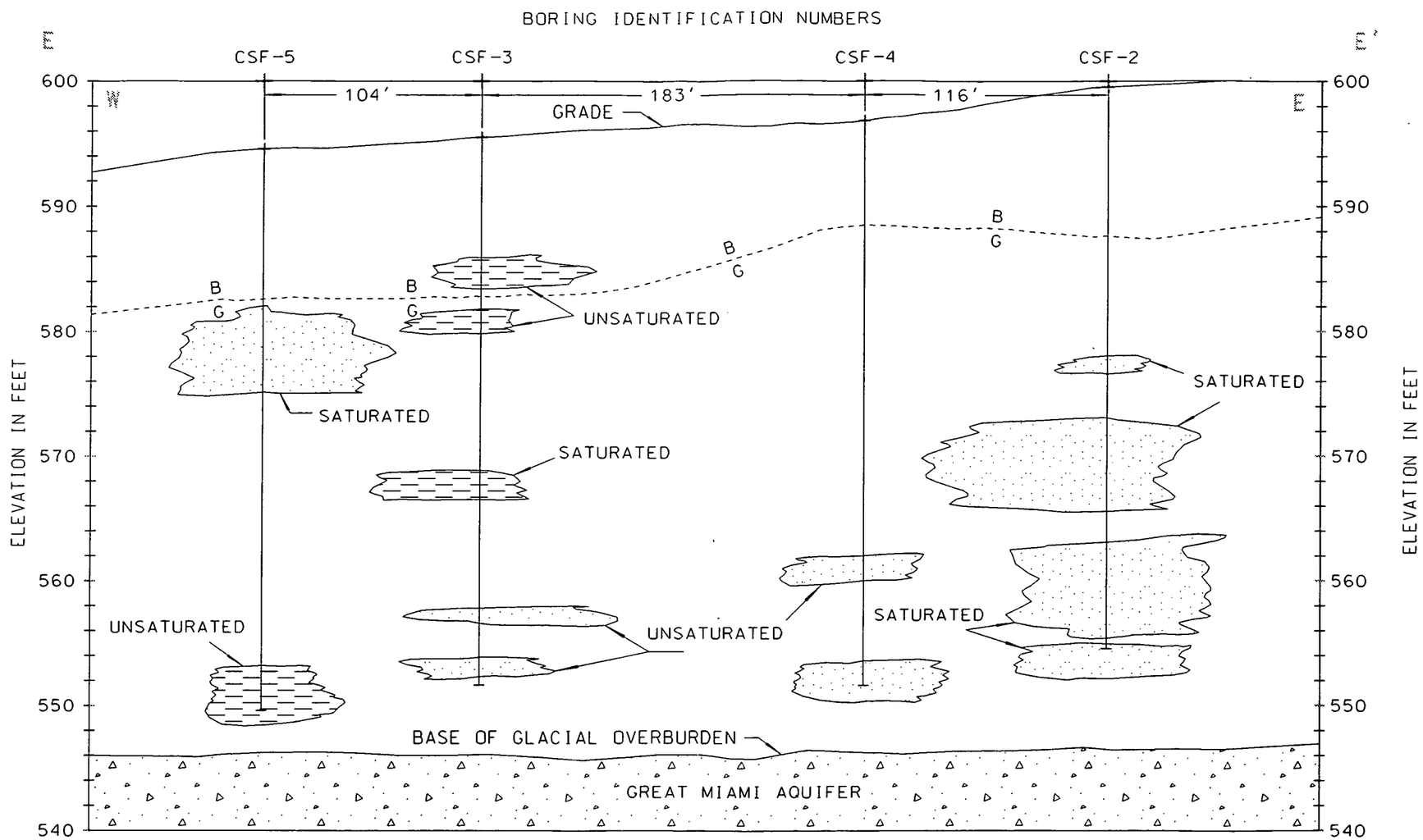


FIGURE 3-7 GEOLOGIC CROSS SECTION D-D'



LEGEND:

- CLAY
- SILT
- SAND
- SAND & GRAVEL
- B / G — BASE OF WEATHERED HORIZON

NOTE:

SCALE IS APPROXIMATE, VERTICAL EXAGGERATION APPROXIMATELY 6 TO 1.

PRELIMINARY

SCALE 0 10

RES2245 B FIG3-8.DGN CRU-4 FERMCO/ENG/DRAFT MET 9-2-93

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FIGURE 3-8 GEOLOGIC CROSS SECTION E-E'

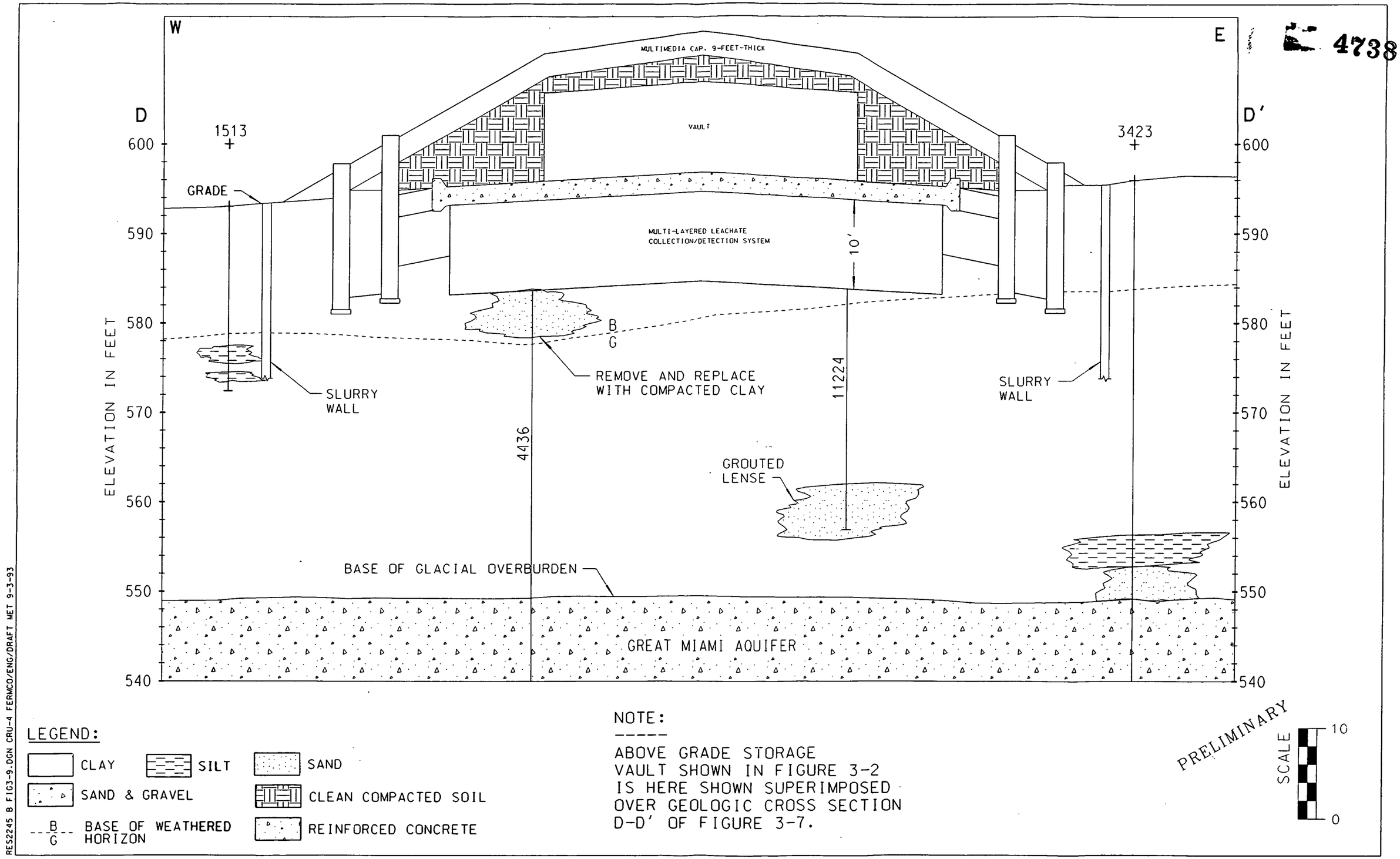

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FIGURE 3-9 CROSS SECTION OF DISPOSAL VAULT AND SITE GEOLOGY

All strata that lie above the sand and gravel deposits of the GMA are together called glacial overburden. The glacial overburden in the proposed area is till overlain by several feet of loess. The till is a heterogeneous mixture of clay, silt, sand and pebble to cobble size material; with clay and silt constituting the dominant grain size fraction. Scattered and discontinuous lenses of silty and clayey sand are located within the till.

Each geologic material has different hydraulic properties. The sands and gravels of the GMA have very little fine-grain-size material (silt and clay). The GMA has a high hydraulic conductivity and is capable of readily transmitting groundwater in horizontal and vertical directions. Measured hydraulic conductivities for the sand and gravel of the GMA range from 0.042 cm/s to 0.27 cm/s (Klaer and Kazmann 1943; Kazmann 1950; Dove 1961; Spieker and Norris 1962)[1]. The GMA is capable of providing large yields to wells. The Southwestern Ohio Water Company (SOWC) has a well field located adjacent to the Great Miami River, east of the FEMP. A SOWC well installed in 1952 pumped an average of 10 million gallons per day (Mgd) from 1952 to 1955. From 1980 to 1982, two collector wells together pumped an average of 18.4 Mgd (Miami Conservancy District 1992). Yields are extremely high at the SOWC well field because induced recharge is available from the Great Miami River (Dove 1961; Spieker 1968). Elsewhere, removed from the area where induced recharge is significant, a local industry uses water from two wells located approximately 2000 feet south of the FEMP. The combined flow from these two wells is approximately 225 gpm. In approximately the same area, a second industry operates a production well that pumps at a rate of 0.14 Mgd. The FEMP operates a water supply well (4103) on the FEMP which pumps an average daily flow of 290 gpm. Pumping tests for the South Plume Groundwater Contamination Removal Action obtained yields of 500 gpm west of the FEMP and 425 gpm south of the FEMP.

The till is an unsorted mixture of clay, silt, sand, and pebble to cobble size material. The high percentage of clay and silt size material in till gives it a relatively low hydraulic conductivity; consequently, till is not readily capable of transmitting groundwater. The silty and clayey sand lens of the till strata have hydraulic conductivity values that are between the low values of the clays and the high values of the GMA. Measured hydraulic conductivities of glacial overburden strata that contain sand or sandy silt range from 2.5×10^{-6} cm/s to 3.1×10^{-3} cm/s (Table 3-1). The cohesive strata (clay, silty clay, and clayey silt) that surround the perched groundwater lenses and separate the

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[1]The calibration process for the SWIFT III model of the GMA, used in fate and transport modeling for this FS report, determined that a hydraulic conductivity of 0.16 cm/s best represents the upper and middle layers of the aquifer (IT Corp., 1990; DOE, 1990).

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TABLE 3-1

CORE PERMEABILITY DATA FOR LABORATORY TESTS OF UNDISTURBED COHESIVE SOILS

Boring	Depth (ft.)	Core Permeability (cm/s)
1729[a]	18-21	3.9×10^{-9}
1735[a]	8-11	3.8×10^{-7}
1742[a]	18-21	1.5×10^{-7}
1741[a]	20-23	4.3×10^{-9}
1745[a]	6-9	1.1×10^{-7}
1748[a]	9-12	7.2×10^{-7}
1747[a]	12-14.5	7.6×10^{-9}
1751[a]	8-11	4.1×10^{-7}
2731[a]	8-11	1.3×10^{-7}
B3-3-3[b]	5-7.5	2.6×10^{-8}
B3-3-4[b]	8-10.5	5.3×10^{-7}
B5-3-6[b]	8-9	9.3×10^{-8}
B5-6-13[b]	19-20.5	3.1×10^{-8}
B5-12-3[b]	20-22	6.5×10^{-9}
B5-13-4[b]	9-11.5	1.0×10^{-6}
B5-7-3[b]	7-9.5	7.9×10^{-8}
B5-9-16[b]	31-33	9.3×10^{-9}
BC-1-1[b]	1-3.5	2.0×10^{-7}
B-1[c]	3-5	8.0×10^{-8}
B-2[c]	3-5	3.8×10^{-8}
B-3[c]	3-5	6.2×10^{-8}
B-4[c]	3-5	4.9×10^{-8}
B-4[c]	10-12	5.0×10^{-8}
B-6[c]	3-5	5.7×10^{-8}
B-6[c]	10-12	2.8×10^{-8}
2[d]	3-5	2.5×10^{-8}
2[d]	10-12	1.3×13^{-8}
2[d]	19.5-21	5.7×10^{-9}
Mean	-	1.5×10^{-7}
Standard Deviation	-	2.4×10^{-8}

[a]IT Corporation, 1993, "Technical Report 5.1A Engineering Evaluation Report for On-Site Disposal."
[b]Parsons, 1992, "Waste Pits 3 and 5 and Clearwell Dikes Stability Analysis Report," report prepared for WEMCO.
[c]WMCO, 1988, "Geotechnical Exploration of Coal Storage Facility."
[d]H.C. Nutting Company, 1985, "Proposed Sanitary Landfill Report," prepared for WMCO.

perched groundwater from the underlying GMA have primary permeabilities that range from 4.3×10^{-9} cm/s to 1.0×10^{-6} cm/s (Table 3-2).

The glacial overburden at the FEMP is divided into two parts, a brown weathered (oxidized) zone that generally constitutes the uppermost 10 to 15 feet and an underlying unweathered grey zone (Figure 3-9). The brown till strata have been observed to contain fractures (Brockman 1988; and FEMP field observations); however, the orientation and density of fractures have not been quantified. Recent investigations elsewhere in similar geologic settings have shown that the brown and grey till strata are different from a hydrogeologic standpoint (Barari and Hedges 1985; Hendry 1988; Cravens and Ruedisili 1987). The fractures can impart an enhanced bulk hydraulic conductivity up to 1000 times greater than the unweathered till (Hendry 1988). The studies indicate that infiltration (downward transmission of surface water) is primarily limited to the brown weathered zone. While precipitation enters the brown zone, it does not act as a significant source of recharge to deeper zones. The majority of water lost from till occurs by evapotranspiration. A lesser amount of groundwater moves slowly downward through the till and laterally within sand lenses or the brown fractured zone.

The studies of fractured tills at similar geological settings show that fracture density decreases with depth below ground surface. Grey till at the FEMP site is predicted to have very few fractures relative to the overlying brown clays. The hydraulic conductivity of fractured till decreases with depth because of increased vertical and lateral pressures caused by overlying strata.

Saturated zones are present in the glacial overburden. Many clayey and silty sand lenses are observed to be saturated and much of the clay till strata are assumed to be saturated. The saturated strata are said to have perched groundwater. The water is "perched" because it is blocked from downward migration by the hydraulic barrier properties (low hydraulic conductivity) of underlying clay strata. There are three important groundwater transport paths in the glacial overburden: 1) slow transport in grey clay strata, 2) potentially more rapid transport in brown fractured clay strata, and 3) potentially rapid transport in sand lenses. Within the area depicted in the cross section in Figure 3-9, any groundwater migrating through the disposal facility capping and lining systems is conceptualized to flow along the following path:

A. Groundwater infiltrates downward through unsaturated brown weathered strata.

B. Downward infiltration of groundwater is significantly slowed by the grey till, such that groundwater accumulates above the till and is present as perched groundwater in

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TABLE 3-2

SLUG TEST RESULTS FOR MONITOR WELLS
COMPLETED IN WATER BEARING LENSES OF THE GLACIAL OVERBURDEN

Well No.	Source of Data	Hydraulic Conductivity (cm/s)
PWT-1	SME, 1985[a]	5.6×10^{-6}
PWT-2	SME, 1985[a]	4.3×10^{-4}
PWT-3	SME, 1985[a]	3.5×10^{-4}
PWT-4	SME, 1985[a]	3.4×10^{-4}
PWT-5	SME, 1985[a]	2.0×10^{-4}
1008	GW, SWCR[b]	1.3×10^{-4}
1012	GW, SWCR[b]	1.6×10^{-3}
1018	GW, SWCR[b]	5.7×10^{-4}
1025	GW, SWCR[b]	2.5×10^{-6}
1034*	GW, SWCR[b]	2.5×10^{-5}
1035	GW, SWCR[b]	2.5×10^{-5}
1041	GW, SWCR[b]	1.1×10^{-4}
1046	GW, SWCR[b]	6.8×10^{-5}
1048	GW, SWCR[b]	1.6×10^{-4}
1065	GW, SWCR[b]	2.2×10^{-5}
1079	GW, SWCR[b]	1.8×10^{-5}
1185	OU-3 RI[c]	2.0×10^{-4}
1186	OU-3 RI[c]	2.4×10^{-4}
1195	OU-3 RI[c]	7.6×10^{-4}
1196	OU-3 RI[c]	3.1×10^{-3}
1197	OU-3 RI[c]	8.9×10^{-4}
1199	OU-3 RI[c]	6.2×10^{-4}
1208	OU-3 RI[c]	1.8×10^{-4}
1209	OU-3 RI[c]	1.6×10^{-3}
1212	OU-3 RI[c]	1.2×10^{-3}
1213	OU-3 RI[c]	2.6×10^{-4}
1224	OU-3 RI[c]	1.3×10^{-4}
1228	OU-3 RI[c]	7.0×10^{-5}
1231	OU-3 RI[c]	3.6×10^{-5}
1233	OU-3 RI[c]	1.2×10^{-3}
1234	OU-3 RI[c]	2.2×10^{-4}

[a]Soil and Material Engineers, Inc., 1985, "Hydrogeologic Investigation of the Proposed Storm Water Collection Basin," report prepared for NLO and U.S. DOE.
[b]Groundwater Report (1990) and Site-Wide Characterization Report (1992).
[c]Draft OU-3 RI Report (1990); results were listed incorrectly in the report. The data were recalculated and correct results are presented here.
*Monitor well completed adjacent to Silo 1.

pore spaces of sand lenses, clay, and fractures.

C. Perched groundwater flows along three paths:

(1) water potentially flows laterally through the connected fractures of the brown zone.

(2) water potentially flows laterally in sand lenses only if sand lenses are hydraulically interconnected

(3) water flows laterally or downward through the clay till.

D. Water that reaches the base of the glacial overburden infiltrates downward through 20 to 30 feet of unsaturated sand and gravel before flowing eastward in the saturated portion of the Great Miami Aquifer.

The transport path that is of most concern is potential hydraulically interconnected sand lenses. Till is laterally continuous across the FEMP. Elsewhere at the FEMP, where borings are closely spaced (e.g the former Production Area), lithologic correlations of borings show that sand lenses in till strata have limited lateral dimensions and are not physically connected. The correlations of geologic logs show that the sand lenses within till are generally not correlative over distances greater than 100 feet and have thicknesses less than a few feet. The spacing of available borings within the proposed siting area (Figure 3-3) is not as dense everywhere as the spacing throughout the former Production Area. The geologic correlations completed in the proposed area (Figures 3-4 through 3-8) do not suggest that geologic conditions in the glacial overburden of the proposed area are different from areas that have more complete geologic data.

The design for the above-grade disposal vault would contain provisions for the implementation of engineering controls to eliminate the potential for lateral transport of groundwater in sand lenses occurring in soils beneath the facility. These provisions would include any or all of the following:

- Excavation of shallow sand lenses and replacement with compacted clay
- Jet grouting of deep sand lenses to reduce the permeability of the lenses to values comparable to the grey clays
- Installation of slurry walls, as required, to eliminate hydraulic connection within the brown till and deep sand lenses

With the elimination of any potential lateral transport paths that are identified to exist, the major groundwater transport path that could possibly move contaminants to the underlying Great Miami

Aquifer would be downward migration through the clay strata. As identified on Figure 3-9, the proposed vault location has approximately 30 feet of gray, low permeability till separating the bottom of the facility liner from the uppermost unsaturated portion of the Great Miami Aquifer.

At the FEMP site, the till with its appreciable silt and clay content is regarded as providing the GMA with protection from surface contaminants. The low hydraulic conductivities of clay strata produces very low groundwater velocities even if the hydraulic gradients are high. Additionally, most contaminants of concern being transported by seepage through the clay till undergo attenuation and retardation.

At all locations on the FEMP, the glacial overburden is separated from the saturated portion of the GMA by a sequence of unsaturated sand and gravel. Pump tests within the GMA will not elicit a hydraulic response in the overlying perched groundwater of the glacial overburden. Likewise, pump tests of the perched groundwater would not elicit a hydraulic response in the GMA.

While the perched groundwater within the till is a significant zone of saturation that is located between the ground surface and the GMA, there is no significant hydraulic connection between this zone and the underlying aquifer. This is supported by the available geologic and hydrogeologic data on the glacial till at the FEMP and more specifically from data collected within the area of the proposed disposal facility. Further, available information supports the position that any sand lenses within the till present in the proposed vault area are small and not laterally continuous. Downward transport of groundwater and potential contaminants is insignificant due to the thickness of glacial overburden present. Lateral transport is presumed to be possible within these small sand lenses of the glacial overburden; however, previously discussed engineering measures such as removal or grouting of lenses will mitigate any potentially significant lateral transport. The low permeability, gray glacial overburden coupled with the engineered features of the disposal facility, while not creating an absolute barrier to groundwater migration, provide a superior protective barrier to preclude the migration of contaminants.

3.2.2.2 Groundwater Monitoring

Groundwater monitoring will be a part of all remedial alternatives for each subunit that leave material on property, which includes the no-action alternative, in situ alternatives, and removal and on-property disposal alternatives. Groundwater monitoring networks will be designed to be consistent

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with ARAR/TBC requirements and will continue until site-wide RAOs are attained and to satisfy any post closure monitoring or CERCLA 5-year review requirements.

3.2.3 Summary of Preliminary Alternatives

The process options evaluated and selected in Section 2.0 represent process options for each technology. These process options will be combined into specific remedial action alternatives to fulfill the RAOs. These alternatives represent a full range of potentially viable remedial actions for each waste subunit. The alternatives for each medium provide for no action; material containment; and material removal, treatment, and disposal. The no-action alternative is presented as a basis for comparison. Sections 3.2.3.1 through 3.2.3.3 summarize the alternatives. Sections 3.2.4 through 3.2.6 provide the descriptions and document the development of the alternatives.

3.2.3.1 Subunit A

The following eight alternatives were developed for Subunit A, which includes the contents of Silos 1 and 2 and the sludge in the decant sump tank.

- Alternative 0A - No Action
- Alternative 1A - In Situ Containment
- Alternative 2A - Removal, Stabilization, and On-Property Disposal
- Alternative 3A.1 - Removal, Stabilization, and Off-Site Disposal at NTS
- Alternative 3A.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site
- Alternative 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal
- Alternative 5A.1 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at NTS
- Alternative 5A.2 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

3.2.3.2 Subunit B

The following five alternatives were developed for Subunit B, which includes the contents of Silo 3.

- Alternative 0B - No Action
- Alternative 1B - In Situ Containment

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- Alternative 2B - Removal, Stabilization, and On-Property Disposal
- Alternative 3B.1 - Removal, Stabilization, and Off-Site Disposal at NTS
- Alternative 3B.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

3.2.3.3 Subunit C

The following six alternatives were developed for Subunit C, which includes the Silos 1, 2, 3, and 4 structures, soils, and debris.

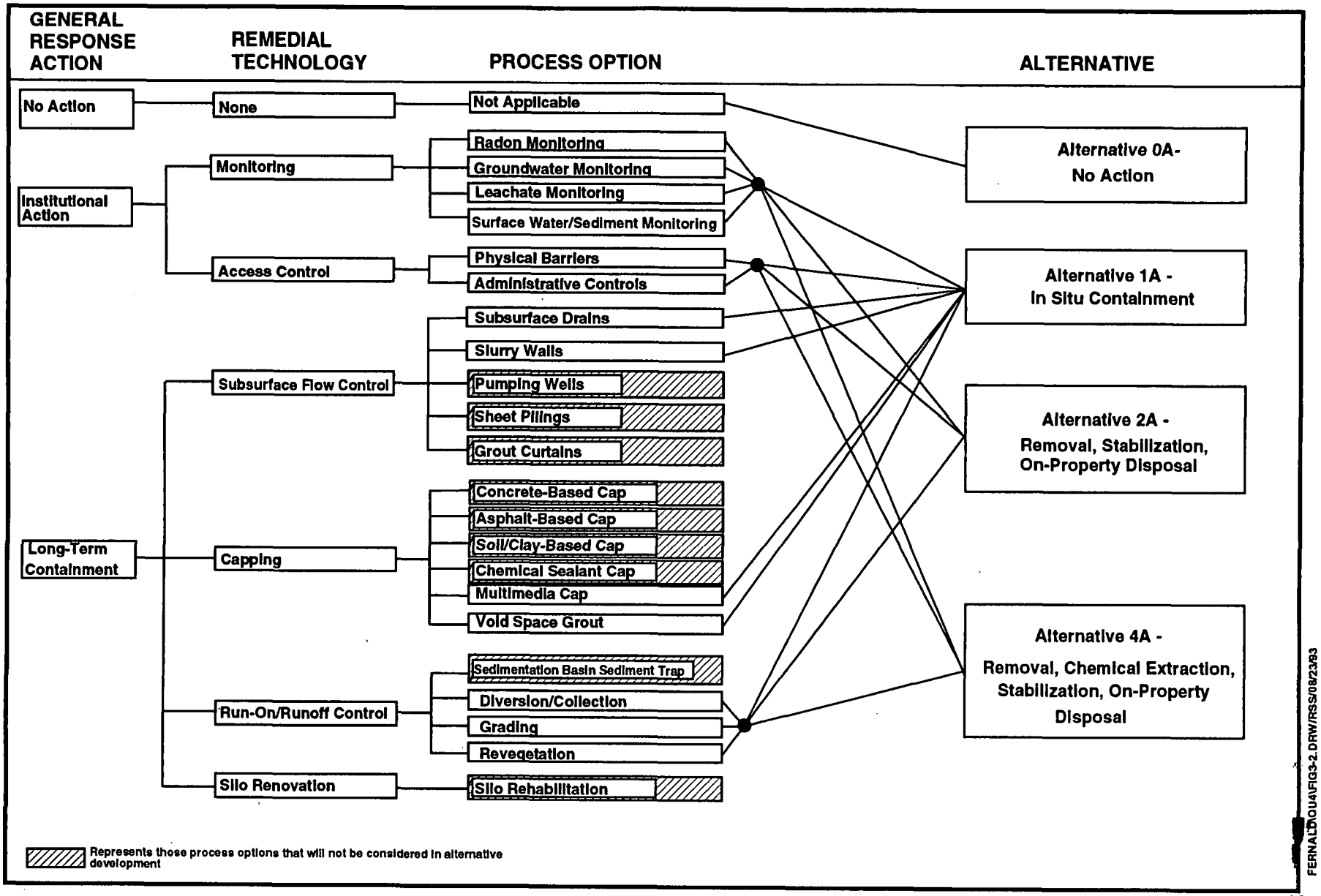
- Alternative 0C - No Action
- Alternative 1C - Demolition and Containment
- Alternative 2C - Demolition, Removal, and On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS
- Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at the Permitted Commercial Disposal Site
- Alternative 3C.3 - Demolition, Removal, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

These alternatives are further described for each of the subunits in Sections 3.2.4 through 3.2.6. The descriptions include a brief description of the remedial alternative including the technologies, process options, and other features that constitute each alternative as well as preliminary estimates of the following information. More detailed estimates are provided in Section 4.0, Detailed Analysis of Alternatives passing the initial screening process.

- Size and configuration
- Remediation time frame
- Spatial requirements
- Packaging/transportation requirements
- Waste generated

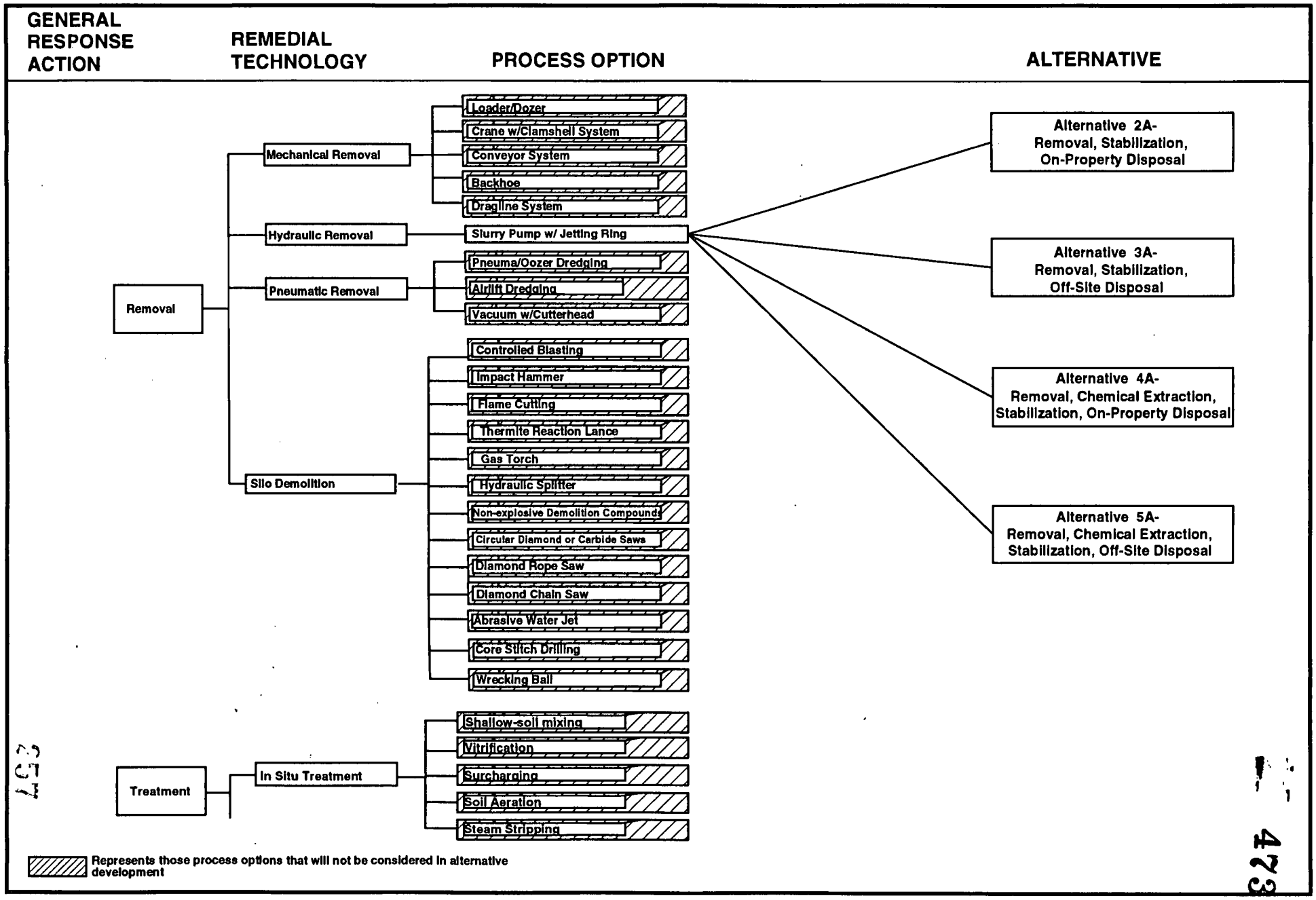
3.2.4 Subunit A Preliminary Alternatives

Figure 3-10 outlines the development of Subunit A preliminary alternatives. A discussion of alternative development follows.



FERNALD\OU4\FIG3-2.DRW/RSS/08/23/93

FIGURE 3-10
SUBUNIT A
DEVELOPMENT OF ALTERNATIVES



FERNALD\OU4\FIG3-2A.DRW/RSS/08/24/93

FIGURE 3-10
(Continued)

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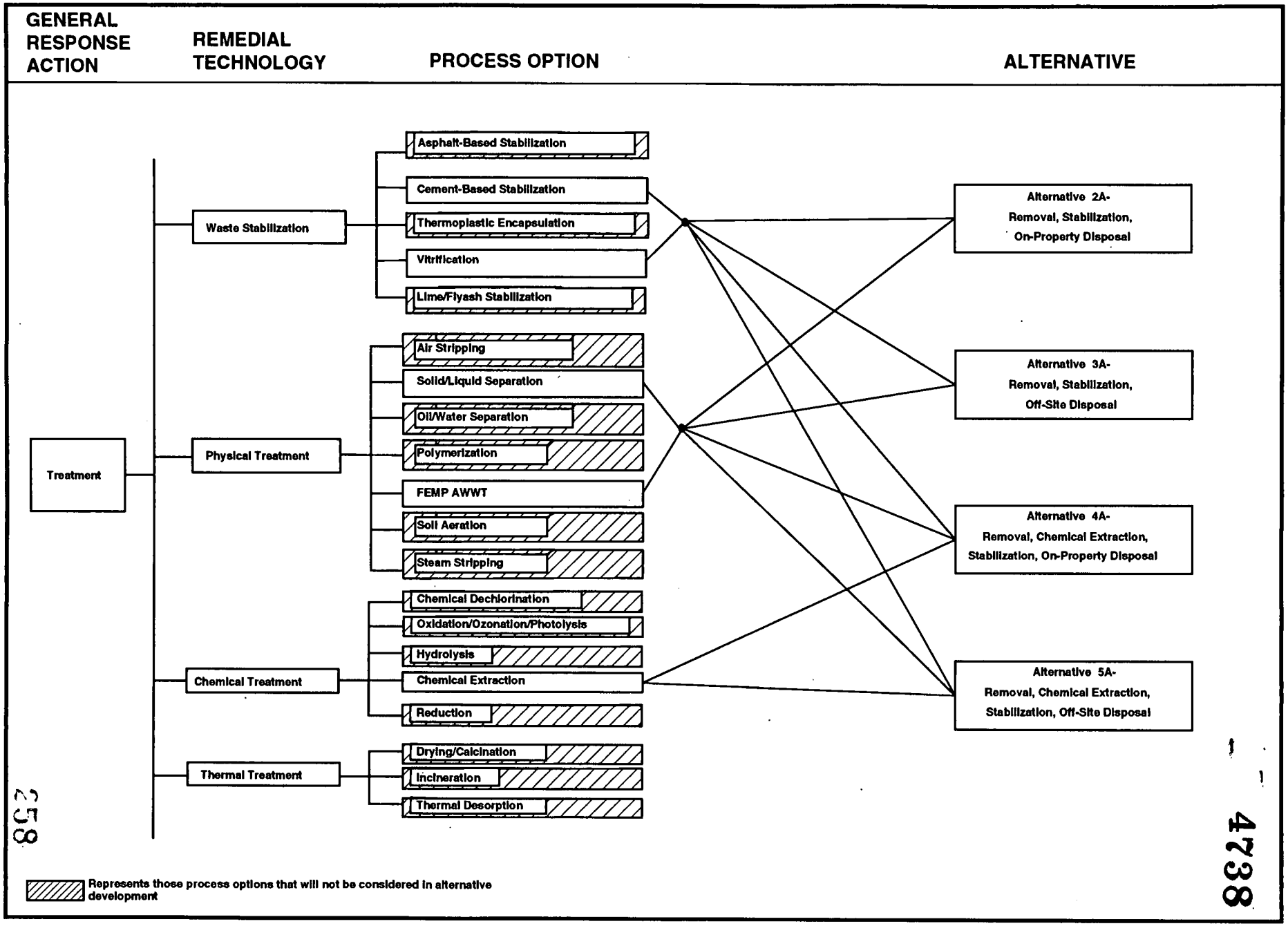

FIGURE 3-10
(Continued)

FERNALD\OU4\FIG3-2B.DRW/RSS/08/24/93

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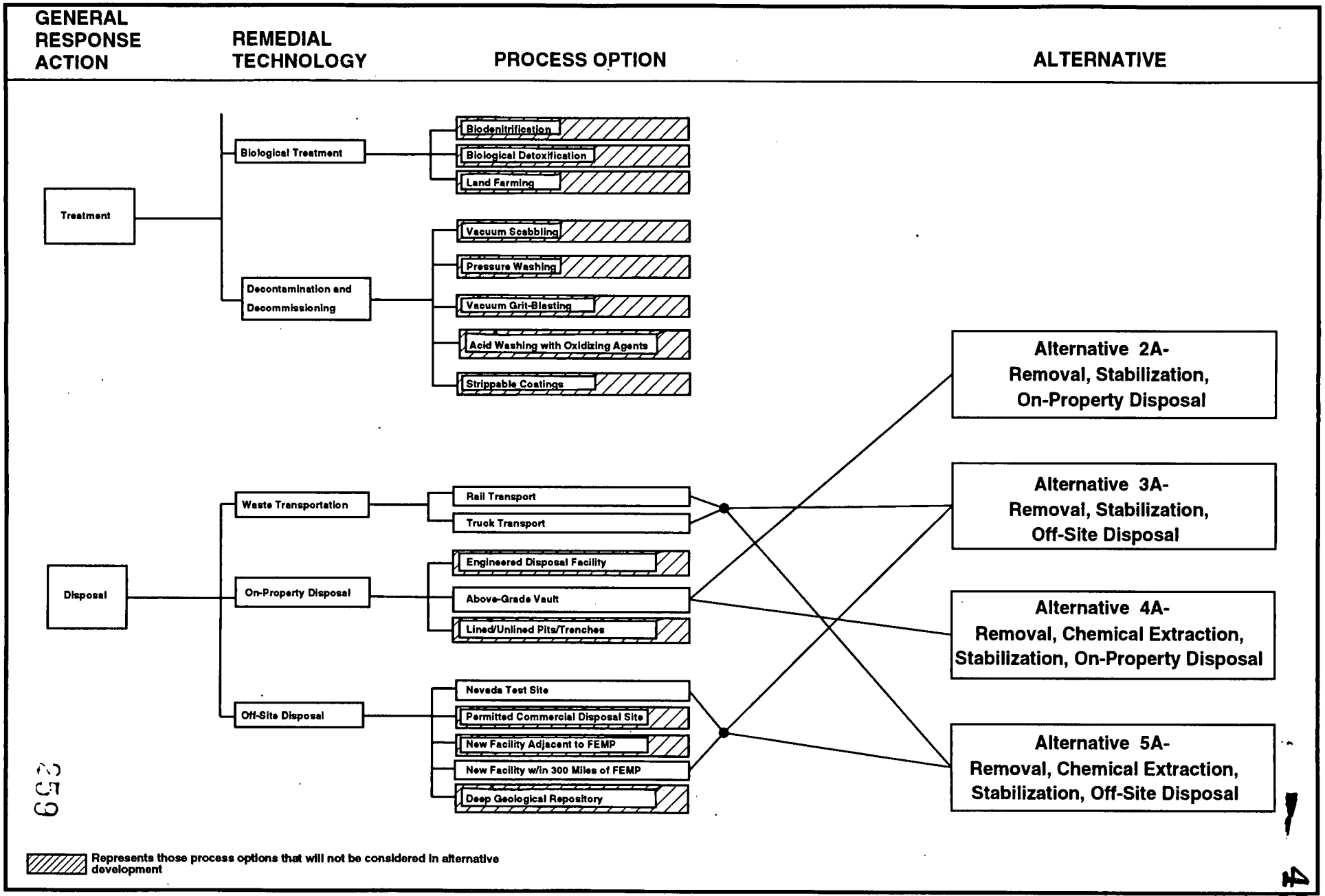

FIGURE 3-10

(Continued)

FERNALD\OU4\FIG3-2C.DRW/RSS/8/24/93

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3.2.4.1 Alternative 0A - No Action

Description

The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken and the material is considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. This alternative does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and does not provide for any active or passive institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

3.2.4.2 Alternative 1A - In Situ Containment

Description

This containment alternative for the Subunit A contents is intended to isolate the contents of the silos and the decant sump tank sludge from the environment and to minimize the generation and release of contaminated leachate to the underlying Great Miami Aquifer. The technologies implemented by this alternative are subsurface flow control, capping, run-on/runoff control, monitoring, and access controls. This alternative includes the introduction of structural grout into the silo void spaces, the installation of an LC/DS beneath the silos, construction of a slurry wall around the silos, and construction of a multimedia cap over the silos. Figure 3-11 illustrates a conceptual flow diagram for this alternative.

The process options selected for this alternative's technologies are described as follows.

Subsurface Flow Control

- Subsurface drains - A basic LC/DS would be installed underneath the silos before the cap is installed. The system would consist of slotted piping inserted underneath the silos and would be connected to leachate extraction wells.

- Slurry Walls - To divert groundwater flow around the silos and decant sump tank, a soil-bentonite slurry wall will be constructed along three sides of the perimeter of Silos 1 and 2 and will extend into the sand/gravel layer of the Great Miami Aquifer. The bentonite will be obtained commercially and mixed on property with existing acceptable soils to produce a 0.9-m (3-ft) wide slurry wall with an approximate depth of 15.2 m (50 ft). The purpose of the slurry wall is to prevent any leachate that may be generated from migrating laterally to Paddy's Run.

Capping

- Silo void space grout - Structural grout would be introduced into the silos through the manways to fill the silo void space. This process would minimize the possibility that

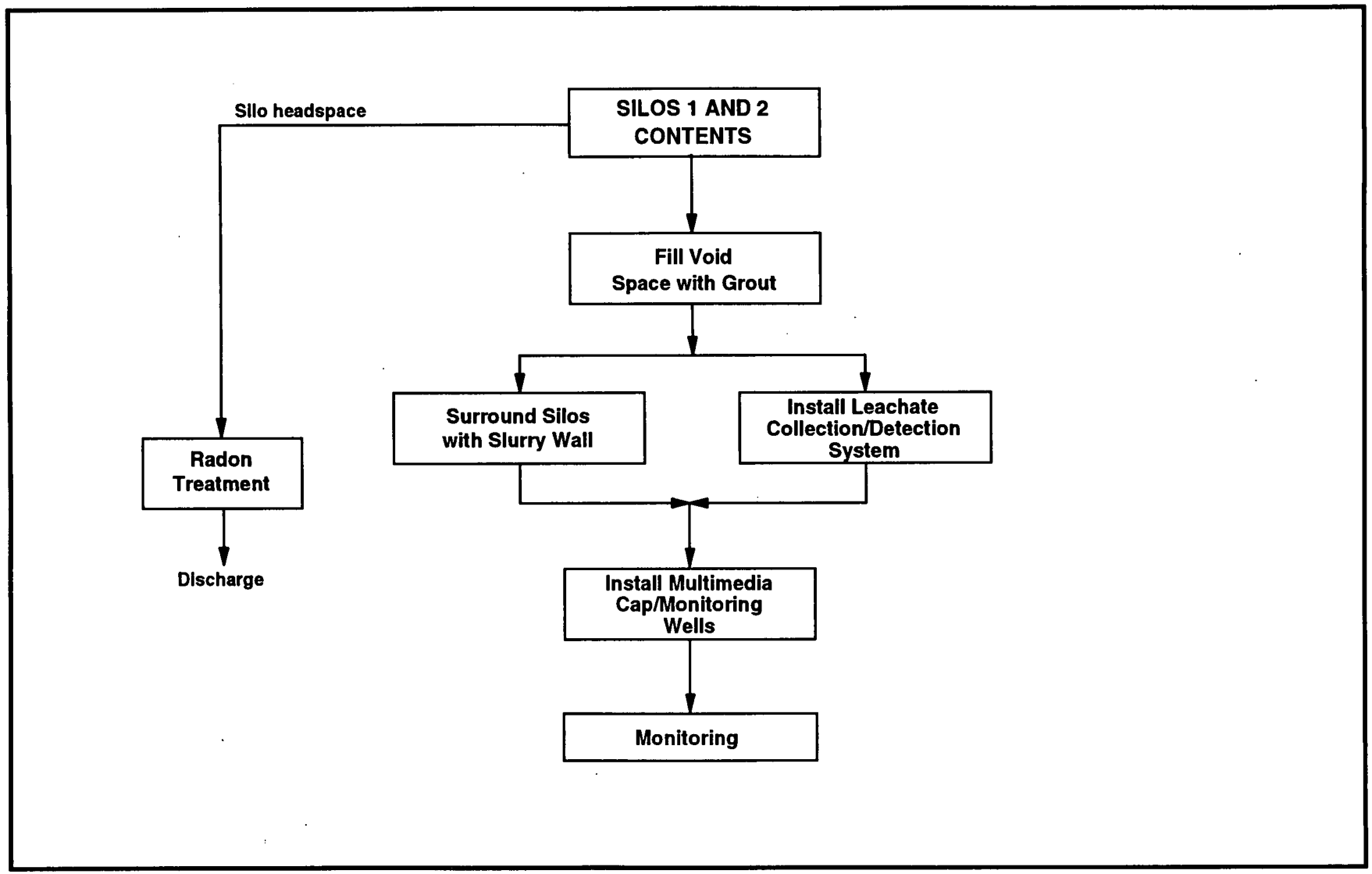

FIGURE 3-11
ALTERNATIVE 1A - IN SITU CONTAINMENT
CONCEPTUAL FLOW DIAGRAM

the silo domes will subside under the weight of the multimedia cap during construction and after the cap is installed. The grout would also serve as a radon barrier and an inadvertent intrusion barrier. A containment device (i.e., glove bag) would be used at the grout injection piping/silo dome interface to mitigate release of contamination during grout injection. A temporary batch plant would be used to provide the required structural grout.

- Multimedia cap - A multimedia cap would be installed to minimize the infiltration of rainwater into the silos and decant sump tank. The cap would consist of the following elements to control erosion and minimize generation of leachate as a result of rainwater infiltration.

  - Upper vegetative layer
  - Drainage layer
  - Low permeability clay layer with a maximum vertical permeability of 1×10^{-7} cm/s
  - Geomembrane layer of 40-mil minimum thickness

  The spatial requirements for the multimedia cap would require the partial relocation of Paddys Run to minimize the possibility of lateral erosion.

Run-on/Runoff Control

- Diversion/collection - The area around the cap may contain small berms, channels, and waterways to redirect runoff.
- Grading - The area around the cap would be contoured or graded to redirect and control runoff.
- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon monitoring - Radon monitors would be installed around the cap to detect and warn of radon emanating from the material underneath the cap. Monitoring would continue as required to demonstrate compliance with relevant ARAR/TBCs and in support of CERCLA 5-year reviews.
- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the cap and sampled routinely to monitor containment system performance.
- Leachate monitoring - The installed LC/DS would be routinely checked to monitor the cap performance.
- Surface water/sediment monitoring - The surface water and sediment near the cap would be monitored to determine if contaminants from the material have been released to these media.

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Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.

- Administrative controls - Access to the site would be confined to authorized personnel through the use of fences, and/or guards, until site-wide RAOs (including Operable Unit 5) are attained. The need or requirement for the application of long-term administrative controls will be examined in the Detailed Analysis phase.

The following system is required to support the implementation of the process options.

- RTS - A newly designed RTS consisting of dehumidification media, carbon absorbers, HEPA filters, and a blower would be used to treat the radon and other airborne contaminants displaced by the grout injection.

Size and Configuration

The following lists the approximate sizes and numbers of the various components for this alternative. These are preliminary and subject to change based upon additional information acquired for each alternative during detailed analysis.

- Slurry wall - Less than 300 m (1000 ft) long by 15 m (50 ft) deep

- Monitoring wells - 6 nests/4 wells per nest

- Grout injection - Less than 3100 m^3 (4000 yd^3)

Remediation Time Frame

Remediation is estimated to take approximately two years from the initial staging of construction equipment to the final capping and isolation of the silos.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 5 hectares (ha) (12 acres). Approximately 4 ha (10 acres) would be used by the cap.

Packaging/Transportation Requirements

The only transportation requirement identified is transporting the grout, cap materials, and bentonite closure materials to the site.

Waste Generated

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- Contact waste (anti-contamination clothing, gloves, HEPA filters, etc.)
- Equipment not feasible to decontaminate
- Clean nonhazardous solid waste from debris and equipment

Contaminated rubble and other debris will be dispositioned as part of Subunit C.

3.2.4.3 Alternative 2A - Removal, Stabilization, and On-Property Disposal

As previously identified in Section 1.0 of the FS, the residues within Subunit A have three significant characteristics contributing to the hazard of the material involved. That is, the residues: 1) contain highly elevated activity concentrations of gamma emitting radionuclides; 2) represent a significant source of radon; and 3) exhibit leachable concentrations of radionuclides and heavy metals. To address these hazards for alternatives considering removal of the wastes and on-site disposal, the following considerations were taken into account in the development of alternatives and the identification of ARARs.

1. Potential on-site removal actions must provide reasonable assurance of the long-term protection of inadvertent intruders into the disposed residues;
2. Due to the high concentration and leachability of the radionuclides and other heavy metals, remedial alternatives must provide a reasonable assurance of the long-term protection of the underlying sole source aquifer; and
3. Remedial alternatives must provide a reasonable assurance of the long-term mitigation of the radon emanation from the disposed wastes.

To accommodate these considerations, all on-site alternatives involving residue removal were developed employing the application of a stabilization process to the wastes. The overall goals of this stabilization process are to support the attainment of RAOs through the reduction of the mobility of the constituents of concern, the radon emanation rate from the residues, and the potential exposure to the inadvertent intruder.

Description

This alternative requires removal of the Silos 1 and 2 contents and the sludge in the decant sump tank, stabilization of the material by vitrification or cement stabilization, and on-property disposal of the stabilized material. The sludge in the decant sump tank would also be removed and stabilized

along with the contents of the silos. The technologies implemented by this alternative are hydraulic removal, physical treatment, material stabilization, on-property disposal, run-on/runoff controls, monitoring, and potential long-term access controls.

The contents of Silos 1 and 2 and the decant sump tank sludge would be removed under this alternative with a hydraulic mining device introduced through the silos' domes. This equipment would be supported by a platform that will span the silos. The material would then be pumped to a material processing facility for cement stabilization or vitrification. The stabilized material would then be disposed in an above-grade disposal vault with an inadvertent intrusion barrier constructed on property. Figure 3-12 illustrates a conceptual flow diagram for this alternative.

The process options selected for this alternative's technologies are described as follows.

Hydraulic Removal

- Jetting ring with slurry pump - The silos' contents and decant sump tank sludge would be removed with a hydraulic mining device supported by a work platform placed over the silos. The removal device would be introduced into the silos through the four perimeter manways and the off-center manway. The hydraulic mining device would consist of a circumfirential jetting ring that would use high pressure water to dislodge and liquify the material and a slurry pump to pump the slurried material from the silos to the material processing facility. The slurry would contain 80 percent water as it is removed from the silos. The majority of the water used would be recycled to the hydraulic removal system. A glove box would be used at the interface of the silo domes and would, in conjunction with the silo domes, function as the silo containment system. In order to maintain the integrity of the silo walls, berm soil will be removed from the outside of the silo at the same rate as material is removed from the inside to maintain an equal level.

Treatment

- Solid/liquid separation - Before stabilizing, the material slurry would be dewatered as necessary using a horizontal belt filter and a water recycle tank and pumps. The water removed would be recycled for use in the hydraulic removal process. The dewatered slurry would be sent to the cement mixing unit or the vitrification unit.

- Material stabilization - The silos' contents would be stabilized by vitrification or cement stabilization. The vitrification process would add soda ash and carbon to produce a monolithic glass product with excellent wear and leach characteristics. The process would use additive storage silos, an additive and material slurry mixer, a glass melter, a fume hood/cap, and an off-gas treatment system. The cement stabilization system would add cement, flyash, and blast furnace slag to the material slurry to provide a monolithic concrete product with very good wear and leach characteristics. The majority of the water used in removing the material would be used in the cement

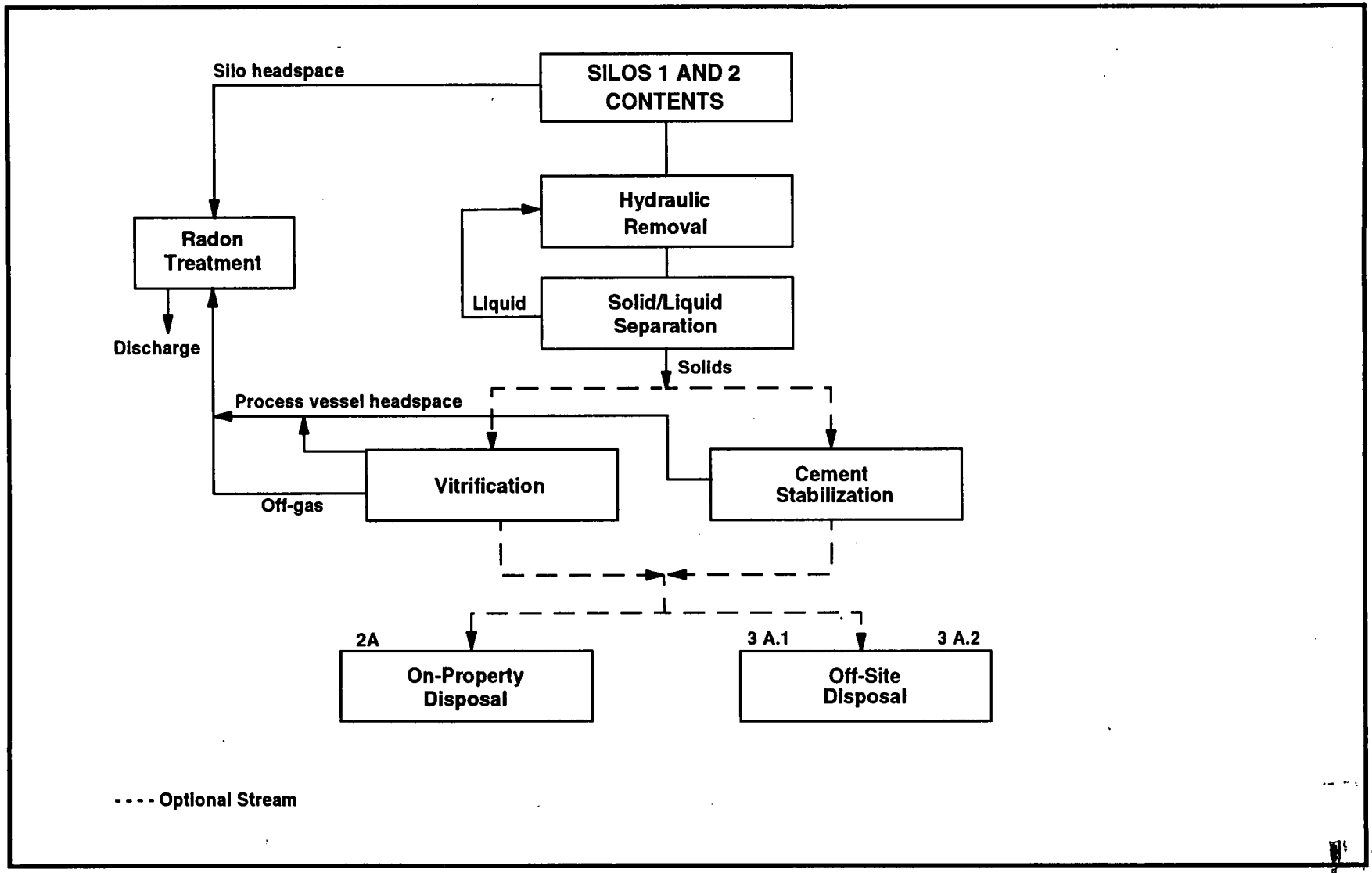

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FIGURE 3 - 12
ALTERNATIVES 2A, 3A - REMOVAL, TREATMENT, DISPOSAL
CONCEPTUAL FLOW DIAGRAM

stabilization process. The process would require additive storage silos, screw feeders and an additive/material slurry mixer.

On-Property Disposal

- Above-grade disposal vault - The stabilized material would be disposed in an above-grade disposal vault. This facility would be constructed at grade and would include an LC/DS, a liner system (including both man-made and natural components), a multimedia type cap, and an inadvertent intrusion barrier. To facilitate construction of the disposal vault, engineering controls may be applied to supplement existing geologic conditions at the proposed siting location. These controls may include, but not be limited to, the excavation or grout injection of sand lenses within the till and the installation of a slurry wall to preclude horizontal flow within the till.

Run-on/Runoff Control

- Diversion/collection - The area around the cap may contain small berms, channels, and waterways to redirect runoff.

- Grading - The area around the cap would be contoured or graded to redirect and control runoff.

- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon monitoring - Radon monitors would be installed around the disposal facility containing the stabilized material to detect radon that emanates from the facility.

- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the disposal facility and sampled routinely to monitor containment system performance.

- Leachate monitoring - The installed LC/DS would be routinely checked to monitor the performance of the facility.

- Surface water/sediment monitoring - The surface water and sediment near the disposal facility would be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.

- Administrative controls - The need or requirement to provide administrative controls will be addressed in the Detailed Analyses phase.

The following systems are designed to support the implementation of the process options.

- RTS - A newly designed RTS using dehumidifiers, carbon absorbers, and HEPA filters would reduce the radon in the silo dome void space during removal operations. The system would maintain the silo headspace under negative pressure to minimize the possibility of leakage.

- Material processing facility - A material processing facility would be constructed to house the processing, packaging, and storage of material from sampling/assaying operations. It would incorporate shielding, air treatment systems, and negative ventilation to minimize emissions.

- FEMP AWWT facility - All contaminated process and decontamination water would be transported to and treated at the FEMP AWWT facility.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tons per day (TPD)

- Processing rate (stabilized product)
  - Cement stabilization - up to 40 tpd
  - Vitrification - up to 15 tpd

- Volume disposed
  - Cement-stabilized product - approximately 18,000 m^3 (24,000 yd^3)
  - Vitrified product - approximately 2800 m^3 (3,600 yd^3)

Estimated treated volumes for disposal are based upon benchscale treatability study data and literature values from similar operations at other sites. The results of more detailed treatability studies will be presented in the Detailed Analysis section.

Remediation Time Frame

Site preparation, material processing facility construction, and material removal and processing equipment installation would take approximately three years. Removing, processing, and packaging the material would take an additional three years. The total remediation time for this alternative would be approximately six years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 4.5 ha (11 acres) for vitrification and approximately 6 ha (14 acres) for cementation. The area of the

disposal vault would be approximately 3 ha (7 acres) for vitrification and approximately 4.5 ha (11 acres) for cementation.

Packaging/Transportation Requirements

The on-property disposal facility would accept only stabilized and/or rigidly-containerized material. The cement stabilized or vitrified material would be poured directly into the disposal containers, DOT specification 7A Type A packaging. The contaminated debris would also be placed in DOT specification 7A Type A or strong tight containers before disposal.

Waste Generated

- Wastewater from hydraulic removal (recycled where possible)
- Contact waste (anti-contamination clothing, gloves, HEPA filters, carbon adsorption media, etc.)
- Equipment not feasible to decontaminate
- Process water contained in the process piping at the completion of material processing
- Berm soils staged as removal of silo contents progresses
- Clean, nonhazardous, solid waste from debris and equipment

Contaminated rubble and other debris will be dispositioned as part of Subunit C.

3.2.4.4 Alternative 3A- Removal, Stabilization, and Off-Site Disposal

A number of programmatic and waste specific considerations were factored into the development of alternatives for residue removal and off-site disposal options. The considerations included:

1. the need to adhere to waste acceptance criteria for the disposal facility including constituent specific leachability requirements;
2. the need to reduce or control radon emanation rates to meet disposal facility acceptance requirements; and
3. the need to reduce exposures during loading, transport, and disposal operations consistent with ALARA principles.

In accordance with these considerations, only alternatives which employed residue stabilization were considered. Waste stabilization, through cement stabilization or vitrification, accommodates these considerations by reducing the leachability of the metals to below waste acceptance thresholds,

attenuating radon emanation rates to ensure waste acceptance, and by reducing the volume (vitrification) or direct radiation (cement stabilization) to minimize exposures associated with the handling, transport, and disposal of the residues.

Description

This alternative requires removal of the Silos 1 and 2 contents and the decant sump tank sludge, stabilization of the contents by vitrification or cement stabilization, and off-site disposal of these stabilized materials. This alternative is identical to Alternative 2A with the exception that the on-property disposal, run-on/runoff control, monitoring, and access control technologies have been replaced by the transportation and off-site disposal technologies. Material would be disposed at the NTS or a hypothetical facility to be constructed within 483 km (300 mi) of the FEMP site. The material would be transported to the disposal facility by rail and/or truck. These disposal alternatives are discussed separately as Alternatives 3A.1 and 3A.2, respectively. Figure 3-12 provides a conceptual flow diagram for of these two alternatives.

The additional process options for this alternative's technologies are described as follows.

Material Transportation

- Rail/truck transport - The FEMP site can support rail transport to either disposal facility by using existing on-property rail spurs. A rail spur can be built at the off-site disposal facilities, or, in the case of NTS, a combination of rail and truck transport can be used around the facilities. Truck transport can offer portal-to-portal service with the road system available at the FEMP site. Improvements to the existing road system at the FEMP site may be required to accommodate the increased truck activity.

Off-Site Disposal

- NTS - The stabilized material would be shipped to NTS for disposal. Waste material would be treated emphasizing stabilization technologies to the extent necessary to meet NTS waste acceptance criteria. All necessary approval and certifications would be received prior to shipment.

- New facility within 483 km (300 mi) - The stabilized material would be shipped to a facility to be constructed within 483 km (300 mi) of the FEMP site. The stabilized material and debris must meet the new facilities waste acceptance criteria.

These process options would be supported by a newly designed RTS and a material processing facility as described previously under Alternative 2A.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tons per day (tpd)
- Processing rate (stabilized product)
  - Cement stabilization - up to 40 tpd
  - Vitrification - up to 15 tpd
- Volume transported and disposed
  - Cement-stabilized product - approximately 18,000 m^3 (24,000 yd^3)
  - Vitrified product - approximately 2800 m^3 (3600 yd^3)

Remediation Time Frame

Site preparation, material processing facility construction, and material removal and processing equipment installation would take approximately three years. Removing, processing, and packaging the material would take an additional three years. The total remediation time for this alternative would be approximately six years. The material would be shipped and disposed as it is processed. All shipments are planned to be completed shortly after the material processing is completed.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 1.5 ha (3 acres) for vitrification and cementation.

Packaging/Transportation Requirements

The stabilized product would be poured directly into the disposal containers. The treated material would be transported by truck or rail/truck combination to NTS, or by rail or truck to the disposal facility built within 483 km (300 mi) of the FEMP site. The material would be held in an on-site staging area until proper release tests have been performed.

Waste Generated

- Wastewater from hydraulic removal (recycled where possible)
- Contact waste (anti-contamination clothing, gloves, HEPA filters, carbon adsorption media, etc.)
- Equipment not feasible to decontaminate
- Process water contained in the process piping at the completion of material processing

- Clean, nonhazardous, solid waste from debris and equipment
- Berm soils staged as removal of silo contents progresses

Contaminated rubble and other debris will be dispositioned as part of Subunit C.

Alternative 3A.1 - Removal, Stabilization, and Off-Site Disposal at NTS

Under Alternative 3A.1, treated material would be disposed off site at NTS, which is a DOE-owned facility that currently accepts LLRW from DOE facilities. It is located approximately 3541 km (2200 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 3A.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

Under Alternative 3A.2, off-site disposal would occur at an above-grade disposal vault to be constructed within 483 km (300 mi) of the FEMP site. This facility may be a centralized or regional DOE disposal facility. Material must meet the waste acceptance criteria for this facility when developed.

3.2.4.5 Alternative 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal

Description

This alternative requires removal of the Silos 1 and 2 contents and the decant sump tank sludge, chemical extraction of the radioactive and chemical constituents (high-activity component) from the material, stabilization of this extract residue by cement stabilization or vitrification, and on-property disposal of the stabilized high-activity component and the remaining low-activity component. This alternative uses the same technologies as those for Alternative 2A with the exception that the material undergoes a chemical extraction process before stabilization.

The proposed chemical treatment process would use an ethylenediaminetetraacetic acid (EDTA) leaching process to remove the high-activity component from the waste stream. This component would then be cement stabilized or vitrified. The material remaining after the high-activity component is extracted (the low-activity component) would not be treated further, although it may ultimately have to be stabilized. Both waste streams would then be disposed on property. The high-activity component and low-activity component would be disposed in an above-grade disposal vault with an inadvertent intrusion barrier (due to elevated levels of long-lived, alpha-emitting

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radionuclides). The chemical extraction process option is intended to reduce greatly the volume of material containing elevated levels of long-lived, alpha-emitting radionuclides. Figure 3-13 provides a conceptual flow diagram for this alternative.

The additional process options for this alternative's technologies are described as follows.

Chemical Treatment

- Chemical extraction - Chemical extraction would be accomplished with a multi-stage extraction process using an EDTA solution as the extractant. The Silos 1 and 2 contents would be removed from the silos as a slurry of 20 percent solids. The slurry would be pumped to the chemical extraction process where the solids will be separated from the slurry with a belt filter. The solids material would be transferred to a potassium chloride (KCl) soak tank to prepare them for a six-stage extraction with the EDTA solution. The slurry would be pumped from the KCl soak tank to a belt filter. Solids from the belt filter would drop into the stage extraction tank to be extracted with weak extract solution. The slurry would be recirculated from the Stage 1 extraction tank through a steam injector to maintain a temperature of 80°C (176°F). A slip stream of about 37.9 L/min (10 gpm) would be processed in the Stage 1 belt filter and the solids from this filter would drop into the Stage 2 extraction tank. Five more extractions would be performed in Stages 2 through 6 using the same technique as for Stage 1. EDTA would be conserved by reusing weak extract solutions from the last stages of the extraction process and by recovering EDTA through crystallization.

  Chemical extraction equipment would likely consist of a series of agitated batch tanks, precipitation tanks, and associated piping and hardware. The equipment would be remotely operated in a separate material processing building.

Material Stabilization

- Cement stabilization - The high-activity component would be stabilized in a cement stabilization process identical to that described for Alternative 2A with the exception that the stabilization additives are cement, flyash, clinoptilolite, and blast furnace slag.

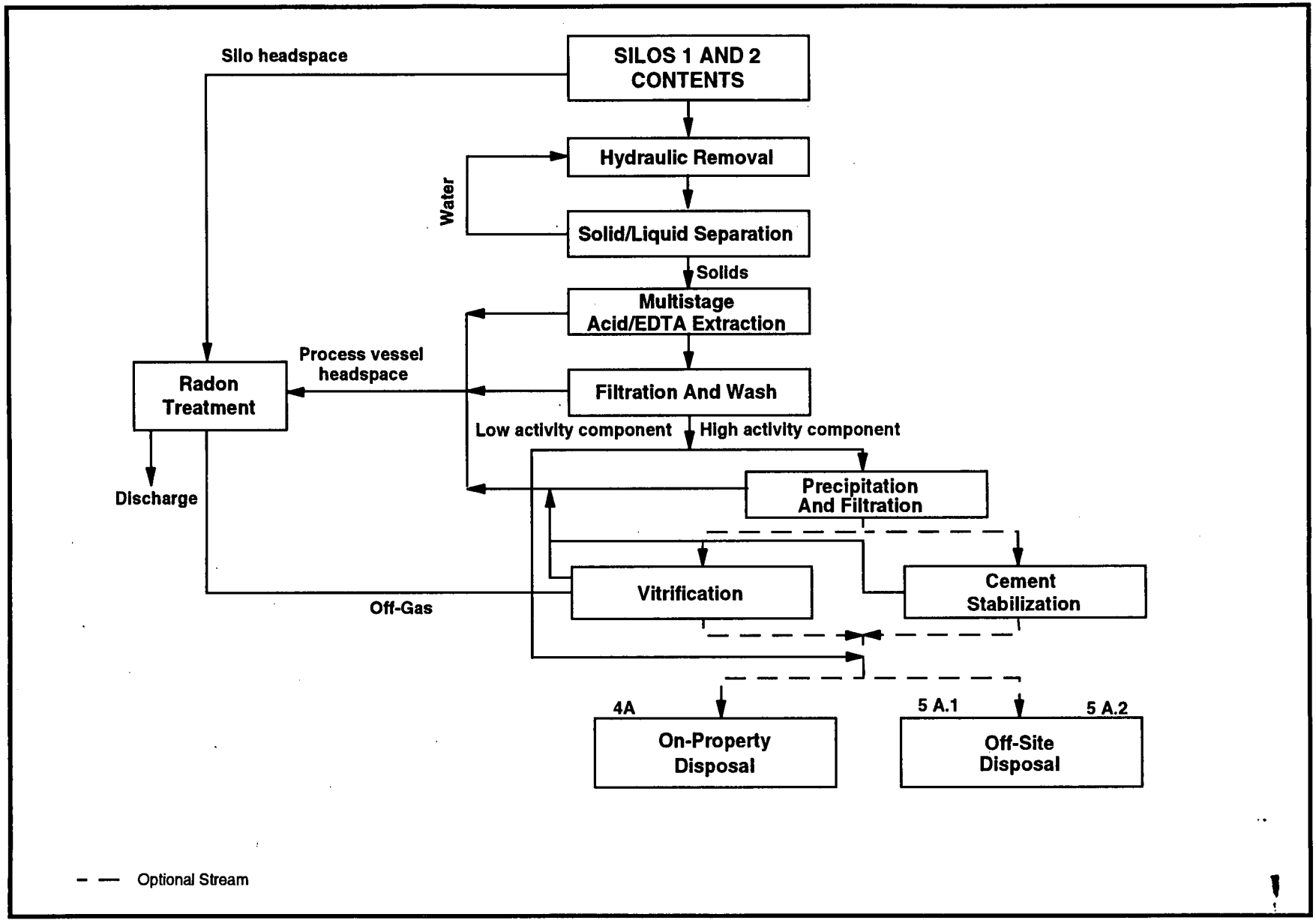
- Vitrification - The high-activity component would be stabilized in a vitrification process identical to that described for Alternative 2A with the exception that the vitrification additives are site flyash and soda ash.

These process options would be supported by a newly designed RTS and a material processing facility as described previously under Alternative 2A.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tpd



FERNALD\OU4\FIG3-5.DRW/RSS/8/24/93

FIGURE 3 - 13
ALTERNATIVES 4A, 5A - REMOVAL, CHEMICAL EXTRACTION, STABILIZATION, DISPOSAL CONCEPTUAL FLOW DIAGRAM

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- Processing rate (treated product)
  - Vitrification (high-activity component) - up to 5 tpd
  - Cement stabilization (high-activity component) - up to 40 tpd
  - Low-activity component - up to 25 tpd

- Volume disposed
  - Vitrified product - approximately 340 m^3 (440 yd^3)
  - Cement-stabilized product - approximately 7600 m^3 (10,000 yd^3)
  - Low-activity component - approximately 7400 m^3 (9700 yd^3)

Remediation Time Frame

Site preparation, material processing facility construction, and material removal and processing equipment installation would take approximately three years. Removal of the material, chemical extraction, stabilization, and packaging would take an additional three years. The total remediation time for this alternative would be approximately six years. During site preparation, facility construction, and equipment installation, the on-property disposal facility would be built.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is 5 ha (12 acres) for vitrification and 5.5 ha (13 acres) for cementation. The area of the disposal vault would be approximately 3 ha (8 acres) for vitrification and 4 ha (10 acres) for cementation.

Packaging/Transportation Requirements

The on-property disposal facilities would accept only stabilized and/or rigidly containerized material. The stabilized material would be poured directly into DOT specification 7A Type A or strong tight containers.

Waste Generated

- Wastewater from hydraulic removal (recycled where possible)
- Contact waste (anti-contamination clothing, gloves, carbon absorbers, dehumidification media, HEPA filters, etc.)
- Equipment not feasible to decontaminate
- Secondary wastewater streams from the chemical extraction process
- Clean, nonhazardous, solid waste from debris and equipment

- Berm soils staged as removal of silo contents progresses

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Contaminated rubble and other debris will be dispositioned as part of Subunit C.

3.2.4.6 Alternative 5A - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal Description

This alternative requires removal of the Silos 1 and 2 contents and the decant sump tank sludge, chemical extraction of significant quantities of radioactive and chemical constituents (high-activity component) from the material, stabilization of this extract residue by cement stabilization or vitrification, and off-site disposal of the stabilized high-activity component and the remaining low-activity component. This alternative is identical to Alternative 4A with the exception that the on-property disposal, run-on/runoff control, monitoring, and access control technologies have been replaced by the material transportation and off-site disposal technologies. Material would be disposed at NTS or a facility to be constructed within 483 km (300 mi) of the FEMP site. The material would be transported to the disposal facility by rail and/or truck. These disposal alternatives are discussed separately as Alternatives 5A.1 and 5A.2, respectively.

The additional process options for this alternative's technologies are described as follows.

Material Transportation

- Rail/truck transport - The FEMP site can support rail transport to either disposal facility by using existing on-property rail spurs. A rail spur can be built at the off-site disposal facility, or, in the case of NTS, a combination of rail and truck transport can be used around the facility. Truck transport can offer portal-to-portal service with the road system available at the FEMP site. Improvements to the existing road system at the FEMP site may be required to accommodate the increased truck activity.

Off-Site Disposal

- NTS - The stabilized material would be shipped to NTS for disposal. Waste material would be treated to the extent necessary to meet the NTS waste acceptance criteria. All necessary approvals and certifications would be received prior to shipping.

- New facility within 483 km (300 mi) - The stabilized material would be shipped to an above-grade disposal vault facility to be constructed within 483 km (300 mi) of the FEMP site. The stabilized material and debris must meet the new facility's waste acceptance criteria when developed.

These process options would be supported by a newly designed RTS and a material processing facility as described previously under Alternative 2A.

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Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tpd

- Processing rate (treated product)
  - Vitrification (high-activity component) - up to 5 tpd
  - Cement stabilization (high-activity component) - up to 40 tpd
  - Low-activity component - up to 25 tpd

- Volume transported and disposed
  - Vitrified product - Approximately 340 m^3 (440 yd^3)
  - Cement-stabilized product - Approximately 7600 m^3 (10,000 yd^3)
  - Low-activity component - Approximately 7400 m^3 (9700 yd^3)

Remediation Time Frame

Site preparation, material processing facility construction, and material removal and processing equipment installation would take approximately three years. Removing, processing, and packaging the material would take an additional three years. The total remediation time for this alternative would be approximately six years.

Spatial Requirements

Overall area at the FEMP required for implementation of this alternative is approximately 1.5 ha (3 acres) for both vitrification and cementation.

Packaging/Transportation Requirements

The packaging option selected for the high-activity component and low-activity component is DOT specification 7A Type A or strong tight container.

The material would be shipped by truck or rail/truck combination to NTS, or by rail or truck to the disposal facility to be constructed within 483 km (300 mi) of the FEMP site. The material would be held in an on-site staging area until proper release tests have been performed.

Waste Generated

- Wastewater from hydraulic removal (recycled where possible)

- Contact waste (anti-contamination clothing, gloves, carbon absorbers, dehumidification media, HEPA filters, etc.)

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- Equipment not feasible to decontaminate
- Secondary wastewater streams from the chemical extraction process
- Clean, nonhazardous, solid waste from debris and equipment
- Berm soils staged as removal of silo contents progresses

Contaminated rubble and other debris will be dispositioned as part of Subunit C.

Alternative 5A.1 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at NTS

Under Alternative 4A.1, material would be disposed off site at NTS, which is a DOE-owned facility that currently accepts LLRW from DOE facilities. It is located approximately 3541 km (2200 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 5A.2 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

Under Alternative 4A.2, material would be disposed off site at an above-grade disposal vault to be constructed within 483 km (300 mi) of the FEMP site. This facility may be a centralized or regional DOE disposal facility to be developed later. Material must meet the waste acceptance criteria for this facility when developed.

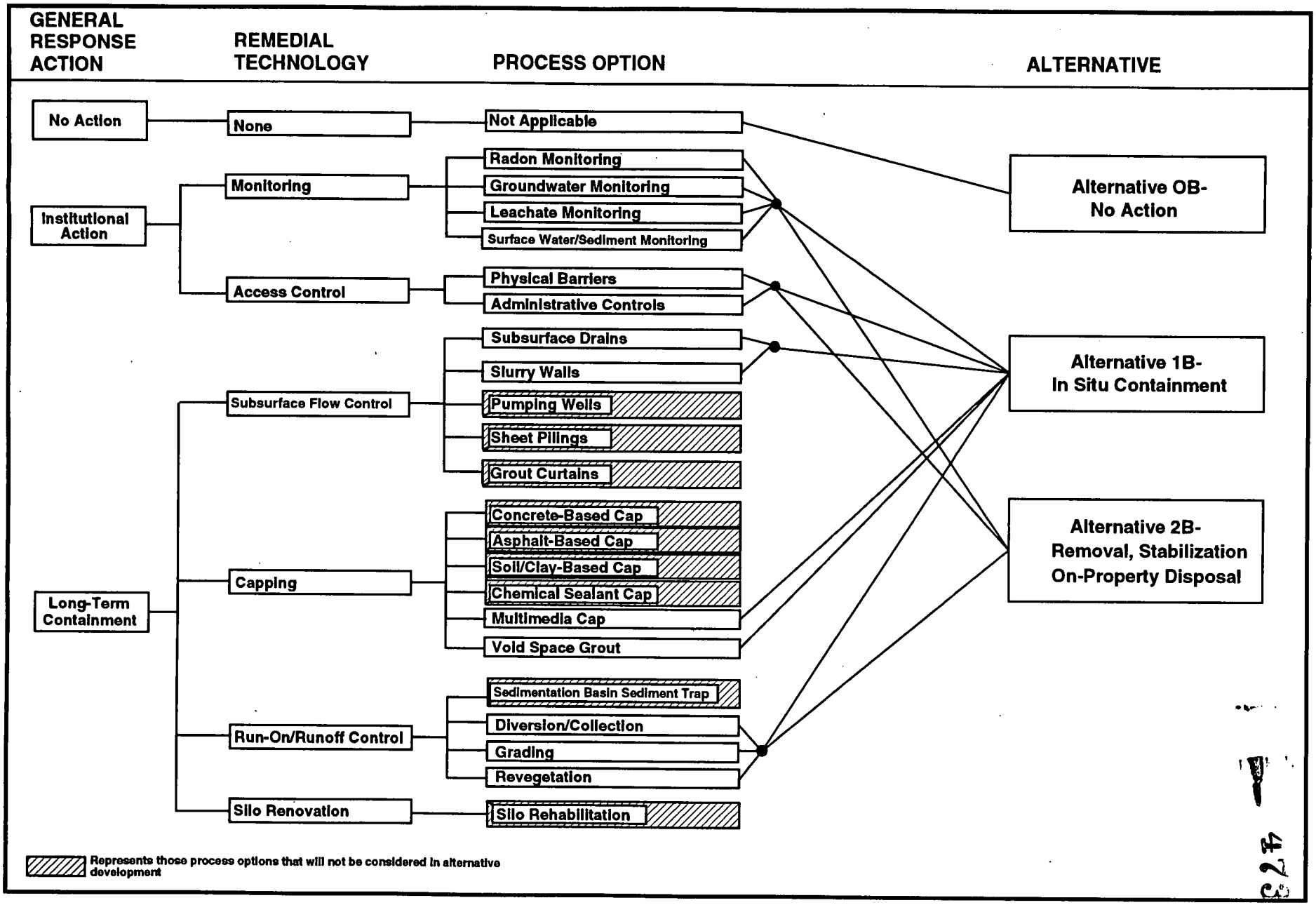
3.2.5 Subunit B Preliminary Alternatives

Figure 3-14 outlines the development of Subunit B preliminary alternatives. Narrative discussion of the alternative development follows.

3.2.5.1 Alternative 0B - No Action

Description

The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action would be taken and the material is considered to be left "as is," without the implementation of any containment, removal, treatment, or other mitigating actions. This alternative does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and does not provide for active or passive institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).



FERNALD\OU4\FIG3-6.DRW/BJD/7/29/93

FIGURE 3-14
SUBUNIT B
DEVELOPMENT OF ALTERNATIVES

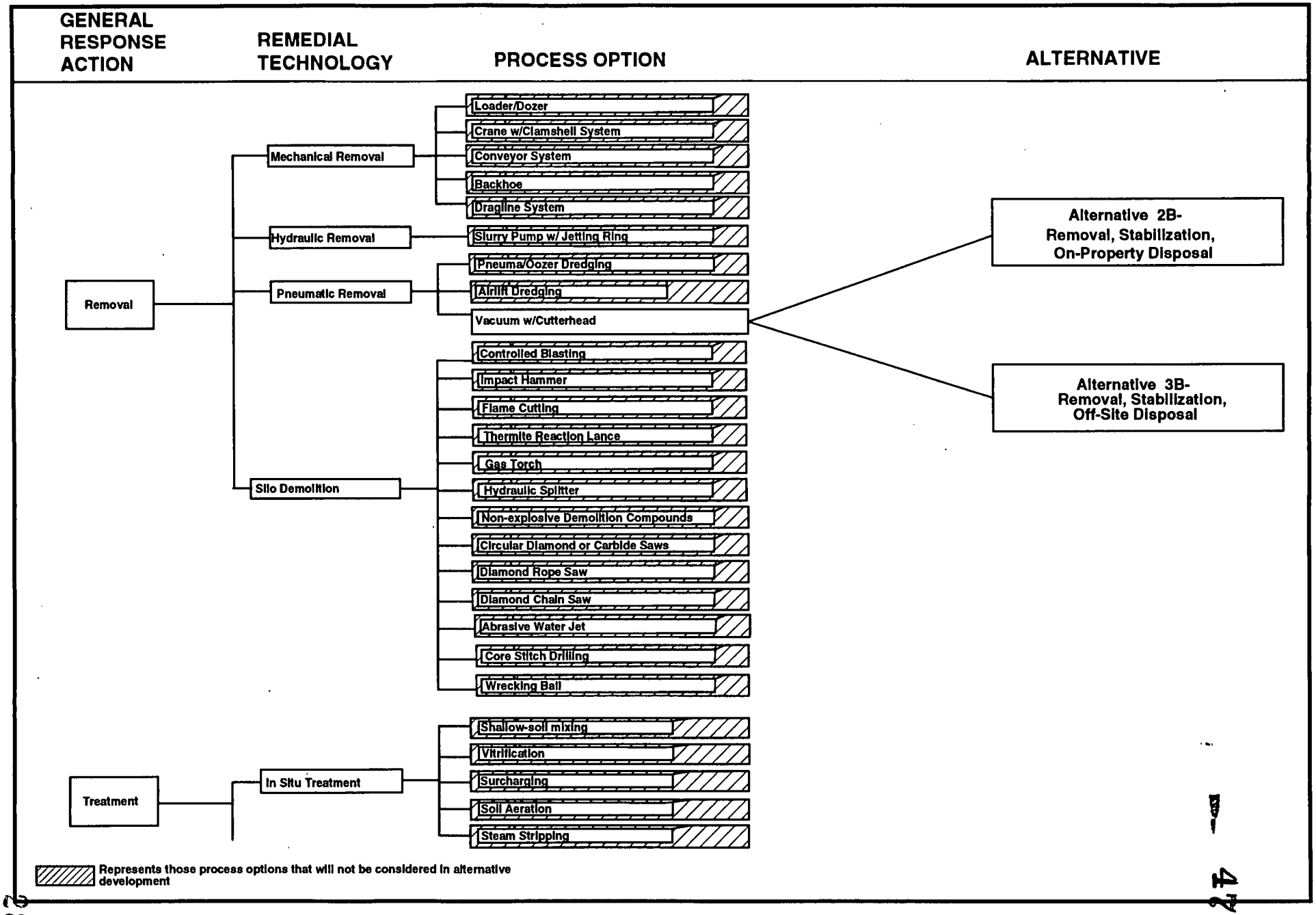


FIGURE 3-14
(Continued)

FERNALD\OU4\FIG3-6A.DRW/RSS/8/24/93

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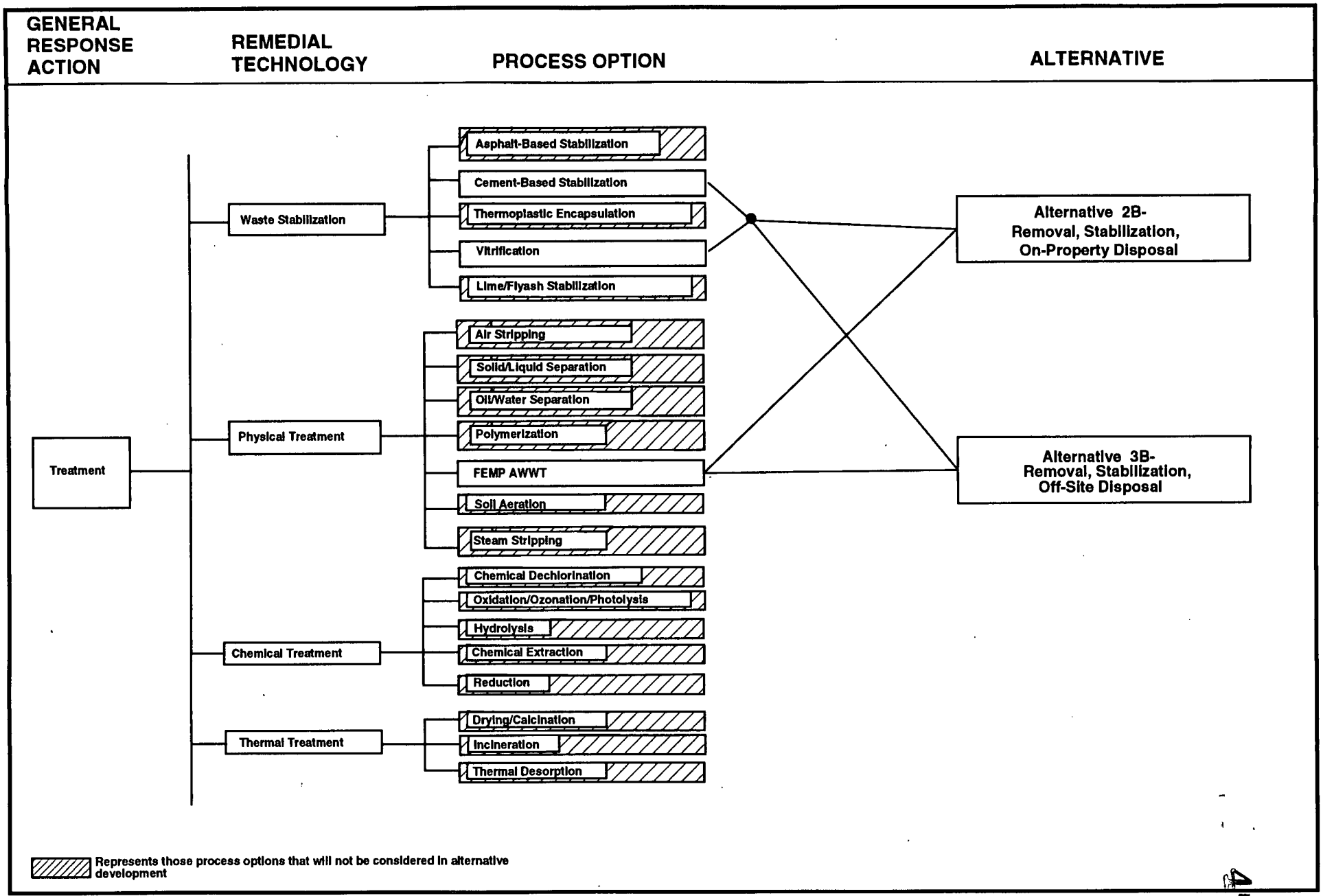

FIGURE 3-14
(Continued)

FERNALD\OU4\FIG3-6B.DRW/RSS/8/24/93

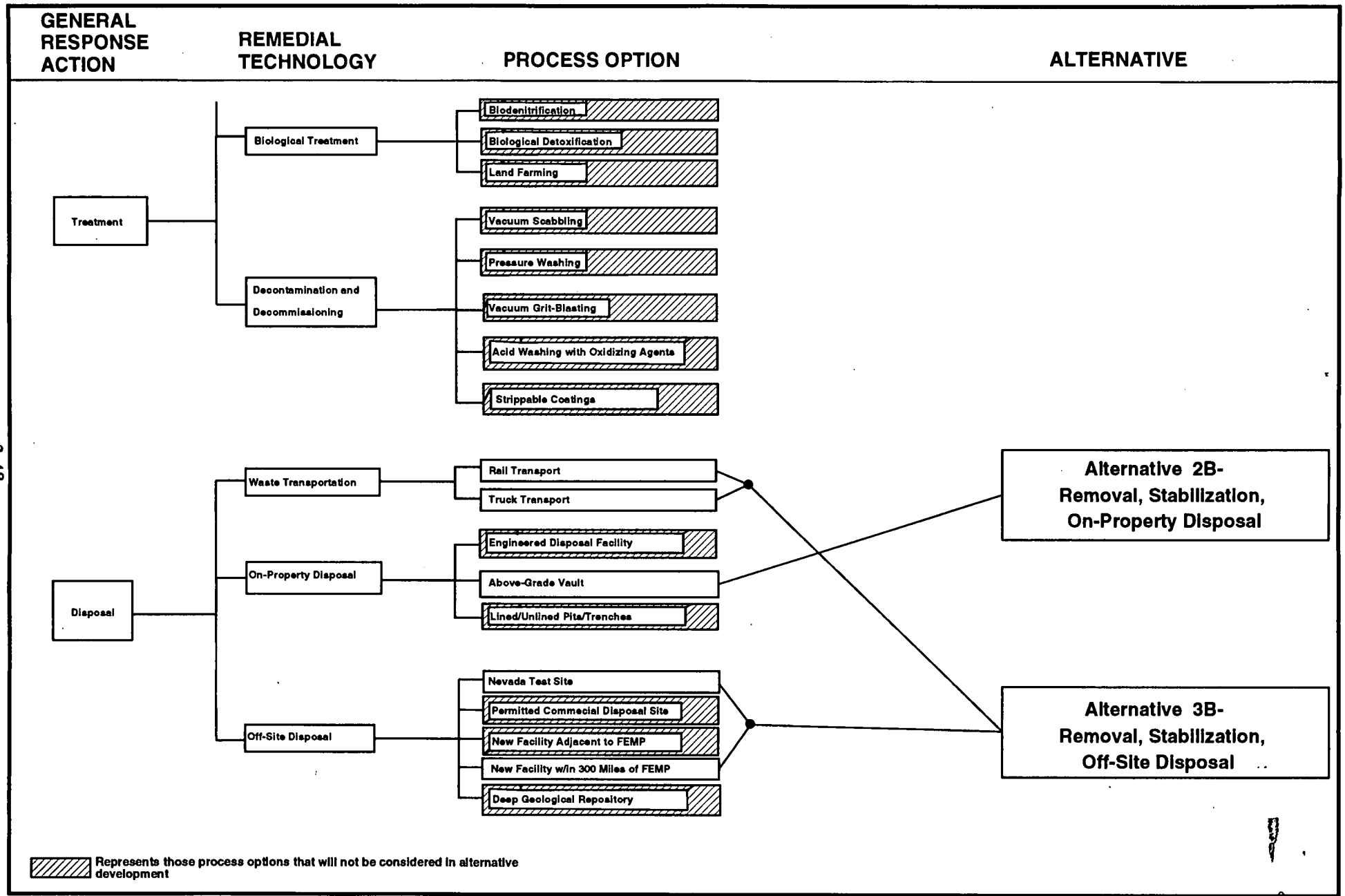

FIGURE 3-14
(Continued)

FERNALD\OU4\FIG3-6C.DRW/RSS/8/24/93

3.2.5.2 Alternative 1B - In Situ Containment

Description

This containment alternative for the Silo 3 contents is intended to isolate the silo contents from the environment and to minimize the generation and release of contaminated leachate to the underlying Great Miami Aquifer. The technologies implemented by this alternative are subsurface flow control, capping, run-on/runoff control, monitoring, and access control. This alternative includes introducing structural grout into the silo void spaces, installing an LC/DS beneath the silos, building a slurry wall around the silos, relocating Paddys Run, and constructing a multimedia cap over the silos. Figure 3-15 provides a conceptual flow diagram for this alternative.

The process options selected for this alternative's technologies are described as follows:

Subsurface Flow Control

- Subsurface drains - A basic LC/DS would be installed underneath the silo before the cap is installed. The system would consist of slotted piping inserted underneath the silo and connected to leachate extraction wells.

- Slurry Walls - To divert groundwater flow around the silo, a soil-bentonite slurry wall will be constructed along three sides of the perimeter of Silos 1 and 2 and will extend into the sand/gravel layer of the Great Miami Aquifer. The bentonite will be obtained commercially and mixed on property with existing acceptable soils to produce a 0.9-m (3-ft) wide slurry wall with an approximate depth of 15.2 m (50 ft). The purpose of the slurry wall is to prevent any leachate that may be generated from migrating laterally to Paddy's Run.

Capping

- Silo void space grout - Structural grout would be introduced into the silo through the manways to fill the silo void space. This grout would minimize the possibility for silo dome to subside under the weight of the multimedia cap during construction and after the cap is installed. A local containment device (i.e., glove bag) would be used at the grout injection piping/silo dome interface to mitigate contaminant release during grout injection. A temporary batch plant would be used to provide the required structural grout.

- Multimedia cap - A multimedia cap would be installed to minimize the infiltration of rainwater into the silo. The cap would consist of the following elements to control erosion and minimize leachate generation as a result of rainwater infiltration.

  - Upper vegetative layer

  - Drainage layer

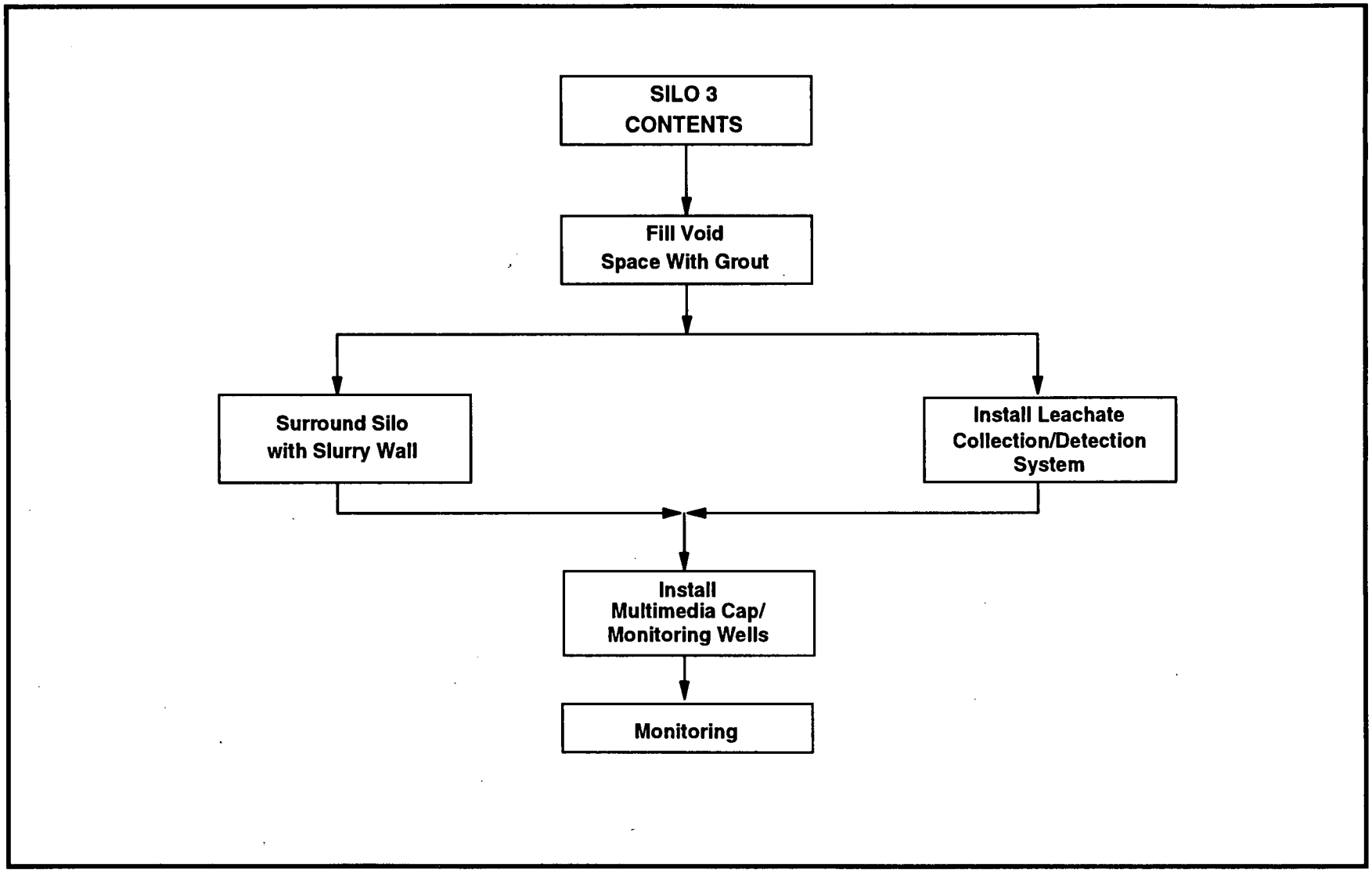

FIGURE 3 - 15
ALTERNATIVES 1B - IN SITU CONTAINMENT
CONCEPTUAL FLOW DIAGRAM

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- Low permeability clay layer with a maximum vertical permeability of 1×10^{-7} cm/s

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- Geomembrane layer of 40 mil minimum thickness

The spatial requirements for the multimedia cap would require the partial relocation of Paddys Run to minimize the possibility of lateral erosion.

Run-on/Runoff Control

- Diversion/collection - The area around the cap may contain small berms, channels, and waterways to redirect runoff.
- Grading - The area around the cap would be contoured or graded to redirect and control runoff.
- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon monitoring - Radon monitors would be installed around the disposal facility containing the material to detect radon that emanates from the facility.
- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the cap and sampled routinely to monitor containment system performance.
- Leachate monitoring - The installed LC/DS would be routinely checked to monitor the cap performance.
- Surface water/sediment monitoring - The surface water and sediment near the cap will be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.
- Administrative controls - Access to the site would be confined to authorized personnel. Permanent physical markers would also be used to identify disposal areas. The need or requirement for the application of long-term administrative controls will be examined in the Detailed Analysis phase.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process.

- Slurry wall - less than 300 m (1000 ft) long x 15 m (50 ft) deep

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- Monitoring wells - 6 nests/4 wells per nest
- Grout injection - less than 750 m^3 (1,000 yd^3)

Remediation Time Frame

Remediation would take approximately two years from the initial staging of construction equipment to the final capping and isolation of the silo.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 3 ha (7.5 acres). Approximately 2 ha (5 acres) would be used by the cap.

Packaging/Transportation Requirements

The only identified transportation requirement is shipping the grout, bentonite, and bentonite closure materials to the site.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, HEPA filters, etc.)
- Equipment not feasible to decontaminate
- Clean, nonhazardous, solid waste from equipment and debris

Contaminated rubble and other debris will be dispositioned as part of Subunit C.

3.2.5.3 Alternative 2B - Removal, Stabilization, and On-Property Disposal

As a consequence of the elevated leachability of select radionuclides and other heavy metals in the Subunit B residues, all alternatives developed for on-site disposal alternatives employ the use of a stabilization technology. The goal of this stabilization process is to reduce leachability below regulatory limits applicable to land disposal and as necessary to ensure the protection of human health and the environment.

Description

This alternative requires removal of the Silo 3 contents, stabilization of the contents by vitrification or cement stabilization, and on-property disposal of the stabilized material. The technologies implemented by this alternative are pneumatic removal, material stabilization, on-property disposal, physical treatment, run-on/runoff controls, monitoring, and access controls.

The silo contents would be removed with a pneumatic device introduced through the silo domes. This equipment would be supported by a work platform that will span the silo. The material would then be pneumatically conveyed to a material processing facility for cement stabilization or vitrification. The stabilized material would then be disposed in an above-grade disposal vault. Figure 3-16 provides a conceptual flow diagram for this alternative.

The process options selected for this alternative's technologies are described as follows:

Pneumatic Removal

- Vacuum with cutterhead - The silo contents would be removed with a vacuum and cutterhead device. The device would be supported by a work platform placed over the silo and would be introduced into the silos through the four perimeter manways and the off-center manway. The device consists of a cutterhead that would dislodge the material and a vacuum nozzle that would pneumatically remove the material.

  A glove bag would be used at the interface of the silo domes and would, in conjunction with the silo domes, function as the silo containment system.

Treatment

- Material stabilization - The silo contents would be stabilized by vitrification or cement stabilization. The vitrification process would add silica, alumina, and borate to produce a monolithic glass product with excellent wear and leach characteristics. The process would use additive storage silos, an additive and material slurry mixer, a glass melter, a fume hood/cap, and an off-gas treatment system. The cement stabilization system would add cement, flyash, and blast furnace slag to the material slurry to provide a monolithic concrete product with very good wear and leach characteristics. The majority of the water used in removing the material would be used in the cement stabilization process. The process would require additive storage silos, screw feeders, and an additive/material slurry mixer.

On-Property Disposal

- Above-grade disposal vault - The resultant stabilized material would be disposed in an above-grade disposal vault. This facility would use an LC/DS, a multimedia cap, and a multilayered lining system.

Run-on/Runoff Control

- Diversion/collection - The area around the cap may contain small berms, channels, and waterways to redirect runoff.

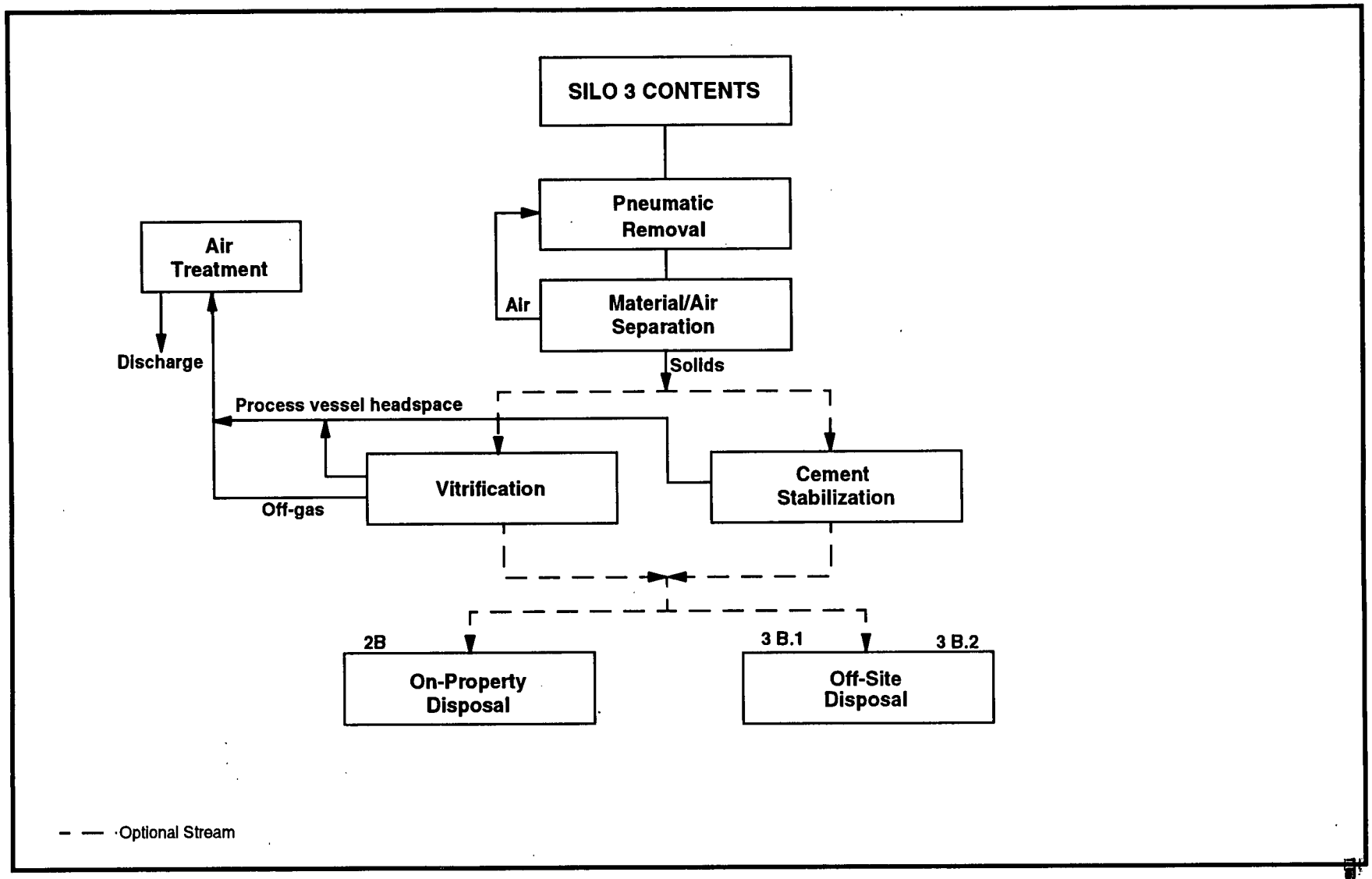

FIGURE 3 - 16
ALTERNATIVES 2B, 3B - REMOVAL, TREATMENT, DISPOSAL
CONCEPTUAL FLOW DIAGRAM

FERNALD\OU4\FIG3-8.DRW/RSS/08/24/93

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- Grading - The area around the cap would be contoured or graded to redirect and control runoff.

- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon monitoring - Radon monitors would be installed around the disposal facility containing the stabilized material to detect radon that emanates from the facility.

- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the facility and sampled routinely to monitor containment system performance.

- Leachate monitoring - The installed LC/DSs would be routinely checked to monitor the facility's performance.

- Surface water/sediment monitoring - The surface water and sediment near the disposal facility will be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.

- Administrative controls - Site access would be confined to authorized personnel during implementation of remedial activity. Permanent physical markers would be used. The need for long-term administrative controls will be addressed during the Detailed Analysis phase.

These process options would be supported by a local containment at the point of silo entry, a material processing facility, and the AWWT facility.

Size and Configuration

The following are estimates based upon data available during the initial screening process.

- Removal rate - 10 to 15 tpd

- Processing rate
  - Cement stabilization - up to 40 tpd
  - Vitrification - up to 15 tpd

- Volume disposed
  - Cement-stabilized product - less than 6000 m^3 (7,900 yd^3)
  - Vitrified product - less than 1,500 m^3 (1,900 yd^3)

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Remediation Time Frame

Site preparation, construction of the material processing facility, and the installation of the material removal and material processing equipment would take approximately three years. Removing,processing, and packaging the material would take an additional year. The total remediation time for this alternative will be approximately four years. During this time, the on-property disposal facility would be constructed.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 4 ha (10 acres) for vitrification and 4.5 ha (11 acres) for cementation. The area of the disposal vault would be approximately 2.5 ha (6 acres) for vitrification and approximately 3 ha (7.5 acres) for cementation.

Packaging/Transportation Requirements

The on-property disposal facility would accept only stabilized and/or rigidly containerized material. The cement stabilized or vitrified material would be poured directly into DOT specification 7A Type A or strong tight containers.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, carbon absorbers, dehumidification media, HEPA filters, etc.)
- Equipment not feasible to decontaminate
- Clean, nonhazardous, solid waste from equipment and debris

Contaminated rubble or other debris will be dispositioned as part of Subunit C.

3.2.5.4 Alternative 3B - Removal, Stabilization, and Off-Site Disposal

In order to attain waste acceptance criteria at the off-site disposal facility pertaining to the leachability of heavy metals, all alternatives developed for Subunit B involving off-site disposal include a waste stabilization processing step.

Description

This alternative requires removal of the Silo 3 contents, and off-site disposal of these materials. This alternative is identical to Alternative 2B with the exception that the on-property disposal, run-on/runoff controls, monitoring, and access control technologies have been replaced by the

transportation and off-site disposal technologies. Material disposal would be at NTS or a facility to be constructed within 483 km (300 mi) of the FEMP site. The material will be shipped to the disposal facility by rail or truck. These disposal alternatives are discussed separately as Alternatives 3B.1 and 3B.2, respectively.

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The process options for this alternative's additional technologies are described as follows:

Waste Transportation

- Rail/truck transport - The FEMP site can support rail transport to either disposal facility by using an existing on-property rail spur. A rail spur can be built at the off-site disposal facility, or a combination of rail and truck transport can be used around the facility. Truck transport can offer portal-to-portal service with the road system available at the FEMP site. Improvements to the existing road system in the vicinity of the FEMP site may be required to accommodate the increased truck activity.

Off-Site Disposal

- NTS - The stabilized material would be shipped to NTS for disposal. Stabilized material would be treated to meet the NTS waste acceptance criteria. All necessary approvals and certifications would be received prior to shipping.

- New facility within 483 km (300 mi) - The stabilized material would be shipped to a facility to be built within 483 km (300 mi) of the FEMP site. The stabilized material must meet the new facility's waste acceptance criteria when developed.

These process options will be supported by a local containment at the point of silo entry, a material processing facility, and the FEMP AWWT facility.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Removal rate - 10 to 15 tpd

- Processing rate (stabilized product)
  - Cement stabilization - up to 40 tpd
  - Vitrification - up to 15 tpd

- Volume transported and disposed
  - Cement-stabilized product - less than 6000 m^3 (7,900 yd^3)
  - Vitrified product - less than 1,500 m^2 (1,900 yd^3)

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Remediation Time Frame

Site preparation, construction of the material processing facility, and the installation of the material removal and material processing equipment would take approximately three years. Removing, processing, and packaging the material would take an additional year. The total remediation time for this alternative would be approximately four years.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 1.5 ha (3 acre) for vitrification and cementation.

Packaging/Transportation Requirements

The stabilized Silo 3 contents would be shipped in DOT specification 7A Type A or strong tight containers. The material would be transported by truck or rail/truck combination to NTS, or by rail or truck to the disposal facility proposed to be built within 483 km (300 mi) of the FEMP site. The material will be held in an on-site staging area until proper release tests have been performed.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, carbon absorbers, dehumidification media, HEPA filters, etc.)
- Equipment not feasible to decontaminate
- Clean, nonhazardous, solid waste from equipment and debris

Contaminated rubble or other debris will be dispositioned as part of Subunit C.

Alternative 3B.1 - Removal, Stabilization, and Off-Site Disposal at NTS

Under Alternative 3B.1, material would be disposed off site at NTS. NTS is a DOE-owned facility that currently accepts LLRW from DOE facilities. It is located approximately 3541 km (2200 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 3B.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

Under Alternative 3B.2, material would be disposed off site at an above-grade disposal vault to be constructed within 483 km (300 mi) of the FEMP site. This facility may be a centralized or regional

DOE disposal facility to be developed later. Material must meet the waste acceptance criteria for this facility when developed.

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3.2.6 Subunit C Preliminary Alternatives

The alternatives presented for this subunit (except no action) would be combined with subunit A and B alternative that remove the silo contents and the berms surrounding Silos 1 and 2. Also, the berms will have been assayed and segregated with the contaminated berm placed in DOT specification 7A Type A, or strong tight containers and the clean berm available as clean fill. The in place containment alternative for Subunits A and B would preclude selection of a Subunit C alternative since the cap would cover Subunit C components.

Figure 3-17 outlines the development of Subunit C preliminary alternatives. Narrative discussion of the alternatives development follows.

3.2.6.1 Alternative 0C - No Action

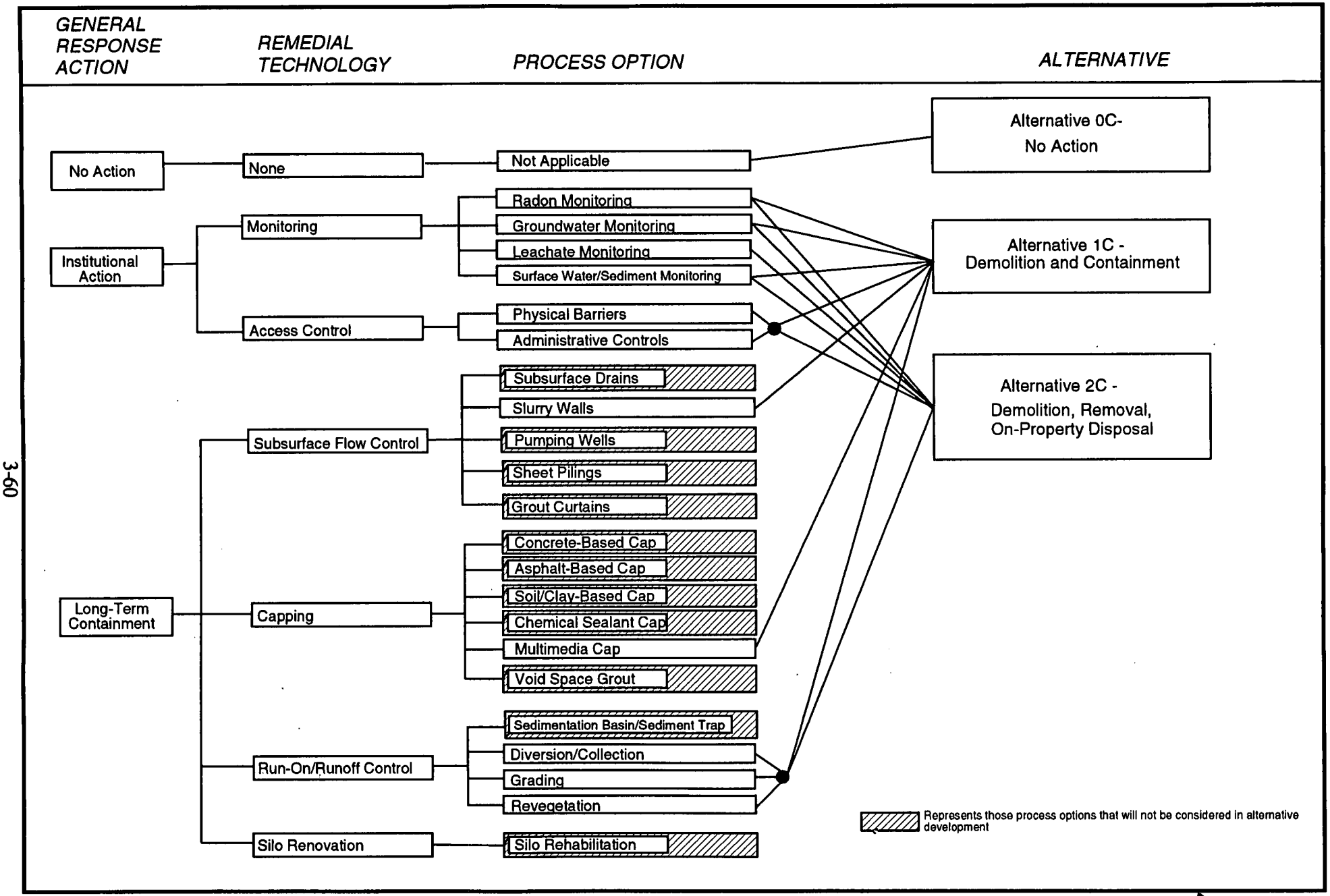
Description

The no-action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken and the material is considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. This alternative does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and does not provide for active or passive institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

3.2.6.2 Alternative 1C - Demolition and Containment

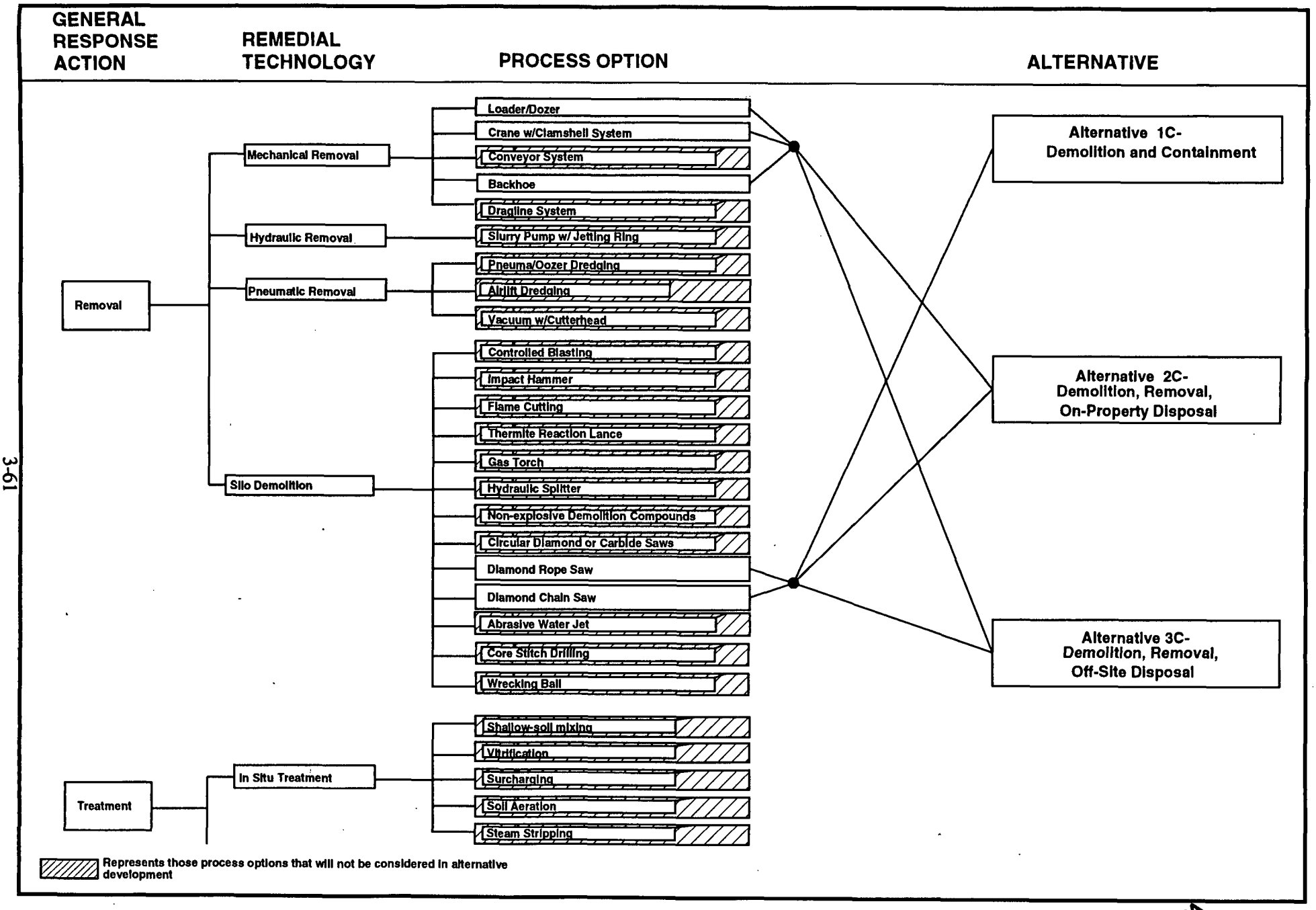
Description

This treatment/containment alternative involves demolition, decontamination, and containerization of the Silos 1, 2, 3, and 4 structures, the existing RTS for Silos 1 and 2, disposition of any contaminated rubble or debris generated during implementation of Subunit A and B alternatives, placement of the containerized silo rubble and previously containerized contaminated berm in the former location of Silos 1 and 2, and the placement of a multimedia cap over the material. The surface soil within the Operable Unit 4 boundary would be removed to meet the soil PRGs. For the purpose of the initial screening process, the soil is assumed to be removed such that: the Silo 1 and 2 berms are removed entirely; surface soils within the Operable Unit 4 boundary are removed to a depth of 15 cm (6 in); and soils beneath Silo 1 and 2 and the decant sump are removed to a depth of five feet. The



FERNALDOU4\FIG3-9.DRW/RSS/8/24/93

FIGURE 3-17
SUBUNIT C
DEVELOPMENT OF ALTERNATIVES



FERNALD\OU4\FIG3-9A.DRW/RSS/8/24/93

FIGURE 3-17
(Continued)

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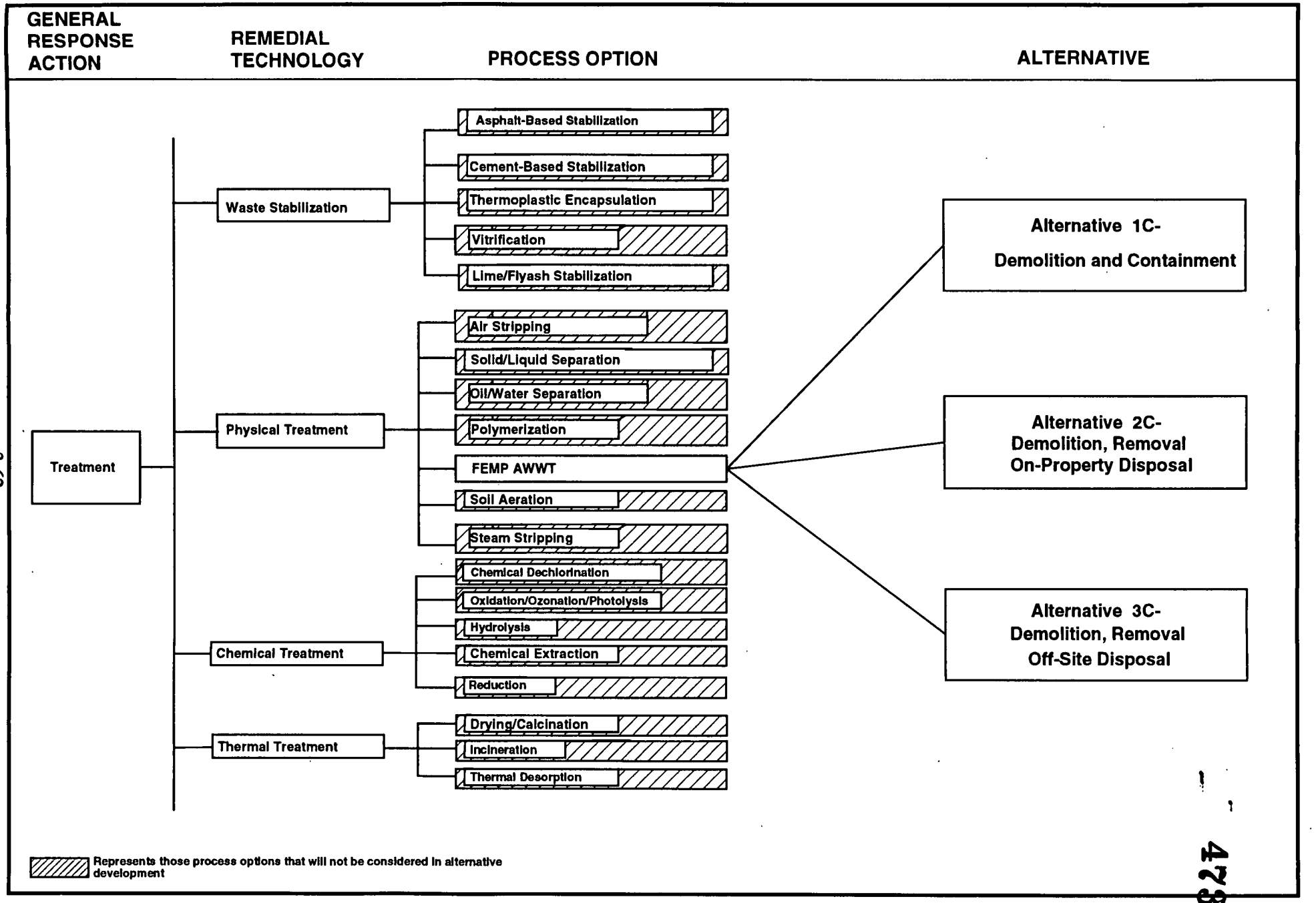

FIGURE 3-17
(Continued)

FERNALD\OU4\FIG3-9B.DRW/RSS/8/24/93

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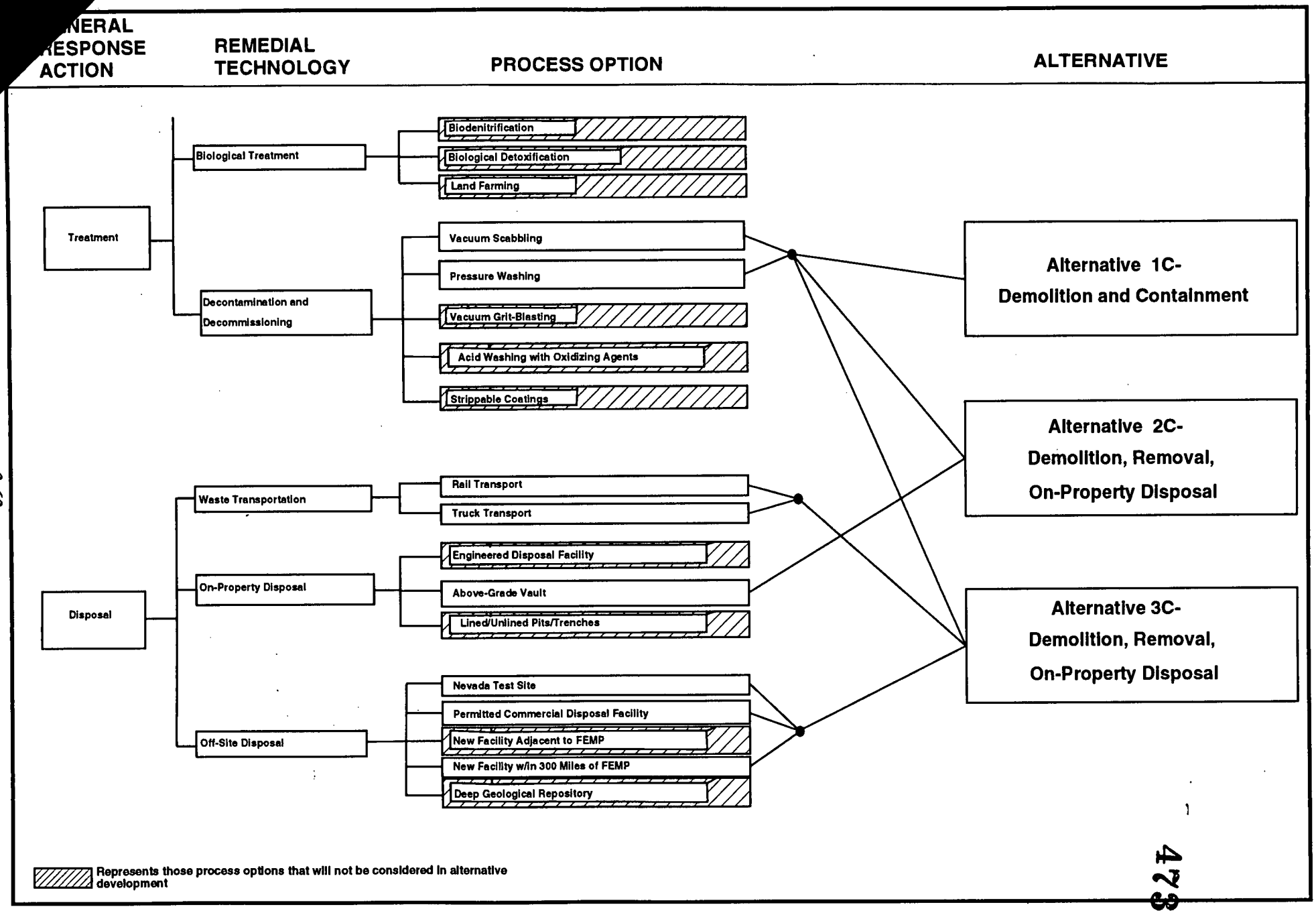

FIGURE 3-17
(Continued)

FERNALD\OU4\FIG3-9C.DRW/RSS/8/24/93

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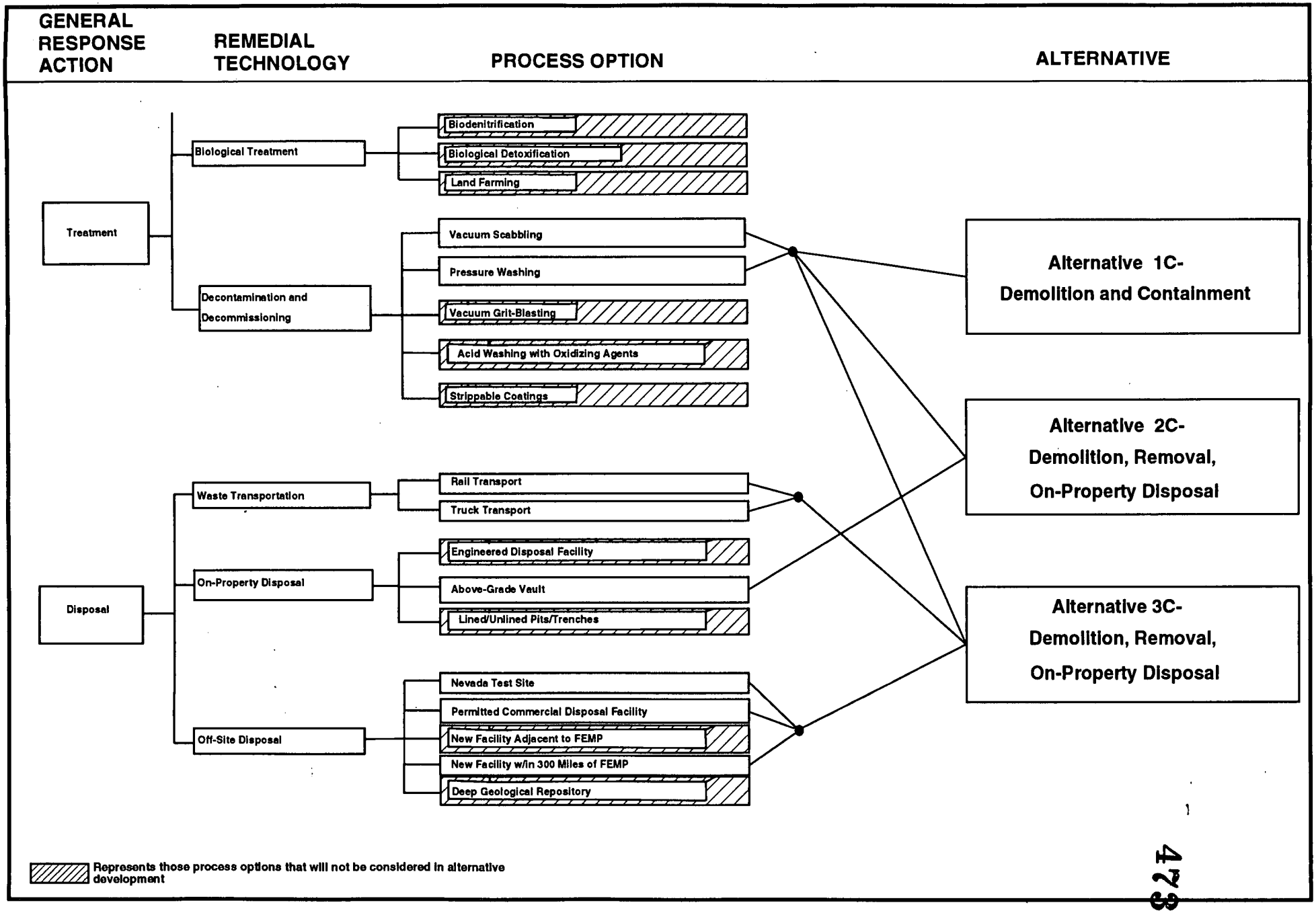

FIGURE 3-17
(Continued)

FERNALD\OU4\FIG3-9C.DRW/RSS/8/24/93

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technologies implemented by this alternative are silo demolition, concrete decontamination, subsurface flow control capping, run-on/runoff control, monitoring, and access controls.

This alternative assumes that the silos' contents and the berms have been removed under Subunits A and B. Once the silo contents have been removed, the silo structures would be characterized both structurally and radiologically. Data from the structural characterization would be used to determine the safest approach to demolition, and data from the radiological characterization would be used to determine the depths to which the concrete must be removed to facilitate decontamination (if viable). Any concrete and debris generated during remediation which meets the free release criteria, as developed and presented in the RD/RA work plan, would be disposed in a solid waste/sanitary landfill. The subsurface soil, decant sump tank, and process piping and trenches would not be removed in this alternative, although they would be covered by the multimedia cap. Any water remaining in the decant sump tank would be evacuated and the tank would be filled with grout before capping to prevent future infiltration of water into the tank. Any facilities constructed to temporarily support remediation in Operable Unit 4 will be decontaminated and demolished. Figure 3-18 provides a conceptual flow diagram for this alternative.

The process options for this alternative's technologies are described as follows:

Subsurface Flow Control

- Slurry wall around the silo area - To divert groundwater flow around the former silo area, a soil-bentonite slurry wall will be constructed along three sides of the perimeter of Silos 1, 2 and 3 and will extend into the sand/gravel layer of the Great Miami Aquifer. The bentonite will be obtained commercially and mixed on property with existing acceptable soils to produce a 0.9-m (3-ft) wide slurry wall with an approximate depth of 15.2 m (50 ft).

Silo Demolition

- Diamond rope/chain saw - A diamond wire rope saw would be used to cut the silo domes into sections for removal. Cranes would be used to remove the cut sections of the dome and to support the remaining dome. The cut sections of the dome would be lifted to the decontamination and packaging pad for decontamination and size reduction, and packaging. The silo walls would be cut into sections with the diamond chain saw and lifted to the pad with the crane for similar treatment. The silo floors and footers would remain in place.

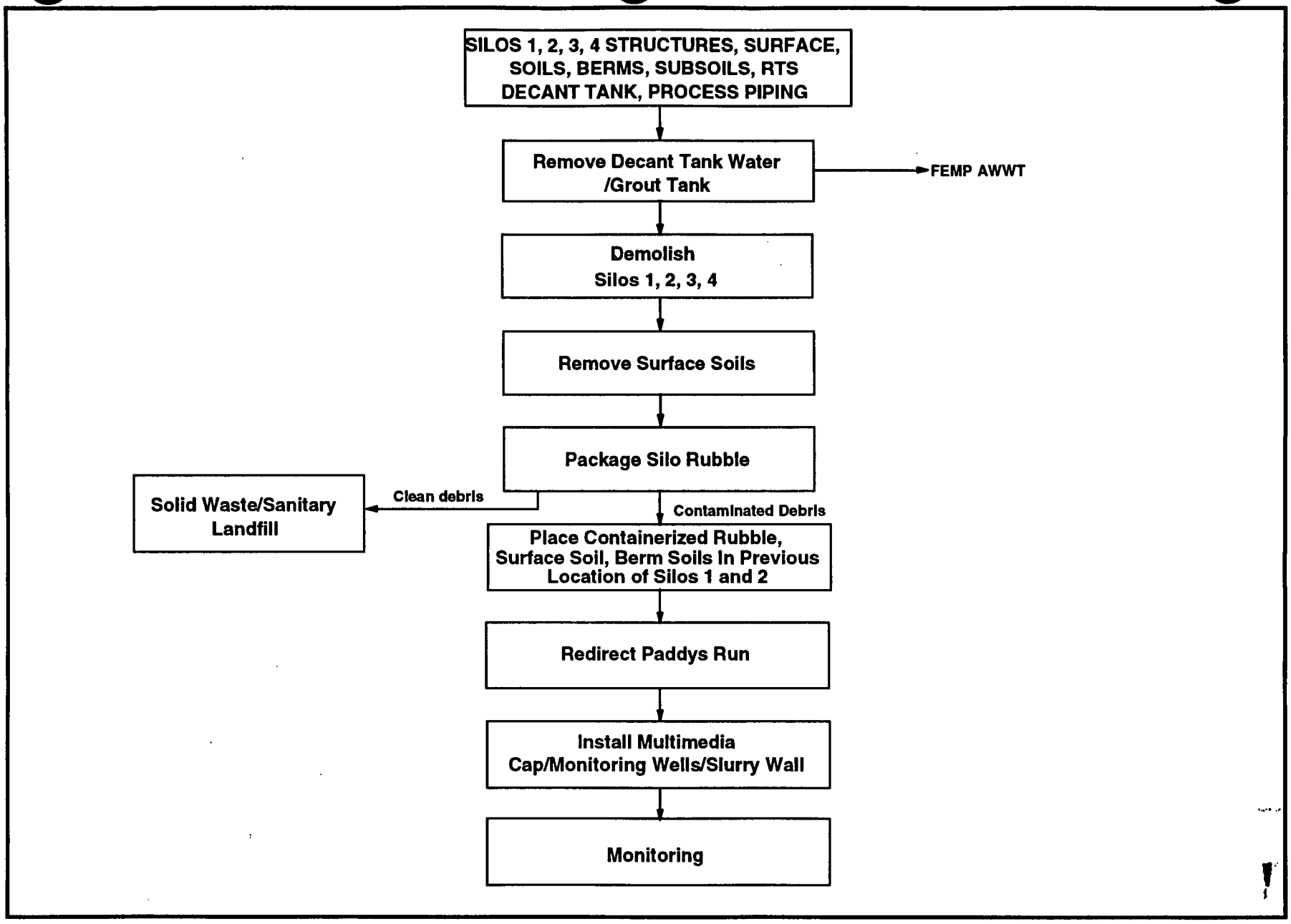

FIGURE 3 - 18
ALTERNATIVE 1C - DEMOLITION and CONTAINMENT
CONCEPTUAL FLOW DIAGRAM

FERNALD\OU4\FIG3-10.DRW/RSS/08/24/93

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Decontamination

- Pressure washer - The loose interior concrete and loose interior contamination can be removed with a remotely controlled, robotic high-pressure water jet or an abrasive water jet. The collected water and debris can be removed with the hydraulic material removal device and sent to the FEMP AWWT facility for treatment.

- Concrete scabbling - The contaminated concrete layers would be removed with a vacuum scabbling device. This device would use small, pneumatically actuated pistons or hammers to strike the concrete surface, chipping the upper concrete layer for removal by the vacuum system.

Capping

- Multimedia cap - A multimedia cap would be installed to minimize the infiltration of rainwater into the silos. The cap would consist of the following elements to control erosion and minimize leachate generation as a result of rainwater infiltration.

  - Upper vegetative layer

  - Drainage layer

  - Low-permeability clay layer with a maximum vertical permeability of 1×10^{-7} cm/s

  - Geomembrane layer of 40-mil minimum thickness

  The spatial requirements for the multimedia cap would require the partial relocation of Paddys Run to minimize the possibility of lateral erosion.

Run-on/Runoff Control

- Diversion/collection - The area around the cap may contain small berms, channels, and waterways to redirect runoff.

- Grading - The area around the cap would be contoured or graded to redirect and control runoff.

- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon Monitoring - Radon monitors would be installed around the cap to detect and warn of radon emanating from the material underneath the cap. Monitoring would continue as required to demonstrate compliance with relevant ARARs/TBCs and in support of CERCLA five-year reviews.

- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the cap and sampled routinely to monitor containment system performance.

- Surface Water/Sediment Monitoring - The surface water and sediment near the cap would be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical barriers - A security fence topped with barbed wire would surround the cap to discourage intruders.

- Administrative controls - Access to the site would be confined to authorized personnel during the implementation of remedial actions. Permanent physical markers would be used to mark the disposal unit. The need for long-term administrative controls will be addressed during the Detailed Analysis phase.

The following are descriptions of activities that would support the implementation of the process options.

- Decant sump tank evacuation - The liquid from the decant sump tank material would be evacuated with a sludge pump to a tanker truck, and the liquid would be transported to the FEMP AWWT facility for treatment. The decant sump tank would then be filled with grout to prevent water from infiltrating into the tank.

- Existing Silo RTS demolition - The existing RTS piping, HEPA filters, fan, dehumidification media, and carbon adsorption canisters would be dismantled and packaged for disposal. The concrete block building where this equipment is kept would also be demolished and packaged for disposal.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process.

- Slurry wall - Approximately 270 m (900 ft) x 15 m (50 ft)

- Material disposed in multimedia cap
  - Silo debris - Approximately 1500 m^3 (2000 yd^3)
  - Contaminated berm soil, surface soils - Approximately 11,000 m^3 (15000 yd^3)

- Material transferred to solid waste/sanitary landfill
  - Silo 4 debris - Approximately 500 m^3 (700 yd^3)

- Grout injected into decant sump tank - Approximately 40 m^3 (50 yd^3)

- Volume of decant sump tank water sent to the AWWT facility - Approximately 30,280 L (8000 gallons)

Remediation Time Frame

It would take approximately three months to prepare the site and stage the remediation equipment, nine months to demolish and package the silo structures, and one year to relocate Paddys Run and

construct the multimedia cap. The overall duration for this alternative would be approximately two years.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 5 ha (12.5 acres). Approximately 4 ha (10 acres) would be used by the cap.

Packaging/Transportation Requirements

The contaminated silo debris and contaminated berm and surface soils would be placed in DOT specification 7A Type A or strong tight containers before disposal.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, etc.)
- Equipment not feasible to decontaminate
- Water evacuated from the decant sump tank

3.2.6.3 Alternative 2C - Demolition, Removal, and On-Property Disposal

Description

This removal, treatment, and on-property disposal alternative would demolish the Silos 1, 2, 3 and 4 structures and would excavate the silo subsoil, as well as the Operable Unit 4 surface soil, decant sump tank process piping and trenches. This alternative would also demolish and dispose of the existing RTS for Silos 1 and 2 and dispose of any contaminated rubble or debris generated during implementation of Subunits A and B alternatives. This material, in addition to the contaminated berm material, would be packaged and disposed in an above-grade disposal vault constructed on property. This alternative is identical to Alternative 1C except that the silo floors, silo subsoil, decant sump tank, process piping and trenches that were left in situ in the previous alternative would now be excavated, packaged, and disposed on property. The technologies implemented by this alternative are demolition, concrete decontamination, mechanical removal, physical treatment, on-property disposal, run-on/runoff control, monitoring, and access controls.

Once the silo contents have been removed, the silo structures would be characterized both structurally and radiologically. Data from the structural characterization would be used to determine the safest approach to demolition, and data from the radiological characterization would be used to determine the depths to which the contaminated concrete must be removed. Any concrete and debris generated

during remediation which meets the free release criteria, as developed and presented in the RD/RA work plan, would be disposed in a solid waste/sanitary landfill. Figure 3-19 illustrates the logic of this alternative.

The additional process options for this alternative's technologies are described as follows:

Demolition

- In addition to the silo demolition process option previously described for the silo domes and walls (diamond rope saw/diamond chain saw), the silo floors would be scored with a masonry saw in a criss-cross pattern and divided and transported by front-end loader to the decontamination and packaging pad. The silo footers would be fractured with a backhoe-mounted pneumatic hammer and transported to the decontamination pad with a front end-loader.

Mechanical Removal

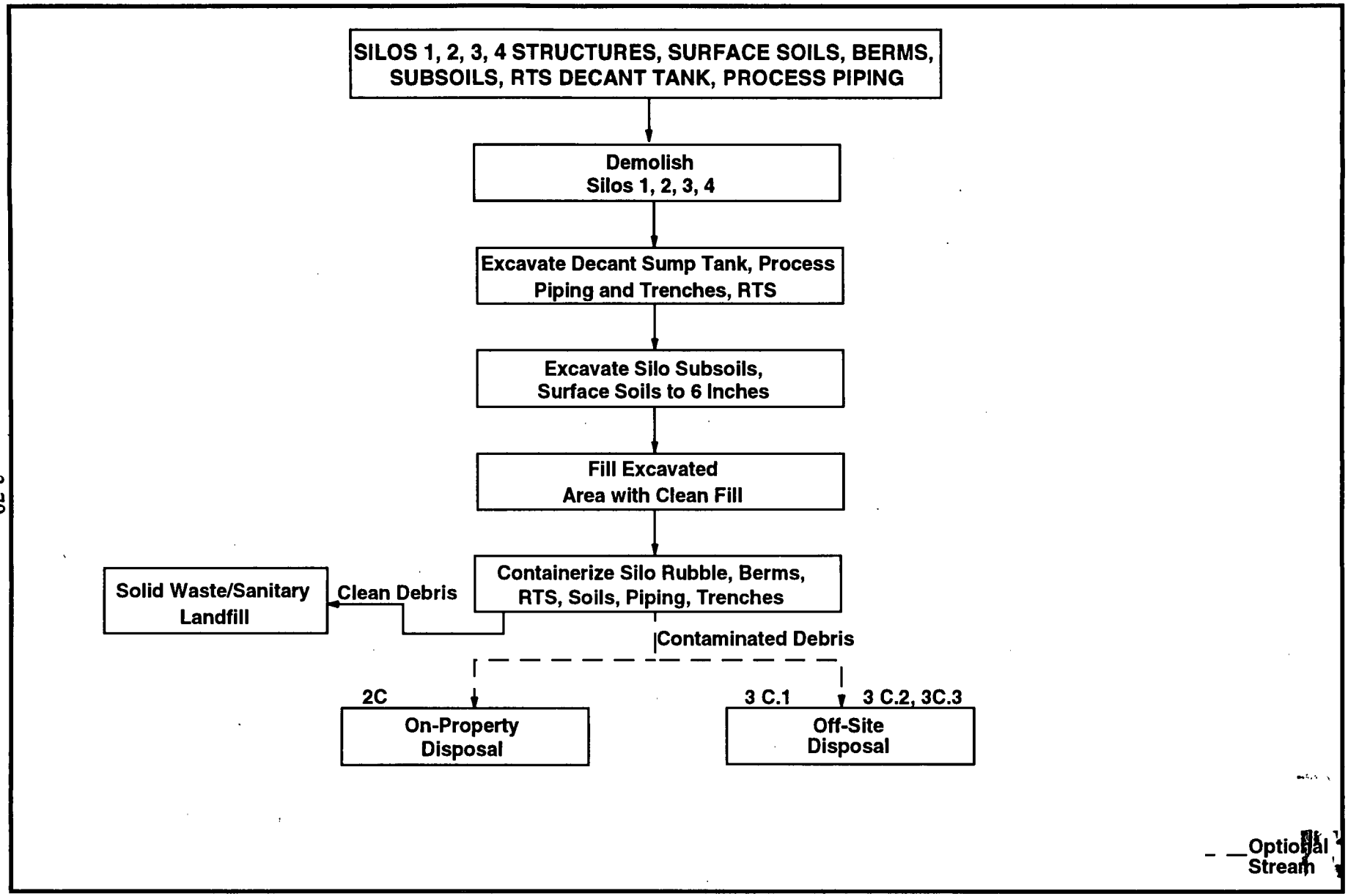
- Loader/dozer, crane with clamshell, backhoe - This equipment would be used to excavate the silo floors and foundations, the silo subsoil, the surface soil, the decant sump tank, and the process piping and trenches.

- After removal of the silo structures and the decant sump tank, the silo subsoil would be excavated using a backhoe. For the purpose of the cost estimate, the soil would be excavated to a depth of approximately 1.5 m (5 ft) and laterally to the toe of the berm. The volume is a conservative estimate of contaminated hot spots of soil and any other soil above the restricted use of PRGs. Regardless of the volume estimated, all soil exceeding the applicable PRGs would be excavated as part of this alternative. The surface soil within the Operable Unit 4 Study Area would be excavated with a dozer to a depth of 15 cm (6 in.) and packaged for disposal. The soil will be assayed, segregated, boxed, and disposed appropriately as it is removed. The affected areas of soil excavated would be backfilled to grade with clean soil.

- The liquid from the decant sump tank would be pumped to a tanker truck, and the contents will be transported to the AWWT facility for treatment. The decant sump tank would then be excavated and transferred to the decontamination pad for demolition and disposal. The soil above, around, and to a depth of 1.5 m (5 ft) below the tank would be excavated and segregated for disposal or use as clean fill.

- The process piping in the piping trench would be cut into manageable sections and placed in boxes for disposal without being decontaminated. The concrete piping trench would be fractured using a backhoe-mounted pneumatic hammer and would be excavated using a backhoe or clamshell. This concrete would be shipped to the decontamination pad for scabbling, if necessary, and packaging.

- The silo berms are assumed to have been removed, assayed, and staged during the removal of the Silos 1 and 2 contents.



FERNALD\OU4\FIG3-11.DRW/RSS/08/24/93

FIGURE 3 - 19
ALTERNATIVES 2C, 3C - REMOVE, TREAT, DISPOSE
CONCEPTUAL FLOW DIAGRAM

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On-Property Disposal

- Above-grade disposal vault - The resultant material would be disposed on property in an above-grade disposal vault. This facility would include an LC/DS and a multimedia cap.

Run-on/Runoff Control

- Diversion/collection - The area around the cap may contain small berms, channels, and waterways to redirect runoff.
- Grading - The area around the cap would be contoured or graded to redirect and control runoff.
- Revegetation - Vegetation would be used both on the multimedia cap and the area surrounding the cap to reduce erosion sedimentation runoff.

Monitoring

- Radon Monitoring - Radon monitors would be installed around the disposal facility containing the material to measure radon that emanates from the facility.
- Groundwater monitoring - A series of groundwater monitoring wells would be installed around the disposal area and sampled routinely to monitor containment system performance.
- Leachate monitoring - The installed LC/DSs would be routinely checked to monitor the facility's performance.
- Surface water/sediment monitoring - The surface water and sediment near the disposal facility would be monitored to determine if contaminants from the material have been released to these media.

Access Controls

- Physical Barriers - A security fence topped with barbed wire would surround the disposal area to discourage intruders. A security force would patrol the area while access controls are in effect.
- Administrative Controls - During the access control period, access to the site would be confined to authorized personnel. Permanent physical markers would also be used to restrict access.

The following are descriptions of activities that would support the implementation of the process options.

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- Decant sump tank evacuation - The liquid from the decant sump tank material would be evacuated with a sludge pump to a tanker truck, and the liquid would be transported to the FEMP AWWT facility for treatment.

- Existing Silo RTS demolition - The existing RTS piping, HEPA filters, fan, dehumidification media, and carbon adsorption canisters would be dismantled and packaged for disposal. The concrete block building where this equipment is kept would also be demolished and packaged for disposal.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process.

- Material disposed in above-grade disposal vault.
  - Contaminated silo debris - Approximately 1,500 m^3 (2,000 yd^3)
  - Decant sump tank, process piping, piping trenches, RTS - Approximately 280 m^3 (370 yd^3)
  - Contaminated berm soils - Approximately 8000 m^3 (10,500 yd^3)
  - Contaminated subsoils and surface soils - Approximately 14,500 m^3 (19,000 yd^3)

- Material transferred to solid waste/sanitary landfill.
  - Silo 4 debris - Approximately 500 m^3 (700 yd^3)

- Volume of water sent to AWWT facility - Approximately 80,000 L (21,000 gal.)

Remediation Time Frame

Approximately three months would be required to prepare the site and stage the remediation equipment; 15 months would be required to demolish, decontaminate, and box the silo structures, as well as to excavate and box the silo subsoil, decant sump tank, and process piping trenches. The above-grade disposal vault would be constructed during this time. The overall duration of this alternative will be 18 months to two years.

Spatial Requirements

Overall area at the FEMP site required to implement this alternative is approximately 6 ha (14 acres). Approximately 5 ha (12 acres) would be used by the disposal vault.

Packaging/Transportation Requirements

All contaminated material would be placed in DOT specification 7A Type A or strong tight containers before disposal.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, etc.)
- Equipment not feasible to decontaminate
- Water evacuated from decant sump tank

3.2.6.4 Alternative 3C - Demolition, Removal, and Off-Site Disposal

Description

This removal, treatment, and off-site disposal alternative would demolish and decontaminate the Silos 1, 2, 3, and 4 structures and would excavate the silo subsoil as well as the Operable Unit 4 surface soil, decant sump tank, and process piping and trenches. This alternative would also demolish and dispose of the existing RTS for Silos 1 and 2 and dispose of any contaminated rubble or debris generated during implementation of Subunits A and B alternatives. This material, in addition to the contaminated berm material, will be packaged and disposed in an off-site disposal facility. This alternative is identical to Alternative 2C with the exception that the on-property disposal and monitoring technologies have been replaced by the material transportation and off-site disposal technologies. Also long-term institutional controls at the FEMP would not be required. Contaminated material would be disposed at NTS, the permitted commercial disposal site, or a facility to be constructed within 483 km (300 mi) of the FEMP site. The material would be shipped to the disposal facility by rail or truck. These disposal alternatives are discussed separately as Alternatives 3C.1, 3C.2, and 3C.3, respectively.

The additional process options for this alternative's technologies are described as follows.

Material Transportation

- Rail/truck transport - The FEMP site can support rail transport to any of the disposal facilities by using an existing on-property rail spur. A rail spur can be built at the off-site disposal facility, or a combination of rail and truck transport can be used around the facility. Truck transport can offer portal-to-portal service with the road system available at the FEMP site. Improvements to the existing road system around the FEMP site may be required to accommodate the increased truck activity.

Off-Site Disposal

- NTS - The contaminated soils, berm, and debris would be shipped to NTS for disposal. Based on evaluation of the contaminated berm and debris, it would meet the NTS waste acceptance criteria. Approvals and certifications would be received prior to shipment.

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- Permitted commercial disposal site - The contaminated soils, berm, and debris would be shipped to the permitted commercial disposal site for disposal. Based on evaluation of the contaminated berm and debris it would meet the permitted commercial disposal site waste acceptance criteria. Approvals and certifications would be received prior to the shipment.

- New facility within 483 km (300 mi) - The stabilized material and demolition debris would be shipped to a facility to be constructed within 483 km (300 mi) of the FEMP site. All waste shipped to a new facility must meet the new facility's waste acceptance criteria when developed.

Size and Configuration

The following are preliminary estimates based upon data available during the initial screening process:

- Material volume transported to off-site disposal facility.
  - Silo debris - Approximately 1,500 m^3 (2,000 yd^3)
  - Decant sump tank, process piping, trenches, RTS - Approximately 280 m^3 (370 yd^3)
  - Contaminated berm soils - Approximately 8000 m^3 (10,500 yd^3)
  - Contaminated subsoil and surface soil - Approximately 14,500 m^3 (19,000 yd^3)

- Material transferred to solid waste/sanitary landfill
  - Silo 4 debris - Approximately 500 m^3 (700 yd^3)

- Volume of water sent to AWWT facility - Approximately 80,000 L (21,000 gal.)

Remediation Time Frame

Approximately three months would be required to prepare the site and stage the remediation equipment. An additional 15 months would be required to demolish and box the silo rubble, and excavate and box the remaining material. The overall duration of this alternative will be 18 months to two years.

Spatial Requirements

Overall area at the FEMP site required for implementation of this alternative is approximately 1 ha (2 acres) for vitrification and cementation.

Packaging/Transportation Requirements

All contaminated material would be placed in DOT specification 7A Type A or strong tight containers and shipped by rail or truck. Removed material would be temporarily stored at a staging area while final release tests are conducted.

Waste Generated

- Contact waste (anti-contamination clothing, gloves, etc.)
- Equipment not feasible to decontaminate
- Water evacuated from decant sump tank

Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS

Under Alternative 3C.1, material would be disposed off site at NTS. NTS is a DOE-owned facility that currently accepts LLRW from DOE facilities. It is located approximately 3541 km (2200 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at the Permitted Commercial Disposal Site

Under Alternative 3C.2, material would be disposed off site at the permitted commercial disposal site in Clive, Utah, located approximately 3058 km (1900 mi) from the FEMP site in an arid environment far from any population centers.

Alternative 3C.3 - Demolition, Removal, and Off-Site Disposal at a Facility to be Located Within 483 Kilometers (300 Miles) of the FEMP Site

Under Alternative 3C.3, material would be disposed at an above-grade disposal vault to be constructed within 483 km (300 mi) of the FEMP site. This facility may be a centralized or regional DOE disposal facility to be developed later. Material must meet the waste acceptance criteria for this facility when developed.

3.3 SCREENING OF ALTERNATIVES

The alternatives presented in the previous subsection were evaluated against three broad criteria: effectiveness (short- and long-term), implementability, and cost. The criteria for evaluating alternatives are provided in EPA guidance (EPA 1988a) and in the NCP (40 CFR 300) (EPA 1990). Of these criteria, effectiveness was given the highest consideration. Because this screening reduced the number of alternatives undergoing a more extensive and qualitative analysis, alternatives were evaluated more generally in this phase than during the subsequent detailed analysis task. The no-action alternative was retained as a baseline against which other alternatives were compared. Consistent with the NCP, nine specific criteria are emphasized to perform the Detailed Analysis of Alternatives. Seven of these criteria are taken into consideration during the initial screening of alternatives. The relationship between the three screening criteria and the seven specific detailed analyses criteria is illustrated in Figure 3-20.

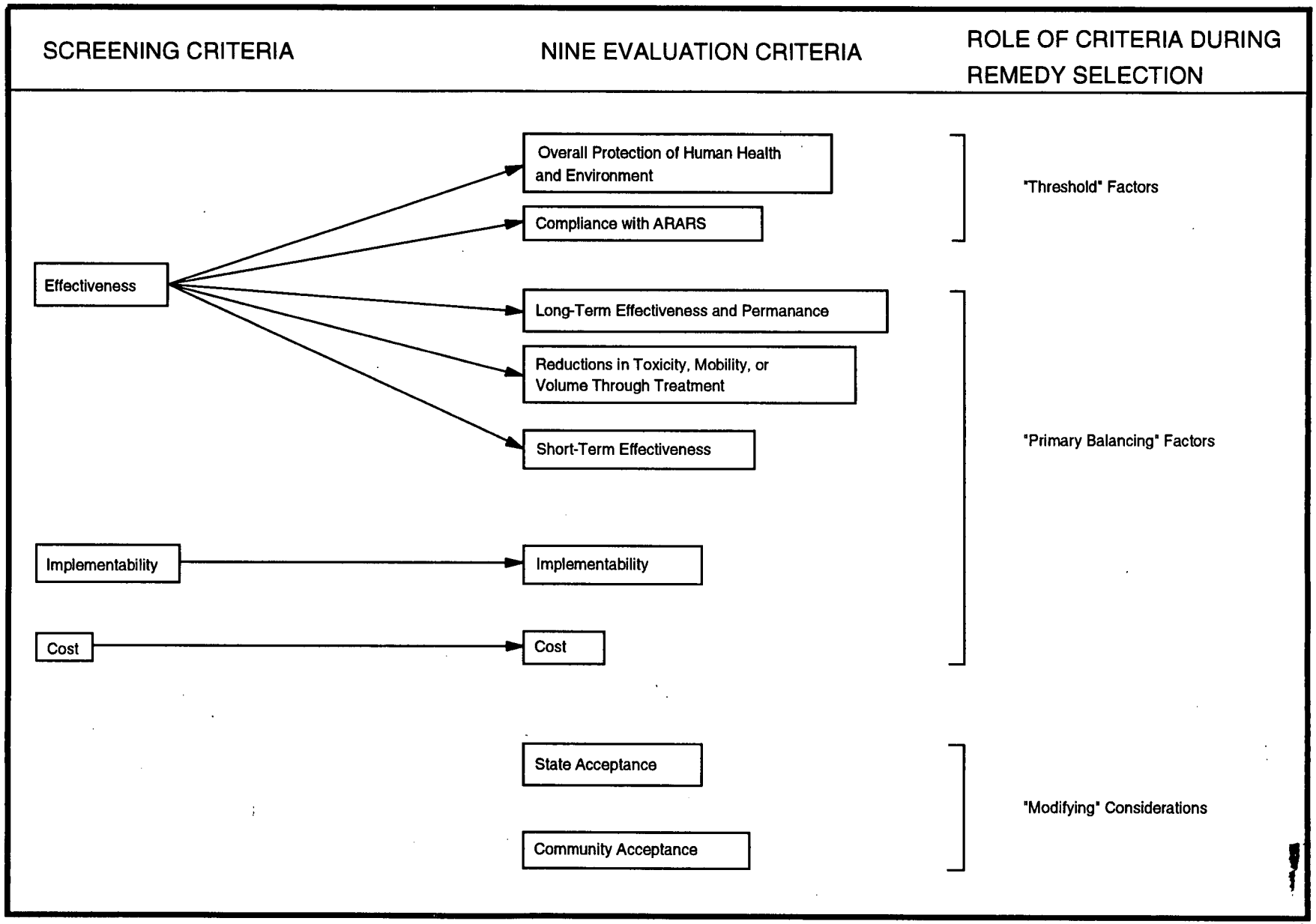

FIGURE 3-20
RELATIONSHIP OF SCREENING CRITERIA TO THE NINE EVALUATION CRITERIA

Alternatives with innovative technologies were carried through the screening process if there was reason to believe that they offered significant advantages in performance or implementability. Technologies are classified as innovative if they are fully developed but lack sufficient cost or performance data for routine use at CERCLA-regulated cleanup sites. An example of an innovative technology is in the vitrification of removed waste materials.

Effectiveness Evaluation

The key aspect of the screening evaluation is the assessment of the alternatives ability to meet the RAOs in order to provide protection of human health and the environment in both the short term and long term. Measures of effectiveness include (1) reduction of contaminant toxicity, mobility, or volume through treatment; (2) long-term protection of human health and the environment; and (3) short-term protection of human health and the environment during the remedial action.

Implementability Evaluation

Implementability is the measure of (1) the technical feasibility and (2) administrative feasibility to construct, operate, and maintain a remedial action alternative, and (3) the availability of services and materials. This criterion provides a way to evaluate the potential of an alternative to be adapted to site-specific conditions.

The technical feasibility evaluation considered the following.

- Constructability
- Reliability (e.g., demonstrated performance and operation)
- Maintenance

The administrative feasibility evaluation considered the following.

- Ability to obtain permitting and licensing approval

The availability of services and materials evaluation considered the following.

- Availability of on-property/off-site treatment, storage, and disposal facilities and capacity
- Availability of equipment
- Availability of design, operation, and support personnel

Cost Evaluation

Cost estimates were prepared for each alternative to compare similar alternatives. The cost estimates were based on a variety of cost-estimating data such as cost curves, generic unit costs, vendor information, conventional cost-estimating guides, commercial remedial costs, and previous similar estimates as modified by site-specific information.

The categories of costs considered were (1) capital cost and (2) operation and maintenance (O&M) cost. The capital cost includes the cost of constructing remediation facilities, disposal facilities, and purchasing equipment. Cost estimates were prepared to aid in the evaluation of alternatives using information currently available. The cost estimates presented are order-of-magnitude estimates with an intended accuracy range of +50 percent to -30 percent. Estimates are considered to be order-of-magnitude because of the uncertainties in the information used to develop the alternatives. More detailed cost estimates are provided to support the analysis conducted on the alternatives in Section 4.0.

O&M cost includes short-term and long-term O&M costs. Short-term O&M cost includes labor and material costs incurred during remediation. Long-term O&M costs include those annual costs incurred after remediation is complete and typically include cap or disposal facility maintenance, sampling and analytical costs, and any monitoring activities. The monitoring costs will be associated with all alternatives that leave waste materials on the property, except for the no-action alternative.

Present worth costs combine capital, short-term costs (assuming a discount rate of seven percent and a construction period), and long-term O&M costs (assuming a discount rate of seven percent and an O&M period of 30 years).

3.3.1 Subunit A - Residues Within Silo 1 and 2 and Decant Sump Sludge

3.3.1.1 Alternative 0A - No Action

A description of this alternative is provided in Section 3.2.4.1.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment. Under this alternative, Subunit A would remain unchanged except for conditions resulting from the completion of any

removal actions that have already been completed or approved. Because the material is not treated or further contained, the material's toxicity, mobility, and volume would not be reduced.

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Long-Term Protection of Human Health and the Environment. The material is not contained, treated, or modified under the no-action alternative. RAO's for the Silo 1 and 2 residues are not altered under the no-action alternative. As described in the Baseline Risk Assessment (BRA), the potential incremental lifetime cancer risk to a number of evaluated receptors exceeds the generally accepted risk range as defined in the NCP. The assessment of the risks due to no action for the residues is based upon an assumption that continued deterioration would lead to dome collapse on Silos 1 and 2. This collapse would lead to an exposure of the bentonite cover over the residues to the atmosphere. While the BRA assumes the long term integrity of the bentonite cover following a hypothetical dome collapse, it is conceivable that this cover on the dome side walls could be breached due to the effects of erosion or other internal or intruder actions. Potential exposures to both on- and off-property receptors under such release scenarios would greatly exceed those calculated under the BRA. Hypothetical loss of containment scenarios would also lead to significant detrimental impacts to the regional environment including degradation of the sole source aquifer.

Short-Term Protection of Human Health and the Environment. The no-action alternative provides for the protection of both human health and the environment during the duration of ongoing site access controls and active maintenance programs. Loss of these controls would produce unacceptable risks to inadvertent intruders. Radon flux standards under the National Emission Standards for Hazardous Air Pollutants (NESHAP) would continue to be exceeded.

Screening Criteria - Implementability

Technical Feasibility. This alternative is technically feasible because no construction or maintenance activities would be performed.

Administrative Feasibility. No permits or licenses are required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials. No equipment or personnel are required to implement this alternative.

Screening Criteria - Cost

Capital Cost. No capital costs are associated with this alternative.

O&M Cost. There are no short-term or long-term O&M costs associated with this alternative.

Summary

This alternative does not meet RAOs and does not reduce the toxicity, mobility, or volume of wastes. Protection of human health and the environment can only be assured during the duration of active access controls and maintenance. The no-action alternative is readily implementable and has the least cost. The no-action alternative was retained for detailed analysis as a baseline comparison to other remediation alternatives.

3.3.1.2 Alternative 1A - In Situ Containment

A description of this alternative is provided in Section 3.2.4.2.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Although migration of contaminants would be reduced by the multimedia cap, LC/DS, slurry wall, and run-on/runoff controls, the waste material will not be treated; therefore, as with the no-action alternative, there is no reduction of contaminant toxicity, mobility, or volume. The volume of contaminated material actually increases due to the injection of structural grout into the headspace of the silos.

Long-Term Protection of Human Health and the Environment. While Alternative 1A would preclude direct contact and ingestion of the residues through containment within a capping system, the long-term protection of human health and the environment could not be assured because of the reliance of this alternative on institutional controls and perpetual maintenance. These active contracts would be required to preclude access to and release from the disposal system. The potential exposures to receptors due to loss of residue containment could be significant and approach baseline conditions.

The feasibility of installing an effective LC/DS under the existing silos is also questionable. Failure of the system coupled with cap degradation could result in significant releases to the underlying soil and groundwater. Such releases could approximate baseline conditions.

The geologic siting conditions present at the Silos 1 and 2 area provide additional uncertainty as to the ability of Alternative 1A to effectively attain RAOs. Underlying the silo area is a fairly continuous silty sand lens providing a preferential horizontal flow path within the till toward Paddys Run. Additionally, only a limited thickness of low permeability clays underlay this sand lens to protect the Great Miami Aquifer. It is questionable whether such siting conditions could ensure continued protection of the environment or comply with ARARs.

Short-Term Protection of Human Health and the Environment. Potential short-term impacts associated with construction of the multimedia cap include the disturbance of soil, airborne emissions due to dust, and the displacement or loss of vegetation. Appropriate mitigative measures would be applied during remedial actions to ensure appropriate worker and public health basic exposure requirements are attained. This alternative is protective of both human health and the environment during remediation because the planned activities minimize handling of the waste material since the waste material and bentonite layer remain in place, thereby minimizing the release of radon gas and direct contact with the waste material during remediation. It achieves ALARA criteria and requires minimal additional worker protection measures.

Because of the proximity of residents to Paddys Run, the potential exists for exposure to trespassing children during the partial relocation of Paddys Run, which is needed to prevent lateral erosion to the cap due to the spatial requirements for the multimedia cap. However, based on the short duration of this activity (28 weeks), this risk is well below the risk associated with the No-Action Current Land Use Without Access Controls scenario, a scenario which assumes exposure to a child trespasser for six years.

Minimal impacts to wetlands and floodplain areas are anticipated. Overall, few additional risks to the public, workers, or the environment result, but this alternative has greater short-term risks than the no-action alternative due to earth-moving activities.

Screening Criteria - Implementability

Technical Feasibility. Although the proposed containment technologies are widely used and well tested, a moderate level of difficulty would be experienced in construction of the multimedia cap, LC/DS, and slurry wall, and in relocation of Paddys Run. Since only a minimal amount of

maintenance would be required for the multimedia cap to continue to provide the necessary level of containment for the untreated material, this can be accomplished using readily available resources.

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Administrative Feasibility. No permits or licenses are required to implement this alternative. Although minimal impacts are anticipated, the relocation of Paddys Run will invoke ARARs related to floodplain, wetlands, and fish and wildlife protection. This will require coordination with the COE in addition to the State of Ohio and EPA Region V. While necessary deed restrictions and marking could be readily implemented, the long-term maintenance of these restrictions and ownership rights are questionable.

Availability of Services and Materials. The cap will be designed for an effective life of at least 1000 years. No special equipment is required to implement this alternative. Installing an HDPE liner requires a specialty contractor. Resources required for maintenance and monitoring should be readily available.

Screening Criteria - Cost

The total present worth cost of this alternative is approximately $17 million(M).

Capital Cost. The major components of capital cost include grouting, cap installation, slurry wall construction, monitoring systems, and partial relocation of Paddys Run.

O&M Cost. Short-term O&M costs include those costs necessary to monitor operations and maintain access controls. Long-term O&M costs include maintaining institutional actions forever and conducting a review every five years to ensure that the remedy continues to provide adequate protection. Cap maintenance is expected to be minimal (e.g., patching and mowing) for the first 1000 years. After that point, cap replacement may be needed. The present worth calculations do not consider O&M costs past 30 years.

Summary

There is significant uncertainty as to the ability of Alternative 1A to attain RAOs for the long term. Additional site conditions associated with the silo area provide significant uncertainty as to the ability to attain ARAR disposal facility siting requirements. The alternative does not reduce the toxicity or mobility of wastes, but it does increase the volume of waste. Migration of and exposure to contaminants are reduced, but the long-term effectiveness is less certain than the remaining

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alternatives due to the dependence on institutional control and cap maintenance. The cost of this alternative is higher than the cost of the no-action alternative, but lower than the costs for all other Subunit A alternatives. This alternative was screened from further evaluation in the detailed analysis of alternatives because: protectiveness cannot be adequately assured; goals of waste reduction/treatment cannot be met; and siting ARARs are not expected to be attained.

3.3.1.3 Alternative 2A - Removal, Stabilization, and On-Property Disposal

A description of this alternative is provided in Section 3.2.4.3.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Cement stabilization and vitrification have been effectively implemented to treat radiological and hazardous waste materials, respectively. Current testing of the vitrification process on FEMP residues has been limited to bench-scale level testing. To better understand the applicability and effectiveness of these treatment processes on the contents of Silos 1, 2, and 3, treatability studies were conducted. The treatability studies evaluated the process options of cement stabilization and vitrification for the contents of Silos 1, 2, and 3, and chemical extraction for the contents of Silos 1 and 2. The objectives of these studies were to determine the ability of the process options to effectively treat the waste material by evaluating volume changes, compressive strengths, and leachability. A more detailed discussion of these treatability studies is provided in Appendix C of this document and in other supporting documents (Cement Stabilization/Chemical Extraction Treatability Study Report for Operable Unit 4 and the Operable Unit 4 Treatability Report for the Vitrification of Residues from Silos 1, 2, and 3; DOE 1993c and d).

Based on the results of the treatability studies performed for the cement stabilization and vitrification process options (see Appendix C), cement stabilization and vitrification achieved similar reductions in the toxicity characteristics of the material and the mobility of the contaminants. However, the resultant material volume increased by a range of 236 to 316 percent for the material from Silos 1 and 2 for the cement stabilization option and decreased by approximately 55 percent for the vitrification option. Vitrification achieves a reduction in contaminant volume and, through organic destruction, a slight reduction in toxicity. Contaminants remaining in the vitrified mass are relatively immobile. Cement stabilization only reduces mobility by reducing the leachability of contaminants. After treatment with either option, the material will be stored in an above-grade disposal vault with a

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multi-media cap, LC/DS, and run-on/runoff controls to minimize the potential for contaminant migration. Residuals will, however, be generated as a by-product of the air emissions control system required for each process. Residuals will be disposed in the vault. Liquid residuals will be treated at the AWWT.

Long-Term Protection of Human Health and the Environment. While the stabilized material is very resistant to leaching, the direct radiation associated with residues would remain relatively unchanged. The treated residues would be disposed in an above-grade disposal vault with an LC/DS. The material would be sited over a sole source aquifer in an area of moderate rainfall. The disposal facility would be designed for a 1000 year life with provisions for intruder protection. Performance of the disposal facility will be measured by a monitoring system. Therefore, this alternative is considered to be protective of human health and the environment for the long term. The uncertainty associated with the long-term effectiveness of this alternative is significantly less than Alternative 1A since the material will be immobilized (through treatment) and placed in an engineered disposal facility.

Short-Term Protection of Human Health and the Environment. In addition to those short-term impacts discussed for Alternative 1A, increased short-term exposure to workers is anticipated due to the additional waste material handling associated with the removal, treatment, disposal, and construction of the various remediation facilities. Of primary concern will be the risks from radon emissions after breaching the bentonite cover in the silos. By processing material in a facility that employs ALARA criteria and DOE Orders, such as air emission control systems, shielding, and appropriate personal protective equipment for the remediation workers, risks due to contaminant exposure should be controlled to acceptable levels.

No impacts to wetlands, floodplain, or wildlife are anticipated. Specific to waste removal activities, potential short-term concerns are associated with removal of berm material and the waste material. The berm currently provides structural stability to the silo structures. As the silo contents are removed, the berm material opposite the silo wall will be removed to ensure that the forces are balanced. However, the potential risk of silo collapse, though minimal, exists. Removal of the berm material will be performed by a hydraulic mining device, but will require that personnel be on the work platform over the silo domes once a week for approximately two hours, thus increasing the workers' physical and exposure hazards. Thus, this alternative will provide short-term protection to human health and the environment.

Screening Criteria - Implementability

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Technical Feasibility. Although the cement stabilization technology is well understood and widely applied, its full-scale application to these materials has yet to be demonstrated. Vitrification is considered an innovative technology and as such, in spite of successful bench-scale treatability studies, the technical feasibility of implementing an effective full-scale system for this material is undetermined. A high level of difficulty would be experienced in the removal of the residues from the silos. Considerable worker protection techniques would be needed during the hydraulic removal of residues. The construction of the RTS, vault, and treatment facility are readily implementable. Monitoring of influent conditions, additive mixtures, effluent characteristics, and off gases would be needed. Residuals from the off-gas system and liquid residuals would require treatment and/or disposal. The disposal facility would be designed to preclude the need for long term maintenance. Similar facilities are in use throughout the hazardous and low level waste disposal industry. Due to these factors, the technical feasibility of this alternative is less than that of Alternatives 0A and 1A.

Administrative Feasibility. No permits or licenses will be required. However, the substantive technical requirements of air emissions permits would need to be demonstrated.

Availability of Services and Materials. The equipment and engineering required for full-scale vitrification are not as readily available as that for cement stabilization and its construction and operation are more complex. The availability of trained and experienced operators of joule heated melters is limited. Maintenance is also considered to be greater for vitrification. As a result, the implementability of the vitrification process option is the lower of the two.

Screening Criteria - Cost

The total present worth cost of this alternative using the vitrification process option is approximately $44M. The total present worth cost of this alternative using the cement stabilization process option is approximately $74M.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs include costs associated with maintaining access controls and monitoring systems, and operation and maintenance of the treatment system. Annual long-term costs include costs associated with maintaining monitoring systems.

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Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. However, to ensure worker protection, significant monitoring, remote operations, and shielding would be required. Residue removal and treatment system operations contribute to the difficult implementability of this alternative. This alternative has higher costs than Alternatives 0A and 1A, but it is also more effective because it treats contaminants. Although the equipment costs for both process options are comparable, the disposal vault costs for the cement stabilization process are estimated to be nearly two times that of the vitrification option due to the increase in material volume resulting from the cement stabilization process. This alternative was retained for detailed evaluation because of its increased long-term effectiveness, relative to 1A, achieved through treatment and vaulting, although it is difficult to implement and more expensive.

3.3.1.4 Alternative 3A.1 - Removal, Stabilization, and Off-Site Disposal at NTS

A description of this alternative is provided in Section 3.2.4.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Alternative 3A.1 includes the same treatment process options as Alternative 2A, and, therefore, provides the same level of reduction in toxicity, mobility, and volume.

Long-Term Protection of Human Health and the Environment. As with Alternative 2A, this alternative will meet the RAOs of preventing direct contact with or ingestion of the material and preventing the release or migration of waste material because the waste material will be treated and disposed in a secure facility. Long-term reliability is likely greater than that of Alternative 2A for both treatment options because the material will be stored off site in a remote location with little rainfall, sparse population, and a greater depth to groundwater. Since this alternative provides for removal and treatment of all the waste material in Silos 1 and 2 and the sludge in the decant sump tank, no residuals will remain at Subunit A and thus, no residual risks will exist at the FEMP site.

Short-Term Protection of Human Health and the Environment. Alternative 3A.1 includes the same site preparation, construction, and material processing options as Alternative 2A and, thus, provides the same short-term protection of human health and the environment as Alternative 2A, with the exception of the disposal component of this alternative. Although the hazards associated with construction of the above-grade disposal vault are eliminated for Alternative 3A.1, packaging, shipping, and disposal of the material lowers the short-term protectiveness of human health due to material shipment hazards associated with additional material handling. Measures to reduce exposures to ALARA and to meet DOE Orders during packaging, shipping, and disposal operations, such as use of mechanical equipment and shielding, will be implemented. Shipment to NTS currently requires rail transport on the CSX rail lines, transfer to the Union Pacific rail lines in St. Louis, Missouri and transfer of the material to trucks for road transportation in Las Vegas, Nevada. If an accident were to occur during transport, the nearby public may be exposed to a relatively large volume of radioactive materials. The exposure would be limited due to the treated form of the waste. Because cement stabilization produces a greater volume of material than vitrification, more shipments will be required, thus increasing transportation risks.

Screening Criteria - Implementability

Technical Feasibility. The same issues related to the process options exist as those described for Alternative 2A. This alternative is slightly more technically straightforward than Alternative 2A because no on-property disposal is included in this alternative. Preliminary evaluation of the treated residue conducted as part of the treatability studies indicates the treated wastes would meet the NTS waste acceptance criteria. No long-term maintenance or monitoring, except as required by NTS, is associated with this alternative.

Administrative Feasibility. NTS is a DOE-owned facility which the FEMP has been utilizing for waste disposition since August 1985. A variance to the provisions of DOE Order 5820.2A would be required to enable receipt of this 11(e)2 by-product material at NTS as low level waste. Also, an addendum to the current NTS waste shipping application would be required for this new stream. This alternative will require agency approvals and coordination for the interstate shipment of the material. As with Alternative 2A, the substantive technical requirements of air emissions permits would also need to be demonstrated.

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Availability of Services and Materials. The availability of equipment and engineering required is the same as for Alternative 2A.

Screening Criteria - Cost

The total present worth cost of the alternative using the vitrification process option is estimated at $42M and the total present worth cost using the cement stabilization option is approximately $70M.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with monitoring, maintaining access controls, and operating and maintaining the treatment system. There are no long-term monitoring costs associated with this alternative for either process option because no material remains on property.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. This alternative would be moderately difficult to implement although feasible. The administrative feasibility is more difficult than Alternatives 0A, 1A, and 2A. This alternative has a much higher cost than Alternatives 0A and 1A, but is only approximately equal to the cost of Alternative 2A. This alternative was retained for detailed evaluation.

3.3.1.5 Alternative 3A.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

A description of this alternative is provided in Section 3.2.4.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Reduction of contaminant toxicity, mobility, or volume is the same as Alternatives 2A and 3A.1.

Long-term Protection of Human Health and the Environment. RAOs are achieved by this alternative. The long-term protection of this alternative is improved over Alternative 2A because it is assumed that the 483-km (300-mi) facility can be sited in a location with slightly better performance

characteristics than the on-property facility; however, the 483-km (300-mi) facility, with its siting in a temperate climate and a populous region, may not offer the long-term protection potentially achieved by disposal at NTS. The long-term effectiveness of each of three disposal options [on-property, NTS, and off-site within 483 km (300 miles)] are uncertain due to the lack of performance data on the long-term reliability of the disposal systems. The effectiveness of disposal systems in arid climates such as NTS would be expected to exceed similar disposal concepts in humid climates such as the FEMP site.

Short-Term Protection of Human Health and the Environment. The short-term protection of human health and the environment is identical to Alternative 2A during the construction and remediation phase. The potential risk due to material shipment off site to the 483-km (300-mi) facility may be lower than Alternative 3A.1 because this facility is closer than NTS; however, the risk is dependent on whether rail or truck is used because the transportation mode is directly related to the volume of material and thus the potential exposure if an accident were to occur during shipment (e.g., injuries or deaths per ton-mile). The risk of transport is also dependent on the nature of loading/unloading cycles, traffic patterns, roadbed conditions, or load configurations (for railroads). Because cement stabilization produces a greater volume of material than vitrification, more shipments will be required thus increasing transportation risks for the cement stabilization process option.

Screening Criteria - Implementability

Technical Feasibility. The technical feasibility is identical to that of Alternative 2A, except additional effort is required for transportation of the treated material to the off-property storage facility.

Administrative Feasibility. The implementability of this alternative with respect to administrative feasibility would be difficult because it is unlikely that a new radioactive waste disposal facility can be sited, constructed, and the necessary agency and community approvals obtained in a timely manner. The difficulties that have been encountered by the state compacts in siting congressionally mandated radioactive waste disposal facilities are likely to be encountered when implementing this alternative. Also, the substantive technical requirements of air emissions permits would also need to be demonstrated.

Availability of Services and Materials. Availability of services and materials is comparable to that for Alternative 2A.

Screening Criteria - Cost

The total present worth cost of the alternative using the vitrification process option is approximately $42M, and the total present worth cost using the cement stabilization process option is approximately $72M. There is a significant uncertainty in these cost estimates due to the uncertainties in facility siting, permitting, etc.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include monitoring, maintaining access controls, and operation and maintenance of the treatment system. There are no long-term O&M costs associated with this alternative for either process option because no material remains on property.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. Construction of the removal system, treatment of the waste, and the administrative requirements related to siting a new disposal facility contribute to the very difficult implementability of this alternative. This alternative has a much higher cost than Alternatives 0A and 1A, but is comparable to the costs of Alternatives 2A and 3A.1. This alternative was screened out from further analysis because it is difficult to implement and provides less long-term protection but has similar costs to Alternative 3A.1.

3.3.1.6 Alternative 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal

A description of this alternative is provided in Section 3.2.4.5.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment: Chemical extraction has been shown to be effective in treating radioactive waste at other sites. To better understand the applicability and effectiveness of this treatment process on the contents of Silos 1 and 2, treatability studies were conducted. The objectives of these studies were to determine the ability of chemical extraction to effectively remove RCRA metals, uranium, thorium, polonium, protactinium, actinium, and radium. A more detailed discussion of these treatability studies is provided in Appendix C of this

document and in a supporting document (Cement Stabilization/Chemical Extraction Treatability Study Report for Operable Unit 4; DOE 1993c). 4738

Based on the results of the treatability studies performed, the chemical extraction process option combined with a stabilization process was determined to be technically feasible in reducing the raw material to a small volume of leach-resistant, vitrified, high-activity material, but a much larger volume of low-activity material is generated. The activity level of this second waste stream is significantly less than that found in the raw residues, but it can not be considered clean material. Insufficient removal occurred during the studies to result in a fraction that could be disposed as nonhazardous, nonradiological waste.

Long-Term Protection of Human Health and the Environment. The long-term protection of human health and the environment is provided because the majority of the radiological and hazardous constituents of the raw material have been concentrated in a smaller quantity of vitrified or cement stabilized product. The remaining material, although much greater in volume, contains significantly less activity than the raw material. The issues of protection for Alternative 2A are similar for this alternative. However, some of the contamination will not be stabilized prior to disposal. Therefore, despite the added treatment process, long-term reliability is slightly decreased.

Short-Term Protection of Human Health and the Environment. This alternative has similar short-term protection as Alternative 2A.

Screening Criteria - Implementability

Technical Feasibility. Although the components of the material processing system, except for the vitrification unit, are readily available and commonly used, the constructability and reliability of this alternative are low because the chemical extraction process is complex and relies on many interdependent subprocesses. Increased shielding will be required to handle the high-activity component. Additionally, the vitrification process has yet to be demonstrated on this scale for these materials.

Maintenance of the processing equipment is expected to be higher than that for other removal and treatment alternatives, and long-term maintenance is required for the on-property disposal facility.

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Administrative Feasibility. The substantive technical requirements of air emissions permits would need to be demonstrated, as described for Alternative 2A.

Availability of Services and Materials. This is the same as Alternative 2A.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $83M, and the total present worth cost of the cement stabilization alternative is approximately $95M.

Capital Cost. The major components of capital cost for this alternative includes the chemical extraction, vitrification, and cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include monitoring, maintaining access controls, and operation and maintenance of the treatment system. Long-term O&M costs include costs associated with monitoring.

Summary

This alternative has similar pros and cons as Alternative 2A. However, treatability studies have shown that clean material can not be achieved with chemical extraction. Therefore, this alternative was not retained for detailed analysis because the additional difficulty, effort, and cost of this alternative provide no benefits over Alternative 2A.

3.3.1.7 Alternative 5A.1 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at NTS

A description of this alternative is provided in Section 3.2.4.6.

Screening Criteria Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. This alternative is less effective in reducing contaminant toxicity, mobility, or volume than Alternative 3A.1 because of the lower effectiveness of the chemical extraction process (refer to Alternative 4A for detailed discussion of chemical extraction effectiveness).

Long-Term Protection of Human Health and the Environment. The long-term protection is lower than for Alternative 3A.1 because clean material can not be achieved with chemical extraction and some of the contamination will not be stabilized prior to disposal. Therefore, despite the added treatment process, long-term reliability is slightly decreased.

Short-Term Protection of Human Health and the Environment. This alternative has similar short-term protection as Alternative 3A.1.

Screening Criteria - Implementability

Technical Feasibility. The constructability and reliability of this alternative are lower than for Alternative 3A.1 because the chemical extraction process is complex and relies on many interdependent subprocesses. Increased shielding will be required to handle the high-activity component. Maintenance of the processing equipment is expected to be higher than for Alternative 3A.1.

Administrative Feasibility. This administrative feasibility is the same as Alternative 3A.1.

Availability of Services and Materials. Availability of resources for this alternative is the same as that described for Alternative 3A.1.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $81M, and the total present worth cost of the cement stabilization alternative is approximately $92M.

Capital Cost. The major components of capital cost for this alternative include the chemical stabilization, vitrification, and cement stabilization process equipment.

O&M Cost. Short-term O&M costs include costs associated with monitoring, maintaining access controls, and operation and maintenance of the treatment system. There are no long-term monitoring costs associated with this alternative for either process option because no material remains on the property.

Summary

This alternative is similar to Alternative 3A.1, but is not as effective since clean material can not be achieved with chemical extraction. Therefore, this alternative was not retained for detailed analysis because the additional effort and cost of this alternative provide no benefits over Alternative 3A.1.

3.3.1.8 Alternative 5A.2 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

A description of this alternative is provided in Section 3.2.4.6.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. This alternative is less effective in reducing contaminant toxicity, mobility, or volume than Alternative 3A.2 because of the lower effectiveness of the chemical extraction process (refer to Alternative 4A for detailed discussion of chemical extraction effectiveness).

Long-Term Protection of Human Health and the Environment. The long-term protection is lower than for Alternative 3A.2 because clean material can not be achieved with chemical extraction and some of the contamination will not be stabilized prior to disposal. Therefore, despite the added treatment process, long-term reliability is slightly decreased.

Short-Term Protection of Human Health and the Environment. This alternative has similar short-term protection as Alternative 3A.2.

Screening Criteria - Implementability

Technical Feasibility. The constructability and reliability of this alternative are lower than for Alternative 3A.2 because the chemical extraction process is complex and relies on many interdependent subprocesses. Increased shielding will be required to handle the high-activity component. Maintenance of the processing equipment is expected to be higher than for Alternative 3A.2.

Administrative Feasibility. This administrative feasibility is similar to that of Alternative 3A.2.

Availability of Services and Materials. Availability of resources for this alternative is the same as 4738 described for Alternative 3A.2.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $82M; the total present worth cost of the cement stabilization alternative is approximately $94M.

Capital Cost. The major components of capital cost for this alternative include the chemical extraction, vitrification, and cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with monitoring, access controls, and operation and maintenance of the treatment system. There are no long-term monitoring costs associated with this alternative for either process option because no material remains on property.

Summary

This alternative has similar advantages and disadvantages as Alternative 3A.2. However, this alternative was not retained for detailed analysis because the additional effort and cost of this alternative provide no benefits over Alternative 3A.2.

3.3.2 Subunit B - Residues Within Silo 3

3.3.2.1 Alternative 0B - No Action

A description of this alternative is provided in Section 3.2.5.1.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Under this alternative, Subunit B would remain unchanged, except for conditions resulting from the completion of any removal actions that have already been completed or approved. Because the material is not treated or further contained, the material's toxicity, mobility, and volume would not be reduced.

Long-Term Protection of Human Health and the Environment. The material is not contained, treated, or modified. This alternative does not meet the RAOs of preventing the release or migration of waste

material. The potential risk to human health and the environment is increased due to the lack of access controls and, in the event of structural failure of the silos, any barrier preventing direct contact with Silo 3 material, the latter being a major concern, particularly if this alternative is coupled with the no-action alternative for the silo structures (Subunit C). The long-term protection of current on-site workers would be increased since the existing facilities would no longer be operated or maintained. The overall current risks to potential receptors are increased and would be consistent with the BRA results. The long-term risks, when exposed to the residues, exhibit risk exceeding the generally accepted risk range as defined in the NCP.

Short-Term Protection of Human Health and the Environment. This alternative would provide short-term protection of both human health and the environment because there is no remediation and, therefore, no additional exposure risk to the public, workers, or the environment associated with waste handling.

Screening Criteria - Implementability

Technical Feasibility. This alternative is technically feasible because no construction or maintenance activities would be performed.

Administrative Feasibility. No permits or licenses are required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials. No equipment or personnel are required to implement this alternative.

Screening Criteria - Cost

Capital Cost. No capital costs are associated with this alternative.

O&M Costs. There are no short-term or long-term O&M costs associated with this alternative.

Summary

This alternative does not meet long-term RAOs and does not reduce the toxicity, mobility, or volume of wastes. It does provide additional short-term protection to human health and the environment.

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The no-action alternative is readily implementable and has the least cost. The no-action alternative was retained for detailed analysis as a baseline comparison to other remediation alternatives, as required by the NCP.

3.3.2.2 Alternative 1B - In Situ Containment

A description of this alternative is provided in Section 3.2.5.2.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Although migration of contaminants would be reduced by the multimedia cap, LC/DS, slurry wall, and run-on/runoff controls, the waste material will not be treated; therefore, as with the no-action alternative, there is no reduction of contaminant toxicity, mobility, or volume. The volume of contaminated material actually increases due to the injection of structural grout into the headspace of the silos.

Long-Term Protection of Human Health and the Environment. While Alternative 1B would preclude direct contact and ingestion of the residues through containment within a capping system, the long-term protection of human health and the environment could not be assured because of the reliance of this alternative on institutional controls and perpetual maintenance. These active contracts would be required to preclude access to and release from the disposal system. The potential exposures to receptors due to loss of residue containment could be significant and approach baseline conditions.

The feasibility of installing an effective LC/DS under the existing silo is also questionable. Failure of the system coupled with cap degradation could result in significant releases to the underlying soil and groundwater. Such releases could approximate baseline conditions.

The geologic siting conditions present at the Silo 3 area provide additional uncertainty as to the ability of Alternative 1B to effectively attain RAOs. Underlying the silo area is a fairly continuous silty sand lens, providing a preferential horizontal flow path within the till toward Paddys Run. Additionally, only a limited thickness of low permeability clays underlay this sand lens to protect the Great Miami Aquifer. It is questionable whether such siting conditions could ensure continued protection of the environment or comply with ARARs.

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Short-Term Protection of Human Health and the Environment. Potential short-term impacts associated with construction of the multimedia cap include the disturbance of soil, airborne emissions due to dust, and the displacement or loss of vegetation. Appropriate mitigative measures would be implemented to ensure DOE Orders for exposure and other worker and public health protection requirements are attained. This alternative is protective of both human health and the environment during remediation because the planned activities minimize handling of the waste material; the waste material remains in place, thereby minimizing the release of radon gas and direct contact with the waste material during remediation. It achieves ALARA criteria and requires minimal additional worker protection measures.

Because of the proximity of residents to Paddys Run, the potential exists for exposure to trespassing children during the partial relocation of Paddys Run, which is needed to prevent lateral erosion to the cap due to the spatial requirements for the multimedia cap. However, based on the short duration of this activity (28 weeks), and the administrative controls to preclude such access, the potential for such exposures is minimal.

Minimal impacts to wetlands and floodplain areas are anticipated. Overall, few additional risks to the public, workers, or the environment result, but this alternative has greater short-term risks than the no-action alternative due to the earth-moving activities.

Screening Criteria - Implementability

Technical Feasibility. Although the proposed containment technologies are widely used and well tested, a moderate level of difficulty would be experienced in construction of the multimedia cap, LC/DS, and slurry wall, and in relocation of Paddys Run. Since only a minimal amount of maintenance would be required for the multimedia cap to continue to provide the necessary level of containment for the untreated material, this can be accomplished using readily available resources.

Administrative Feasibility. No permits or licenses are required to implement this alternative. Although minimal impacts are anticipated, the relocation of Paddys Run will invoke ARARs related to floodplain, wetlands, and fish and wildlife protection. This will require coordination with the COE in addition to the State of Ohio and EPA Region V. While necessary deed restrictions and markings could be readily implemented, the long-term maintenance of these restrictions and ownership rights are questionable.

Availability of Services and Materials. The cap will need to be designed for an effective life of at least 1000 years. No special equipment is required to implement this alternative. Installing an HDPE liner requires a specialty contractor. Resources required for maintenance and monitoring should be readily available.

Screening Criteria - Cost

The total present worth cost of the alternative is approximately $12M.

Capital Cost. The major components of capital cost include grouting, cap installation, slurry wall construction, monitoring systems, and partial relocation of Paddys Run.

O&M Cost. Short-term O&M costs include monitoring and access controls. Long-term O&M costs include required monitoring. Cap maintenance is expected to be minimal (e.g., patching and mowing) for the first 1000 years. After that point, cap replacement may be needed. The present worth calculations do not consider O&M costs past 30 years.

Summary

There is significant uncertainty as to the ability of the Alternative 1B to attain RAOs for the long term. Additionally, site conditions associated with the silo area provide significant uncertainty as to the ability to attain ARAR disposal facility siting requirements. This alternative does not reduce the toxicity or mobility of wastes, but it does increase the volume of waste. Migration of and exposure to contaminants are reduced, but the long-term effectiveness is less certain than the remaining alternatives due to the dependence on institutional controls and cap maintenance. The cost of this alternative is higher than the cost of the no-action alternative, but lower than the costs for all other Subunit B alternatives. This alternative was screened from further evaluation in the detailed analysis of alternatives because protectiveness cannot be adequately assured; goals of waste reduction/treatment cannot be met; and siting ARARs are not expected to be attained.

3.3.2.3 Alternative 2B - Removal, Stabilization, and On-Property Disposal

A description of this alternative is provided in Section 3.2.5.3.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Cement stabilization and vitrification have been effectively implemented to treat radiological and hazardous waste materials, respectively. Current testing of the vitrification process on FEMP residues has been limited to bench-scale level testing. To better understand the applicability and effectiveness of these treatment processes on the contents of Silos 1, 2, and 3, treatability studies were conducted. The treatability studies evaluated the process options of cement stabilization and vitrification for the contents of Silos 1, 2, and 3.

Based on the results of the treatability studies performed for the cement stabilization and vitrification process options (see Appendix C), cement stabilization and vitrification achieved similar reductions in the toxicity characteristics of the material and the mobility of the contaminants. However, the resultant material volume increased by a range of 152 percent to 163 percent for the material from Silo 3 for the cement stabilization option and decreased by approximately 68 percent for the vitrification option. Vitrification achieves a reduction in contaminant volume and, through organic destruction, a slight reduction in toxicity. Contaminants remaining in the vitrified mass are relatively immobile. Cement stabilization only reduces mobility by reducing the leachability of contaminants. After treatment with either option, the material will be stored in an above-grade disposal vault with a cap, LC/DS, and run-on/runoff controls to minimize the potential for contaminant migration. Residuals will, however, be generated as a by-product of the air emissions control system required for each process. Residuals will be disposed in the vault. Liquid residuals will be treated at the AWWT.

Long-Term Protection of Human Health and the Environment. RAOs would be attained through the implementation of this alternative. The stabilized material would be very resistant to leaching with radon emanation essentially eliminated from the treated undisposed residues. The treated residue would be placed in an above-grade disposal vault. The vault would be designed for a life of 1000 years with the requirement for no continued maintenance. Placement of the residues in the vault supplements the treatment process and promotes added assurance that potential future exposures would be negligible. In the event there was future degradation or inadvertent intrusion into the residue, the potential exposure to such receptors would not be expected to be significant as a result of the characteristics of the treated residue.

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Short-Term Protection of Human Health and the Environment. In addition to those short-term impacts discussed for Alternative 1B, increased short-term exposure to workers is anticipated due to the additional waste material handling associated with the removal, treatment, disposal, and construction of various remediation facilities. By processing material in a facility that employs ALARA criteria and DOE Orders, such as the application of air emission, control equipment and appropriate personal protective equipment for the remediation workers, risks due to contaminant exposure should be controlled to acceptable levels.

Screening Criteria - Implementability

Technical Feasibility. Although the cement stabilization technology is well understood and widely applied, its full-scale application to these materials has yet to be demonstrated. Vitrification is considered an innovative technology and as such, in spite of successful bench-scale treatability studies, the technical feasibility of implementing an effective full-scale system for this material is undetermined. A moderate level of difficulty would be experienced in the removal of the waste, in construction of the treatment facility and vault, and in the operation of the treatment system. Monitoring of influent conditions, additive mixtures, effluent characteristics, and off gases would be needed. Residuals from the off-gas system and liquid residuals would require treatment and/or disposal. Due to these factors, the technical feasibility of this alternative is less than that of Alternatives 0B and 1B.

Administrative Feasibility. No permits or licenses will be required. However, the substantive technical requirements of air emissions permits would also need to be demonstrated.

Availability of Services and Materials. The equipment and engineering required for full-scale vitrification are not as readily available as that for cement stabilization and its construction and operation are more complex. The availability of trained and experienced operators of joule heated melters are limited. Maintenance is also considered to be greater for vitrification. As a result, the implementability of the vitrification process option is the lower of the two.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $28M, and the total present worth cost of the cement stabilization alternative is approximately $37M.

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Capital Cost. The major components of capital cost for this alternative include the vitrification and cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with maintaining access controls, operating and maintaining treatment equipment, and monitoring networks. Long-term maintenance costs include costs associated with required monitoring.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. Waste removal, construction of the various facilities required, and treatment system operation provide a moderate level of difficulty to the implementability of this alternative. This alternative has higher costs than Alternatives 0B and 1B, but it is also more effective because it provides treatment to reduce the mobility of the contaminants. Although the equipment costs for both process options are comparable, the disposal vault costs for the cement stabilization process are nearly 1.5 times that of the vitrification option due to the increase in material volume resulting from the cement stabilization process. This alternative was retained for detailed evaluation because of its increased long-term effectiveness, relative to 1B, achieved through treatment and placement in the vault.

3.3.2.4 Alternative 3B.1 - Removal, Stabilization, and Off-Site Disposal at NTS

A description of this alternative is provided in Section 3.2.5.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Alternative 3B.1 includes the same treatment process options as Alternative 2B, and, therefore, provides the same level of reduction in toxicity, mobility, and volume.

Long-Term Protection of Human Health and the Environment. As with Alternative 2B, this alternative will meet the RAOs of preventing direct contact with or ingestion of the material and preventing the release or migration of waste material because the waste material will be treated and secured in a disposal facility. Long-term reliability is likely greater than that of Alternative 2B for both treatment options because the material will be stored off site in a remote location with little rainfall, sparse population, and a greater depth to groundwater. Since this alternative provides for

removal and treatment of all the waste material in Silo 3, no residuals will remain at Subunit B and thus, no residual risks will exist at the FEMP site. 4738

Short-Term Protection of Human Health and the Environment. Alternative 3B.1 includes the same site preparation, construction, and material processing options as Alternative 2B and, thus, provides the same short-term protection of human health and the environment as Alternative 2B, with the exception of the disposal component of this alternative. Although the hazards associated with construction of the above-grade disposal vault are eliminated for Alternative 3B.1, packaging, shipping, and disposal of the material lowers the short-term protectiveness of human health due to material shipment hazards associated with additional material handling. Measures to reduce exposures to ALARA and to meet DOE Orders during packaging, shipping, and disposal operations, such as use of mechanical equipment and shielding, will be implemented. Shipment to NTS currently requires rail transport on the CSX rail lines, transfer to the Union Pacific rail lines in St. Louis, Missouri and transfer of the material to trucks for road transportation in Las Vegas, Nevada. If an accident were to occur during transport, the nearby public may be exposed to a relatively large volume of radioactive material. This exposure would be limited due to the characteristics of the treated waste. Because cement stabilization produces a greater volume of material than vitrification, more shipments will be required, thus increasing transportation risks.

Screening Criteria - Implementability

Technical Feasibility. The same issues related to the process options exist as those described for Alternative 2B. This alternative is slightly more technically straightforward than Alternative 2B because no on-property disposal is included in this alternative. Preliminary evaluation of the treated residues completed as part of the treatability studies indicates the treated residues would meet the NTS waste acceptance criteria. No long-term maintenance or monitoring, except as required by NTS, is associated with this alternative.

Administrative Feasibility. NTS is a DOE-owned facility which the FEMP has been utilizing for waste disposition since August 1985. A variance to the provisions of DOE Order 5820.2A would be required to enable receipt of this 11(e)2 by-product material at NTS as low level waste. Also, an addendum to the current NTS waste shipping application would be required for this new waste stream. This alternative will require agency approvals and coordination for the interstate shipment of the material. As with Alternative 2B, compliance with substantive requirements of air permits will be

required. This will likely require as much effort as obtaining the approvals for construction of the on-property storage for Alternative 2B.

Availability of Services and Materials. The availability of equipment and engineering required is the same as for Alternative 2B.

Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $27M, and the total present worth cost of the cement stabilization alternative is approximately $34M.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include access control costs, monitoring, and operation and maintenance of treatment systems. There are no long-term monitoring costs associated with this alternative for either process option because no material remains on the property.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. This alternative would be moderately difficult to implement although feasible. The administrative feasibility is similar to that of Alternative 2B, but more difficult than Alternatives 0B and 1B. This alternative has a much higher cost than Alternatives 0B and 1B, but has a slightly lower cost than Alternative 2B. This alternative was retained for detailed evaluation.

3.3.2.5 Alternative 3B.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

A description of this alternative is provided in Section 3.2.5.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Reduction of contaminant toxicity, mobility, or volume is the same as Alternatives 2B and 3B.1.

Long-Term Protection of Human Health and the Environment. RAOs are achieved by this alternative. The long-term protection of this alternative is improved over Alternative 2B because it is assumed that the 483-km (300-mi) facility can be sited in a location with slightly better performance characteristics than the on-property facility; however, the 483-km (300-mi) facility, with its siting in a temperate climate and a populous region, may not offer the long-term protection achieved by disposal at NTS. The long-term effectiveness of each of three disposal options [on property, NTS, and off site within 483 km (300 miles)] are uncertain due to the lack of performance data on the long-term reliability of the disposal systems. The effectiveness of disposal systems in arid climates such as at NTS would be expected to exceed similar disposal concepts in humid climates as in the region of the FEMP.

Short-Term Protection of Human Health and the Environment. The short-term protection of human health and the environment is identical to Alternative 2B during the construction and remediation phase. The potential risk due to material shipment off site to the 483-km (300-mi) facility may be lower than Alternative 3B.1 because this facility is closer than NTS; however, the risk is dependent on whether rail or truck is used because the transportation mode is directly related to the volume of material and, thus, the potential exposure if an accident were to occur during shipment (e.g., injuries or deaths per ton-mile). The risk of transport is also dependent on the nature of loading/unloading cycles, traffic patterns, roadbed conditions, or load configurations (for railroads). Because cement stabilization produces a greater volume of material than vitrification, more shipments will be required thus increasing transportation risks for the cement stabilization process option.

Screening Criteria - Implementability

Technical Feasibility. The technical feasibility is identical to that of Alternative 2B, except additional effort is required for transportation of the treated material to the off-property storage facility.

Administrative Feasibility. The implementability of this alternative with respect to administrative feasibility would be difficult because it is unlikely that a new LLRW facility can be sited, constructed, and the necessary agency and community approvals obtained in a timely manner. The difficulties that have been encountered by the state compacts in siting congressionally mandated LLRW facilities are likely to be encountered when implementing this alternative. Additionally, compliance with the substantive requirements of air permits will have to demonstrated.

Availability of Services and Materials. Availability of services and materials is comparable to that for Alternative 2B.

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Screening Criteria - Cost

The total present worth cost of the vitrification alternative is approximately $27M, and the total present worth cost of the cement stabilization alternative is approximately $35M. There is significant uncertainty in these cost estimates due to the uncertainties on facility siting, permitting, design, etc.

Capital Cost. The major components of capital cost for this alternative include the vitrification process and the cement stabilization process equipment.

O&M Cost. Short-term O&M costs incurred during remediation include costs associated with monitoring and maintaining access controls, and operation and maintenance of the treatment system. There are no long-term O&M costs associated with this alternative for either process option because no material remains on property.

Summary

This alternative is effective in reducing the toxicity, mobility, or volume of contaminants. RAOs would be achieved. Construction of the removal system, treatment of the waste, and the administrative requirements related to the substantive requirements of air permits and to siting a new disposal facility contribute to the very difficult implementability of this alternative. This alternative has a much higher cost than Alternatives 0B and 1B, but is comparable to the costs of Alternatives 2B and 3B.1. This alternative was screened out from further analysis because it is difficult to implement, and it provides less long-term protection but has similar costs as Alternative 3B.1.

3.3.3 Subunit C

3.3.3.1 Alternative 0C - No Action

A description of this alternative is provided in Section 3.2.6.1.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Because the soil and structures are not treated, there is no reduction in toxicity, mobility, or volume.

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Long-Term Protection of Human Health and the Environment. The risks from exposure to soil would be consistent with levels presented in the BRA, and would, therefore, be unacceptable. Erosion of the soil would continue to Paddys Run, resulting in off-site migration of contaminants. Without mitigative measures, the silos will deteriorate and collapse.

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Short-Term Protection of Human Health and the Environment. This alternative would provide short-term protection of both human health and the environment because there is no remediation and, therefore, no additional exposure risk to the public, workers, or the environment associated with waste handling.

Screening Criteria - Implementability

Technical Feasibility. This alternative is technically feasible because no construction or maintenance activities would be performed.

Administrative Feasibility. No permits or licenses are required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials. No equipment or personnel are required to implement this alternative.

Screening Criteria - Cost

Capital Cost. No capital costs are associated with this alternative.

O&M Cost. There are no short-term or long-term O&M costs associated with this alternative.

Summary

This alternative does not meet RAOs and does not reduce the toxicity, mobility, or volume of wastes. The no-action alternative is readily implementable and has the least cost. The no-action alternative was retained for detailed analysis as a baseline comparison to other remediation alternatives, as required by the NCP.

3.3.3.2 Alternative 1C - Demolition and Containment

A description of this alternative is provided in Section 3.2.6.2.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Investigations are currently underway within Operable Units 3 and 5 to examine technologies to minimize waste volumes required for disposal. Technologies being examined include surface decontamination techniques, such as vacuum scabbling for construction materials and washing techniques for soil. Such techniques will be employed to the extent feasible by Alternative 1C to minimize the volume of demolition debris and soil requiring containment. Concrete exhibiting highly elevated direct radiation fields would be segregated from Subunit C wastes for disposition in accordance with the selected alternative for Subunits A or Subunit B.

Long-Term Protection of Human Health and the Environment. The long-term protection of human health and the environment is improved by this alternative because the material is contained under a multimedia cap that will significantly reduce the infiltration of rainwater and subsequent leachate generation. However, there is significant uncertainty in the long-term effectiveness of this alternative because of the location of the capping system adjacent to Paddys Run. The cap would be designed to preclude active maintenance for 1000 years. If there is no failure of these components, this alternative prevents access to the waste material, minimizes leachate production, prevents erosion to Paddys Run, and protects against direct contact with the soil. Physical hazards due to the silos are also removed.

Short-Term Protection of Human Health and the Environment. During the implementation of Alternative 1C, the general public is not likely to be exposed to contaminants because this alternative does not involve handling of the silo contents. However, potential short-term impacts associated with demolition of the silos and construction of the multimedia cap include the disturbance of soil, airborne emissions due to dust, injury to workers due to overhead construction activities using a crane, and the displacement or loss of vegetation. Through the implementation of appropriate mitigative measures and the use of personal protective equipment and construction equipment with emission controls, these impacts would meet DOE Orders for exposure to workers and the public. This alternative is protective of both human health and the environment during remediation because the planned activities eliminate handling of the waste material and minimize the direct contact with the concrete and soil

through use of in situ capping of demolished silo structures and of the berm and soil material. It achieves ALARA criteria and requires minimal additional worker protection measures. 4738

Because of the proximity of residents to Paddys Run, the potential exists for exposure to trespassing children during the partial relocation of Paddys Run, which is needed to prevent lateral erosion to the cap due to the spatial requirements for the multimedia cap. However, based on the short duration of this activity (28 weeks), and in consideration of the active access controls in place, this risk is not considered significant.

Minimal impacts to wetlands and floodplain areas are anticipated. Overall, few additional risks to the public, workers, or the environment result, but this alternative has greater short-term risks than the no-action alternative due to demolition and earth-moving activities.

Screening Criteria - Implementability

Technical Feasibility. The feasibility of this alternative is very good because the proposed silo decontamination process option (e.g., vacuum scabbling) has been successfully demonstrated at other facilities on similar media. Diamond wire cutting is an industry-accepted method for cutting concrete at other nuclear facilities, but with heavy, reinforced concrete, it will be a high-maintenance item and will require water coolant for the cable. This alternative can be readily implemented using available resources.

Administrative Feasibility. No permits or licenses will be required. There is significant uncertainty as to the ability of the geologic conditions present at the silo area to fulfill specific siting requirements under the Ohio Administrative Code relative to siting solid waste disposal facilities. These conditions include the existing and rather continuous zone of saturation underlying the silos and a limited thickness of low permeability clays beneath the sands to inhibit vertical migrations.

Availability of Services and Materials. The cap will need to be designed for an effective life of at least 1000 years. No special equipment is required to implement this alternative. Resources required for maintenance and monitoring should be readily available.

Screening Criteria - Cost

The total present worth cost of the alternative is approximately $33M.

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Capital Cost. The major components of capital cost for this alternative include the cap and monitoring systems.

O&M Cost. Short-term O&M costs associated with this alternative are limited and include only monitoring. Long-term O&M costs include costs associated with required monitoring.

Summary

Alternative 1C meets RAOs. Migration of and exposure to contaminants are reduced, but the long-term effectiveness is uncertain. The cost of this alternative is higher than the cost of the no-action alternative, but lower than the costs for all other Subunit C alternatives. The feasibility of demonstrating attainment of siting ARARs is highly uncertain and potentially impossible due to the poor geologic conditions underlying the area. This alternative was screened from further consideration because of these geologic conditions and improbability of meeting siting ARARs.

3.3.3.3 Alternative 2C - Demolition, Removal, and On-Property Disposal

A description of this alternative is provided in Section 3.2.6.3.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Investigations are currently underway within Operable Units 3 and 5 to examine technologies to minimize waste volumes required for disposal. Technologies being examined include surface decontamination techniques such as vacuum scabbling for construction materials and washing techniques for soil. Such techniques will be employed to the extent feasible by Alternative 2C to minimize the volume of demolition debris and soil requiring containment. Concrete exhibiting highly elevated direct radiation fields would be segregated from Subunit C wastes for disposition in accordance with the selected alternative for Subunit A and Subunit B.

Long-Term Protection of Human Health and the Environment. Contaminated soils, concrete, and other debris would be placed in an above-grade disposal vault with a design life of 1000 years. The long-term performance of such systems is uncertain. Modeling studies conducted to support the siting of similar units across the U.S. have projected reliable long-term performance. Similar disposal concepts, fulfilling equivalent design requirements (i.e., 1000 year design life), have been adopted for the disposal of untreated uranium mill tailings and associated debris in compliance with 41 CFR 192

Subpart A. These design concepts have been employed in humid climates, much like that existing at the FEMP.

In the event the disposal system was breached through long-term erosion or intrusion, exposures would be expected to be minimal due to the low concentration levels of the contaminated wastes.

Alternative 2C will be effective in attaining RAOs for residual soils in the Operable Unit 4 area. Soil excavations within Operable Unit 4 will continue until defined cleanup goals are attained. Discussions on proposed cleanup goals are presented on the detailed analysis of Subunit C alternatives in Section 4.0. Long term protectiveness will be attained through cleanup to these levels and placement of clean soils over excavated areas. The need or requirement for continued administrative controls to preclude intrusion activities to remaining residuals will be addressed in Section 4.0.

Short-Term Protection of Human Health and the Environment. In addition to those short-term impacts discussed for Alternative 1C, increased short-term exposure to workers is anticipated due to the additional waste material handling associated with the removal, disposal, and construction of the various facilities. By employing ALARA criteria and appropriate mitigative measures, risks due to contaminant exposure should be controlled to acceptable levels.

No impacts to wetlands, floodplain, or wildlife are anticipated. Thus, this alternative will provide short-term protection to human health and the environment.

Screening Criteria - Implementability

Technical Feasibility. The constructability and reliability of this alternative is moderate when compared to Alternative 1C because of the additional activities required for subsoil, decant sump tank, and process piping excavation.

Administrative Feasibility. No permits or licenses are required.

Availability of Services and Materials. Personnel and equipment required should be readily available.

Screening Criteria - Cost

The total present worth cost of the alternative is approximately $58M. There is uncertainty on the volume of soils to be removed to attain cleanup goals.

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Capital Cost. The major components of capital cost for this alternative include the disposal facility and monitoring system.

O&M Cost. Short-term O&M costs associated with this alternative are limited to monitoring costs. Long-term O&M costs include required monitoring.

Summary

Alternative 2C meets RAOs. Migration of and exposure to contaminants are reduced, but there is some uncertainty as to the long-term effectiveness of the disposal system. Potential risks in the event of degradation of the disposal vault are projected to be low due to the low concentration of contaminants in Subunit C wastes. The cost of this alternative is higher than the cost of the no-action alternative and Alternative 1C, but lower than the costs for all other Subunit C alternatives. This alternative was selected for further evaluation in the detailed analysis of alternatives.

3.3.3.4 Alternative 3C.1 - Demolition, Removal, and Off-Site Disposal at NTS

A description of this alternative is provided in Section 3.2.6.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. Investigations are currently underway within Operable Units 3 to 5 examine technologies to minimize waste volumes required for disposal. Technologies being examined include surface decontamination techniques such as vacuum scabbling for construction materials and washing techniques for soil. Such techniques will be employed to the extent feasible by Alternative 3C.1 to minimize the volume of demolition debris and soils requiring containment. Concrete exhibiting highly elevated direct radiation fields would be segregated from Subunit C wastes for disposition in accordance with the selected alternative for Subunit A and Subunit B.

Long-Term Protection of Human Health and the Environment. As with Alternative 2C, this alternative will meet the RAOs of preventing direct contact with or ingestion of the material and

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preventing the release or migration of waste material because the waste material will be disposed in a secure facility. The assurance of long-term reliability is considered high because the material will be stored off site in a remote location with little rainfall, sparse population, and a greater depth to groundwater.

Alternative 3C.1 will be effective in attaining RAOs for residual soils in the Operable Unit 4 area. Soil excavations within Operable Unit 4 will continue until defined cleanup goals are attained. Discussions on proposed cleanup goals are presented in the detailed analysis of Subunit C alternatives in Section 4.0. Long-term protectiveness will be attained through cleanup to these levels and placement of clean soils over excavated areas. The need or requirement for continued administrative controls to preclude intrusion activities to remaining residuals will be addressed in Section 4.0.

Short-Term Protection of Human Health and the Environment. Alternative 3C.1 includes the same site preparation, construction, and decontamination as Alternative 2C and, thus, provides the same short-term protection of human health and the environment as Alternative 2C, with the exception of the disposal component of this alternative. Although the hazards associated with construction of the above-grade disposal vault are eliminated for Alternative 3C.1, packaging and shipping the material off site to NTS lowers the short-term protectiveness of human health due to material shipment hazards associated with additional material handling. Measures to reduce exposures to ALARA and to meet DOE Orders during packaging, shipping, and disposal operations will be implemented. Shipment to NTS under this alternative currently requires rail transport on the CSX rail lines, transfer to the Union Pacific rail lines in St. Louis, Missouri and transfer of the material to trucks for road transportation in Las Vegas, Nevada. If an accident were to occur during transport, the nearby public may be exposed to a relatively large volume of LLRW. The risks due to such accidents would be limited due to the low concentrations of contaminates in the wastes.

Screening Criteria - Implementability

Technical Feasibility. Preliminary evaluation of the material generated by this alternative indicates it would meet the NTS waste acceptance criteria No long-term maintenance, except as required by NTS, is associated with this alternative.

Administrative Feasibility. NTS is a DOE-owned facility, which has been employed by the FEMP for waste disposition since August 1985. The wastes generated in this alternative are similar to

currently approved waste streams. A variance to the provisions of DOE 5820.2a may be required to enable receipt of this 11(e)2 by-product material for disposal at NTS as low level waste.

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Availability of Services and Materials. The availability of equipment and engineering required is the same as for Alternative 2C.

Screening Criteria - Cost

The total present worth cost of the alternative is estimated at $60M.

Capital Cost. The major components of capital cost for this alternative include removal, packaging, transport, and disposal of wastes.

O&M Cost. Short-term O&M costs associated with this alternative would be limited to monitoring. There are no long-term O&M costs associated with this alternative.

Summary

RAOs would be achieved. The administrative feasibility is more difficult than Alternatives 0C, 1C, and 2C. This alternative has a much higher cost than Alternatives 0C and 1C. This alternative was retained for detailed evaluation.

3.3.3.5 Alternative 3C.2 - Demolition, Removal, and Off-Site Disposal at a Permitted Commercial Disposal Site

A description of this alternative is provided in Section 3.2.6.4.

Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. The reduction in toxicity, mobility, or volume for this alternative is identical to that for Alternative 3C.1.

Long-Term Protection of Human Health and the Environment. The long-term protection for this alternative is almost identical to that for the NTS disposal option (Alternative 3C.1) because both facilities are located in arid climates with sparse populations.

Short-Term Protection of Human Health and the Environment. This alternative includes the same site preparation, construction, material processing, and disposal options as Alternative 3C.1 and, thus, provides the same short-term protection of human health and the environment. Measures to reduce exposures to ALARA and to meet DOE Orders during packaging and shipping operations will be implemented. Shipment to the permitted commercial disposal site contemplates rail transport. If an accident were to occur during transport, the nearby public may be exposed to a relatively large volume of low concentration radioactive material.

Screening Criteria - Implementability

Technical Feasibility. Technical feasibility is the same as Alternative 3C.1.

Administrative Feasibility. DOE Order 5820.2A prohibits DOE material from being disposed in a commercial facility. To implement this alternative, an exemption to this DOE Order would be required. Such exemptions have been previously granted on a limited basis for small quantities of select wastestreams.

Availability of Services and Materials. The availability of equipment and engineering required is the same as for Alternative 3C.1.

Screening Criteria - Cost

The total present worth cost of the alternative is estimated at $82M.

Capital Cost. The major components of capital cost for this alternative include packaging, transport, and disposal of wastes.

O&M Cost. Short-term O&M costs associated with this alternative are limited. There are no long-term O&M costs associated with this alternative for either process option because no material remains on the property.

Summary

RAOs would be achieved. This alternative is moderately difficult to implement based on technical feasibility and administrative feasibility issues, such as disposal at a commercial facility. Costs are the highest of any Subunit C alternative. This alternative was retained for detailed evaluation.

3.3.3.6 Alternative 3C.3 - Demolition, Removal, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

A description of this alternative is provided in Section 3.2.6.4.

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Screening Criteria - Effectiveness

Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment. The reduction in toxicity, mobility, or volume for this alternative is identical to that for Alternative 3C.1.

Long-Term Protection of Human Health and the Environment. RAOs are achieved by this alternative. The long-term protection of this alternative is improved over Alternative 2C because it is assumed that the 483-km (300-mi) facility can be sited in a location with slightly better performance characteristics than the on-property facility; however, the 483-km (300-mi) facility, with its siting in a temperate climate and a populous region, may not offer the long-term protection achieved by disposal at a facility in an arid climate.

Short-Term Protection of Human Health and the Environment. The short-term protection of human health and the environment is identical to Alternative 3C.1 during the construction and remediation phase. The potential risk due to material shipment off site to the 483-km (300-mi) facility may be lower than Alternative 3C.1 because this facility is closer than NTS, but the risk is dependent on the nature of loading/unloading cycles, traffic patterns, roadbed conditions, or load configurations (for railroads).

Screening Criteria - Implementability

Technical Feasibility. The technical feasibility is identical to that of Alternative 3C.1.

Administrative Feasibility. The implementability of this alternative with respect to administrative feasibility would be difficult because it is unlikely that a new radioactive waste disposal facility can be sited, constructed, and the necessary agency and community approvals obtained in a timely manner. The difficulties that have been encountered by the state compacts in siting congressionally mandated radioactive waste disposal facilities are likely to be encountered when implementing this alternative.

Availability of Services and Materials. Availability of services and materials is comparable to that for Alternative 2C.

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Screening Criteria - Cost

The total present worth cost of the alternative is approximately $58M.

Capital Cost. The major components of capital cost for this alternative include the packaging, transport, and disposal of waste.

O&M Cost. Short-term O&M costs associated with this alternative are limited to monitoring. There are no long-term O&M costs associated with this alternative for either process option because no material remains on property.

Summary

RAOs would be achieved. This alternative is moderately difficult to implement based on technical feasibility, but is extremely difficult based on administrative feasibility issues. This alternative was not retained for detailed evaluation because the administrative requirements related to siting a new disposal facility contribute to the very difficult implementability of this alternative.

3.4 ALTERNATIVE SCREENING SUMMARY

The alternatives have been evaluated against the three general criteria of effectiveness, implementability, and cost. The intent of this evaluation and screening was to select those alternatives for a given GRA that best represent the range of options available for that GRA. If a GRA offered several alternatives that provided similar levels of effectiveness, then those alternatives that were most implementable for the least cost were selected for evaluation in the detailed analysis of alternatives. For those GRAs that possessed a number of alternatives offering different treatment processes with similar overall performance, the best alternative representing each treatment option was selected.

3.4.1 Subunit A

The following alternatives have been selected for further evaluation in the detailed analysis of alternatives:

- Alternative 0A - No Action
- Alternative 2A - Removal, Stabilization, and On-Property Disposal

- Alternative 3A.1 - Removal, Stabilization, and Off-Site Disposal at NTS

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The selected alternatives represent the most viable and cost-effective alternatives for the no-action, containment, and removal and treatment GRAs. The material treatment provided in the selected alternatives include vitrification and cement stabilization. The removal and treatment alternatives offer both on-property and off-site disposal to provide additional flexibility in material disposal.

The following alternatives have been eliminated from the alternative screening process:

- Alternative 1A - In Situ Containment
- Alternative 3A.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site
- Alternative 4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal
- Alternative 5A.1 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at NTS
- Alternative 5A.2 - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

All alternatives that included chemical extraction were eliminated from further analysis because chemical extraction was determined to not provide additional benefits relative to the increased costs. All alternatives that dispose of the material at a facility to be constructed within 483 km (300 mi) of the FEMP site were not retained for evaluation in the detailed analysis because of the significant concerns for implementability. The proposed disposal facility does not currently exist and given the present political and social climate concerning radioactive waste disposal facility siting and the fact that no new radioactive waste disposal facility has been constructed and licensed recently, it is extremely unlikely that this facility could be designed, sited, approved, constructed, and made ready to receive material at the conclusion of material processing operations. The in situ containment alternative was eliminated because protectiveness cannot be assured; goals of reduction/treatment cannot be met; and siting ARARs are not expected to be attained.

3.4.2 Subunit B

The following alternatives have been selected for further evaluation in the detailed analysis of alternatives:

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- Alternative 0B - No Action
- Alternative 2B - Removal, Stabilization, and On-Property Disposal
- Alternative 3B.1 - Removal, Stabilization, and Off-Site Disposal at NTS

The selected alternatives represent the most viable and cost-effective alternatives for the no-action, containment, and removal and treatment GRAs. The vitrification and cement stabilization treatment options proposed in the selected alternatives provide distinctly different but viable treatment options. The removal and treatment alternatives offer both on-property and off-site disposal to provide additional flexibility in material disposal.

The following alternatives have been eliminated in the alternative screening process:

- Alternative 1B - In Situ Containment
- Alternative 3B.2 - Removal, Stabilization, and Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

The alternatives that proposed material disposal at a facility to be constructed within 483 km (300 mi) of the FEMP site were not retained for evaluation in the detailed analysis because of the significant concerns for implementability. The proposed disposal facility does not currently exist and given the present political and social climate concerning radioactive waste disposal facility siting and the fact that no new radioactive waste disposal facility has been constructed and licensed recently, it is extremely unlikely that this facility could be designed, sited, approved, constructed, and made ready to receive material at the conclusion of material processing operations. The in situ containment alternative was eliminated because protectiveness cannot be assured; goals of reduction/treatment cannot be met; and siting ARARs are not expected to be attained.

3.4.3 Subunit C

The following alternatives have been selected for further evaluation in the detailed analysis of alternatives:

- Alternative 0C - No Action
- Alternative 2C - Demolition, Removal, and On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, Off-Site Disposal at NTS
- Alternative 3C.2 - Demolition, Removal, Off-Site Disposal at a permitted commercial disposal site

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The selected alternatives preserve the full range of the GRAs and offer the flexibility of on-property or off-site disposal for all material. 4738

The following alternatives have been eliminated from the alternative screening process:

- Alternative 1C - Demolition and Containment
- Alternative 3C.3 - Demolition, Removal, Off-Site Disposal at a Newly Constructed Facility Within 483 Kilometers (300 Miles) of the FEMP Site

The alternatives that proposed material disposal at a facility to be constructed within 483 km (300 mi) of the FEMP site were eliminated for the reasons discussed in Section 3.4.2. The in situ containment alternative was eliminated because of existing geological conditions and improbability of meeting siting ARARs.

Tables 3-3 through 3-5 summarize the alternative screening for each subunit. Shading is used to designate those alternatives eliminated from further evaluation.

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TABLE 3-3

ALTERNATIVE SCREENING ANALYSIS FOR SUBUNIT A

Alternative Title	Applicable Process Option	Effectiveness	Implementability	Cost
0A - No Action	• NA	Does not meet long-term RAOs. Waste is not treated; thus, there are no reductions in toxicity, mobility, and volume.	Readily implementable	Low
1A - In Situ Containment	• Radon monitoring • Groundwater monitoring • Leachate monitoring • Surface water/sediment monitoring • Physical barriers • Administrative controls • Subsurface Drains • Slurry wall • Multimedia cap • Silo void space grout • Diversion/collection • Grading • Revegetation	Meets short-term RAOs. Long-term protection cannot be assured. Does not reduce toxicity or mobility of wastes, but increases volume. Migration of contaminants reduced. Siting ARARs not expected to be achieved.	Technically implementable with moderate difficulty. Long-term maintenance and ownership is questionable.	Low
2A - Removal, Stabilization, and On-Property Disposal	• Radon monitoring • Groundwater monitoring • Leachate monitoring • Surface water/sediment monitoring • Physical barriers • Administrative controls • Diversion/collection • Grading • Revegetation • Slurry pump w/jetting ring • Cement-based stabilization • Vitrification • Solid/liquid separation • AWWT • Above-grade disposal vault	Effective in reducing the toxicity, mobility, or volume of wastes. RAOs achieved. However, short-term effectiveness is moderate due to the required construction activities, and long-term effectiveness is uncertain due to the potential risks associated with intrusion into the treated waste.	Moderately difficult to implement due to the operation treatment process and meeting substantive requirements of air permits	Medium

TABLE 3-3
(Continued)

Alternative Title	Applicable Process Option	Effectiveness	Implementability	Cost
3A - Removal, Stabilization, and Off-Site Disposal	• Jetting ring with slurry pump • Cement-based stabilization • Vitrification • Solid/liquid separation • AWWT • Rail/truck transport • Nevada Test Site (3A.1)	3A.1 - Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. Long-term effectiveness is greater than 2A because waste will be disposed off site in a remote location with better geologic conditions and no residuals remain at Subunit A. Short-term effectiveness is moderate due to the required construction activities and hazards of waste shipments.	Moderately difficult to implement due to operation of treatment system and meeting substantive requirements of air permits, and obtaining disposal approvals	Medium
	• New facility within 483 km (300 mi) (3A.2)	3A.2 - Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. However, short-term effectiveness is moderate due to the required construction activities, but is lowered due to hazards with waste shipments. Long-term effectiveness is greater than 2A because waste will reside off site, but not as great as 3A.1.	Difficult to implement due to operation of treatment system, siting new facility, and meeting substantive requirements of air permits	Medium
4A - Removal, Chemical Extraction, Stabilization, and On-Property Disposal	• Radon monitoring • Groundwater monitoring • Leachate monitoring • Surface water/sediment monitoring • Physical barriers • Administrative controls • Diversion/collection • Grading • Revegetation • Slurry pump w/jetting ring • Cement-based stabilization • Vitrification • Solid/liquid separation • AWWT • Chemical extraction • Above-grade disposal vault	Similar short-term and long-term effectiveness as Alternative 2A. However, some contamination not stabilized prior to disposal, thus long-term reliability is decreased.	Difficult to implement due to complex treatment and reliance on interdependent processes	High

TABLE 3-3
(Continued)

Alternative Title	Applicable Process Option	Effectiveness	Implementability	Cost
5A - Removal, Chemical Extraction, Stabilization, and Off-Site Disposal	• Slurry pump w/jetting ring • Cement-based stabilization • Vitrification • Solid/liquid separation • AWWT • Chemical extraction • Rail/truck transport • Nevada Test Site (5A.1)	5A.1 - Less effective than Alternative 3A.1 because of lower effectiveness of chemical extraction process.	More difficult than Alternative 3A.1 due to complex treatment and reliance on interdependent processes	High
	• New facility within 483 km (300 mi) (5A.2)	5A.2 - Less effective than Alternative 3A.2 because of lower effectiveness of chemical extraction process.	More difficult than Alternative 3A.2 due to complex treatment and reliance on interdependent processes	High

NOTE: Shading designates those alternatives eliminated from further evaluation.

TABLE 3-4

ALTERNATIVE SCREENING ANALYSIS FOR SUBUNIT B

Alternative Title	Applicable Process Option	Effectiveness	Implementability	Cost
0B - No Action	• NA	Does not meet long-term RAOs. Waste is not treated; thus, there are no reductions in toxicity, mobility, and volume.	Readily implementable	Low
1B - In Situ Containment	• Groundwater monitoring • Radon monitoring • Leachate monitoring • Surface water/sediment monitoring • Physical barriers • Administrative controls • Subsurface Drains • Slurry wall • Multimedia cap • Silo void space grout • Diversion/collection • Grading • Revegetation	Meets short-term RAOs. Long-term protection cannot be assured. Does not reduce toxicity or mobility of wastes, but does increases volume. Migration of contaminants reduced. Siting ARARs not expected to be achieved.	Technically implementable with moderate difficulty. Long-term maintenance and ownership is questionable.	Low
2B - Removal, Stabilization, and On-Property Disposal	• Groundwater monitoring • Radon monitoring • Leachate monitoring • Surface water/sediment monitoring • Physical barriers • Administrative controls • Diversion/collection • Grading • Revegetation • Vacuum w/cutterhead • Cement-based stabilization • Vitrification • AWWT • Above-grade disposal vault	Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. However, short-term effectiveness is moderate due to the required construction activities. Some uncertainty in long-term effectiveness related to performance of disposal facility. Risks due to degradation of the disposal system are considered low due to the characteristics of the treated wastes.	Moderately implementable due to treatment process and meeting substantive requirements of air permits	Medium

TABLE 3-4
(Continued)

Alternative Title	Applicable Process Option	Effectiveness	Implementability	Cost
3B - Removal, Stabilization, and Off-Site Disposal	• Vacuum w/cutterhead • Cement-based stabilization • Vitrification • AWWT • Rail/truck transport • Nevada Test Site (3B.1)	3B.1 - Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. Alternative provides long-term effectiveness. Short-term effectiveness is moderate due to the required construction activities and hazards of waste shipments.	Moderate difficulty in implementation due to operation of treatment system and administrative requirements	Medium
	• New facility within 483 km (300 mi) (3B.2)	3B.2 - Effective in reducing the toxicity, mobility, or volume of wastes. RAOs are achieved. The long-term and short-term effectiveness are consistent with 3B.1 except for a reduction in long-term effectiveness relevant to climate of new facility.	Difficult to implement due to siting new facility.	Medium

Note: Shading designates those alternatives eliminated from further evaluation.

TABLE 3-5

ALTERNATIVE SCREENING ANALYSIS FOR SUBUNIT C

Alternative Title	Applicable Process Option	Effectiveness	Implementability	Cost
0C - No Action	• NA	Does not meet long-term RAOs. Waste is not treated; thus, is no reduction in toxicity, mobility, and volume.	Readily implementable	Low
1C - Demolition and Cap	• Radon monitoring • Groundwater monitoring • Leachate monitoring • Surface water/sediment monitoring • Physical barriers • Administrative controls • Slurry wall • Multimedia cap • Diversion/collection • Grading • Revegetation • AWWT • Vacuum Scabbling • Pressure Washer • Diamond rope/chain saw	Meets RAOs. Long-term effectiveness is uncertain.	Technically feasible to implement. Administratively difficult due to ability to demonstrate to attainment of disposal facility siting requirements	Medium

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TABLE 3-5
(Continued)

Alternative Title	Applicable Process Option	Effectiveness	Implementability	Cost
2C - Demolition, Removal, and On-Property Disposal	• Radon Monitoring • Groundwater monitoring • Leachate monitoring • Surface water/sediment monitoring • Physical barriers • Administrative controls • Diversion/collection • Grading • Revegetation • Loader/dozer • Crane w/clamshell system • Backhoe • Vacuum scabbling • Pressure washing • AWWT • Diamond rope saw • Diamond chain saw • Above-grade disposal vault	Meets RAOs. Alternative provides an effective, long-term solution with some uncertainty. Short-term effectiveness is moderate due to the required construction activities.	Moderate difficulty in implementation due to the additional construction activities	High
3C - Demolition, Removal, and Off-Site Disposal	• Loader/dozer • Crane w/clamshell system • Backhoe • Vacuum scabbling • Pressure washing • AWWT • Diamond rope saw • Diamond chain saw • Rail/truck transport			
	• Nevada Test Site (3C.1)	3C.1 - Meets RAOs. Provide effective permanent solution.	Moderate difficulty in implementation due to administrative requirements	High

TABLE 3-5
(Continued)

Alternative Title	Applicable Process Option	Effectiveness	Implementability	Cost
	• Permitted Commercial Disposal Site (3C.2)	3C.2 - Same as 3C.1.	Moderate difficulty in implementation due to administrative requirements for disposal at commercial facility	High
	• New facility within 483 km (300 mi) (3C.3)	3C.3 - Same as 3C.2, but long-term effectiveness may not be as great due to the better climate and lower population at existing disposal facilities.	Very difficult due to siting new facility	High

NOTE: Shading designates those alternatives eliminated from further evaluation.

4.0 DETAILED ANALYSIS OF ALTERNATIVES

4.1 INTRODUCTION

This section presents the detailed analysis of alternatives which passed the screening process conducted previously in Section 3.0. Five alternatives were selected for detailed analysis for Subunit A, five were selected for Subunit B, and four were selected for Subunit C. Table 4-1 summarizes the alternatives to be assessed by the detailed analysis. Reference is also made to Tables 3-3 through 3-5, which highlight the results of the screening of alternatives performed in Section 3.0.

4.1.1 Purpose of the Detailed Analysis

The detailed analysis includes a presentation and assessment of relevant information which provides the basis for selecting an alternative and preparing a ROD. The detailed analysis evaluates each alternative against nine criteria which have been developed by EPA to address CERCLA requirements. Building upon the development and screening of alternatives, the detailed analysis presents more in-depth information, including treatability study and pertinent RI data which are used in the assessment of the alternatives relative to the CERCLA criteria. Following the detailed analysis, a comparative analysis of the alternatives will be presented in Section 5.0. The comparative analysis evaluates the alternatives relative to two threshold criteria which must be met. This is followed by an assessment of the alternatives against the five balancing criteria, highlighting the key advantages, disadvantages, and tradeoffs which are considered as part of the selection process. The Proposed Plan documents selection of a preferred alternative and solicits community and state agency comments which are incorporated into an assessment of the alternatives against the two modifying criteria.

4.1.2 Overview of the Detailed Analysis

Specific statutory requirements for remedial actions are specified under CERCLA Section 121, as amended. These requirements include protection of human health and the environment, compliance with ARARs, a preference for permanent solutions which incorporate treatment as a principal element (to the maximum extent practicable), and cost-effectiveness. To assess whether alternatives meet the requirements, EPA has identified nine criteria in the National Contingency Plan that must be evaluated for each alternative retained through the screening stage [Section 300.430(e)(9)(iii)]. Provided below are summaries of the factors that comprise the nine criteria and an overview of the approach taken by this feasibility study to address the criteria. Because the first two criteria, overall protection of human health and the environment and compliance with ARARs, are the threshold criteria that relate directly to statutory findings that must be made in the Record of Decision,

TABLE 4-1

OPERABLE UNIT 4 SUBUNIT ALTERNATIVES SELECTED FOR DETAILED ANALYSIS

Operable Unit 4 Subunit	Alternative Designation	Description
SUBUNIT A:	0A	No Action
Silos 1 and 2 -	2A/Vit	Removal, Vitrification, On-Property Disposal
Contents and decant tank sludge	2A/Cem	Removal, Cement Stabilization, On-Property Disposal
	3A.1/Vit	Removal, Vitrification, Off-Site Disposal [Nevada Test Site (NTS)]
	3A.1/Cem	Removal, Cement Stabilization, Off-Site Disposal (NTS)
SUBUNIT B:	0B	No Action
Silo 3 Contents -	2B/Vit	Removal, Vitrification, On-Property Disposal
(Cold metal oxides)	2B/Cem	Removal, Cement Stabilization, On-Property Disposal
	3B.1/Vit	Removal, Vitrification, Off-Site Disposal (NTS)
	3B.1/Cem	Removal, Cement Stabilization, Off-Site Disposal (NTS)
SUBUNIT C:	0C	No Action
Silos 1, 2, 3, and 4 -	2C	Demolition, Removal, On-Property Disposal
Structures, soils, and debris	3C.1	Demolition, Removal, Off-Site Disposal (NTS)
	3C.2	Demolition, Removal, Off-Site Disposal (Commercial Facility)

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additional detail is provided for the discussions. Where appropriate, reference is made to related discussions elsewhere in this report.

4.1.2.1 Overall Protection of Human Health and the Environment

This evaluation criterion provides an assessment of whether the alternative achieves and maintains adequate protection of human health and the environment, in accordance with the remedial action objectives established in Section 2.0. Because the scope of this criterion is broad, it also reflects the discussions of the four criteria which follow below. Evaluation of this criterion should describe how site risks, posed through each pathway that is being addressed by the FS, are eliminated, reduced, or mitigated through treatment, engineering, or institutional controls. The acceptable risk levels under CERCLA for known or suspected carcinogens are generally concentration levels in environmental media that represent an excess upper bound of lifetime cancer risk to an individual of between 10^{-4} to 10^{-6}. To achieve this level of human health protection for the entire FEMP site, the initial point of departure for remediation of Operable Unit 4 is less than or equal to 10^{-6}. This will help to ensure that the remediation goal for the entire FEMP site will not exceed 10^{-4} as remedial alternatives are selected for other operable units. The remedial action objectives previously identified in Section 2.1 were developed consistent with this methodology.

To evaluate the alternatives for the attainment of protection of human health (and the associated criteria of compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness), an FS risk assessment was performed employing the methodologies identified in the Risk Assessment Work Plan. The FS risk assessment is included as Appendix D of this report. To assess protectiveness, two viable land use scenarios were evaluated along with representative receptors in order to provide a boundary of risk information to decision makers. The land use scenarios examined included a Future Land Use without Continued Federal Ownership scenario and a Future Land Use with Continued Federal Ownership scenario. The assumptions for these scenarios are summarized below.

Future Land Use without Continued Federal Ownership Scenario

This scenario was examined to assess risk for the least restrictive future land use assumption. Under this scenario, the facility is assumed to revert to the primary land use of the land surrounding the FEMP site, a family farm. For this risk scenario, an on and off-property farmer are examined. For the on-property farmer, two receptors are examined, a Reasonable Maximum Exposure (RME) and a Central Tendency (CT) resident farmer. The RME resident farmer uses risk parameters to provide an

upper bound estimate of the risk an on-property farmer could reasonably be expected to receive. Under the CT resident farmer receptor, risk parameters are adjusted as identified in Appendix D, to provide an estimate of the risk the on-property farmer could reasonably be expected to receive under typical living conditions. For this land use scenario, active operations and maintenance are assumed to continue until site-wide remedial action objectives are attained. After this time, active maintenance is assumed to be discontinued. Five-year CERCLA statutory reviews are assumed to continue. The residue containment system is assumed to remain relatively unchanged with no direct intrusion into the waste materials occurring. Exfiltration from the capped residues is estimated to increase to 1.3 cm/yr to the underlying Great Miami Aquifer. The on-property farmer is assumed to withdraw his drinking , crop irrigation, and livestock water from the Great Miami Aquifer from a point adjacent to the disposal vault or within the Operable Unit 4 boundary.

Future Land Use with Continued Federal Ownership Scenario

This scenario was examined to provide risk information for a viable future site land use which incorporates passive institutional controls. Under this scenario, the FEMP site is assumed to remain under the ownership of the federal government. The government is assumed to continue to exercise its rights as owner of the property to preclude further development of the site. Continued federal ownership would preclude certain activities on the property including homesteading, farming, and the installation of domestic wells. Active access controls are assumed to be discontinued following the attainment of site remedial action objectives. To provide an upper bound estimate of the risk contribution reasonably expected to be received under this land use, a recreational user is examined in addition to the off-property farmer. The recreational user is assumed to be an individual who plays on the property as a child and uses the property less frequently for recreational purposes as an adult. Assumptions for operations and maintenance, and exfiltration rates from the capped residues, are consistent with the other land use scenario described above.

To evaluate the alternatives for attainment of overall protection of the environment, the remaining pathways to environmental receptors were examined to determine the degree to which the alternatives mitigate environmental degradation. Section 2.0 summarizes benchmark values which are considered to be protective of ecological receptors. These can be compared to contaminant concentrations determined by the fate and transport modeling conducted for assessing alternative performance. The prevention of degradation of the Great Miami Aquifer due to migration of contaminants from residual wastes and soils is a remedial action objective which is protective of both human health and the environment. Attainment of this objective can be measured primarily by compliance with maximum

contaminant levels (MCLs), proposed MCLs, and maximum contaminant level goals (MCLGs) established under the Safe Drinking Water Act (SDWA). Each alternative is also assessed for its short-term and long-term effects on soil and geology, water quality and hydrology, air quality, biotic resources, and wetlands and floodplains.

4.1.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

This criterion addresses the attainment of promulgated federal and state environmental or facility siting requirements. If an alternative cannot meet a requirement, a determination can be made that a waiver under CERCLA may be appropriate and a basis for justifying the waiver discussed. ARARs consist of two sets of requirements, those that are applicable and those that are relevant and appropriate. Applicable requirements are those substantive standards that specifically address the situation at a CERCLA site. In certain cases standards may not exist in the promulgated regulation that address the proposed action or the constituents of concern. In these cases, nonpromulgated advisories, criteria, or guidance that were developed by EPA, other federal agencies, or states are to be considered (TBC) in establishing remedial action objectives that are protective of human health and the environment. In addition, there are other requirements which do not fall within the EPA-established criteria for ARARs. These other requirements include DOE Orders[1] which pertain only to DOE facilities. EPA's Compliance with Other Laws Manual (OSWER Directive 9234.1-01) states "...DOE orders are not promulgated requirements and are not potential ARARs." The manual further states that "To the extent that DOE orders are more stringent or cover areas not addressed by existing ARARs, they should be considered when necessary to develop a protective remedy." In this document, DOE Orders are identified as TBCs only when no promulgated ARAR exists to ensure adequate protection of human health and the environment. A table summarizing other requirements pertinent to Operable Unit 4 remediation is included in Appendix F.

Types of ARAR/TBCs

In addressing a requirement that may affect a remedial action being considered for a site, a determination is made regarding its relationship to: (1) the location of the action; (2) the

[1]Atomic Energy Act (AEA) requirements for DOE's waste management are incorporated into DOE Orders, developed under DOE's AEA authority. The Orders are generally consistent with and typically include technical requirements similar or equivalent to those in NRC regulations and that are appropriate for DOE facilities. DOE Order substantive requirements are "To-Be-Considered" (TBC) requirements, which, when included in a DOE CERCLA ROD, are enforceable cleanup standards under CERCLA. Substantive technical requirements of promulgated and non-promulgated NRC requirements may be "Relevant and Appropriate" or TBCs to ensure protection of human health and the environment.

contaminants involved, and (3) the specific components of the action, such as factors unique to a certain technology. Three types of ARARs result from this process: location-specific ARARs, chemical-specific ARARs, and action-specific ARARs.

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Chemical-specific ARARs are usually health- or risk-derived numerical values that establish an acceptable level or concentration of chemical or radionuclide that may remain in specific environmental media after remediation is complete. These levels are deemed to be protective of human health, and are used to help establish remedial cleanup goals.

Location-specific ARARs generally restrict certain activities, or dictate where certain activities may be conducted solely because of geographical, hydrologic, or land use concerns.

Action-specific ARARs are usually restrictions on the conduct of certain activities or the operation of certain technologies at the site.

Summary of Key ARAR/TBCs

Appendix F of this report provides an analysis of potential ARARs for Operable Unit 4. Included are tables which present the documentation of ARARs for each of the alternatives. The approach adopted by this FS is to focus the evaluation discussion on the alternatives' ability to comply with key ARARs which are critical to meeting this threshold criterion. The key ARAR/TBCs include the following:

Chemical-Specific ARAR/TBCs

- 40 CFR 141.11, 141.15, 141.16, 141.61, and 141.62 (Safe Drinking Water Act)-MCLs
- 40 CFR 141.51 - nonzero MCLGs
- 40 CFR 191.16 - groundwater protection limitations
- 40 CFR 191.13 - annual dose equivalent, groundwater
- DOE Order 5400.5 - annual effective dose equivalent from all pathways
- 40 CFR 264.94 - groundwater point of compliance
- 40 CFR 61 Subpart Q (NESHAP) - radon-222 flux
- 40 CFR 192 Subpart A - average annual radon-222 concentrations

Location-Specific ARAR/TBCs

- OAC 3745-27-07 - solid waste disposal vault design
- OAC 3745-27-07 (B)(5) - siting prohibition, sole-source aquifers
- OAC 3745-27-07 (C) (1) and (2) - technical considerations for exemption to above

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- 40 CFR 258.12 - wetlands restrictions
- 10 CFR 1022 - Floodplain/wetlands review
- 40 CFR 257.3-1 - location standards for solid waste disposal facilities
- 40 CFR 264.18 - prohibition for locating disposal facilities in the 100-year floodplain

Action-Specific ARAR/TBCs

- ORC 3734.02 - prohibition for building/drilling on land where hazardous/solid waste disposed
- 40 CFR 264 - protection and marking of landfill capping systems
- 10 CFR 61 - intruder protection requirements for capping systems
- 40 CFR 191 - standards for management, storage, and disposal of spent nuclear, high level and transuranic wastes (as directed by USEPA out of concern for intruder protection)

4.1.2.3 Long-term Effectiveness and Permanence

This criterion evaluates the extent to which an alternative achieves an overall reduction in risk to human health and the environment after the response objectives have been met. It considers the degree to which the alternative provides sufficient long-term controls and reliability to maintain exposures to human and environmental receptors within protective levels. The principal factors addressed by this criterion include magnitude of residual risk and adequacy and reliability of controls. Also discussed are the uncertainties associated with both of these factors.

This FS evaluates the magnitude of residual risk to human health in terms of a risk evaluation under the land use scenarios previously discussed in Section 4.1.2.1. The basis of this evaluation is presented in Appendix D. The evaluation considers the characteristics of any remaining untreated and treated waste forms which pose potential risks in the future. The magnitude of residual risk to environmental receptors is assessed in a qualitative manner by describing the potential long-term environmental impacts of the alternative on soil and geology, water quality and hydrology, air quality, biotic resources, and wetlands and floodplains. Impacts on socioeconomics, land use, and cultural resources are also considered.

The evaluation of adequacy and reliability of controls assesses the effectiveness of any treatment, containment, or institutional measures which are part of the alternative. Factors considered include performance characteristics, maintenance requirements, and expected durability. Information and data from treatability studies, past performance, and similar technology applications are incorporated into

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the evaluation as appropriate. Institutional controls are considered where they potentially improve the effectiveness of engineered measures.

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4.1.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion reflects the statutory preference for remedial alternatives containing a principal component which substantially reduces toxicity, mobility, or volume of hazardous substances. The evaluation considers the extent to which remedial action process technologies can effectively and irreversibly fix, transform, immobilize, and/or reduce the volume of waste materials and contaminated media.

Two treatment technologies are principal components of several alternatives selected for this detailed analysis. Vitrification and cement stabilization are assessed for their ability to reduce the toxicity, mobility, and volume of the contents of Silos 1, 2, and 3. The evaluation includes the results of treatability studies which were conducted during the RI/FS. The treatability study results are presented in Appendix C and Appendix H of this document. The treatability studies compare key characteristics (e.g., leachability of constituents of concern, reduction of radon emanation) of the untreated and treated waste forms in order to assess the reduction of risk afforded by the treatment processes. Additional tests were conducted to determine the expected long-term performance of the treated waste forms in maintaining the level of protectiveness achieved.

4.1.2.5 Short-term Effectiveness

This criterion addresses the effects of the alternative during the construction and implementation phase until the remedial action objectives are achieved. The evaluation considers the effects on human health and the environment posed by operations conducted during the remedial action. Both the potential impacts and associated mitigative measures are examined for maintaining protectiveness for the community, remedial action workers, and environmental receptors over the duration of the activities.

Appendix D of this FS provides an evaluation of short-term risks to the public and workers under various scenarios associated with an alternative's operations. Potential short-term risks to the public include inhalation of radon gas released during waste removal and treatment operations, radiological exposure and physical injury during waste transport off site, and potential exposure to a trespassing child postulated to intrude on site during remedial activities. Potential short-term risks to workers include: direct radiation exposures during construction, waste treatment, and transportation; physical

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injury or death during construction and transportation activities; and non-remediation worker exposures to airborne radioactive and chemical contaminants during soil removal operations. The alternative analysis also includes an assessment of mitigative measures such as engineering and institutional controls which are expected to minimize potential risks to the public and workers.

Short-term environmental impacts and mitigation measures are assessed in a qualitative manner including environmental media and potentially sensitive resources.

4.1.2.6 Implementability

This criterion examines the technical and administrative factors affecting implementation of an alternative and considers the availability of services and materials required during implementation. Technical factors to be assessed include the ease and reliability to initiate construction and operations, the prospects for implementing any needed future actions, and the adequacy of monitoring systems to detect failures. Administrative factors examined include permitting and coordination requirements among the lead agency and regulatory agencies. Services and materials considerations include: treatment, storage, and disposal capacities; equipment and operator availability; and prospective technology applicability or development requirements.

Where proven technologies are proposed for use by an alternative, the assessment of technical feasibility examines the performance history of the technologies in direct applications, or considers the expected performance for similar applications. For innovative technologies, data from bench-scale tests are evaluated for expected scale-up performance characteristics; and, the feasibility of scaling up bench tests to pilot tests is reviewed. Any uncertainties associated with construction, operation, and performance monitoring are also addressed.

The evaluation of administrative feasibility includes a discussion of those actions required to coordinate with regulatory agencies to establish the framework for complying with any key substantive technical requirements which must be attained by an alternative. Additionally, alternatives involving off-site transportation are reviewed to assess the feasibility of implementing interstate transportation and disposal.

The availability of services and materials is addressed by analyzing the material components of the proposed technologies to determine the locations and quantities of those materials, and by reviewing

process operations to identify any special services, operator skills, or training required to readily implement the process. 738

4.1.2.7 Cost

The cost criterion reviews capital costs (direct and indirect) and operating and maintenance costs. A present worth analysis evaluates costs that occur over different time periods. A sensitivity analysis may be conducted if there is sufficient uncertainty concerning specific assumptions.

The approach adopted by this FS includes a presentation of capital costs, along with a summary of assumptions used to estimate the capital cost for each major component of the alternative. A cost estimate table provides detail for each of the major cost elements of each alternative, including operating and maintenance costs and total present worth costs. Sensitivity analyses are provided in Section 5.0.

4.1.2.8 State Acceptance

This criterion addresses the comments made by the affected state on the alternatives being considered for site remediation. Because formal state comments will not be received until after the FS-EIS has been issued for public review, this criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.1.2.9 Community Acceptance

This criterion addresses the comments made by the community on the alternatives being considered. Because public comments will not be received until after the FS-EIS has been issued for review, this criterion will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period.

4.1.3 Overview of Section 4.0

Sections 4.2 through 4.4 present the detailed analysis of alternatives for Subunits A, B, and C, respectively. Consistent with the approach of presenting Operable Unit 4 alternatives for each of Subunits A, B, and C, the detailed analysis evaluates the respective subunit alternatives against the CERCLA criteria.

The remaining sections include: Section 4.5, Monitoring and Mitigative Measures; Section 4.6, Unavoidable Adverse Impacts; Section 4.7, Irreversible and Irretrievable Commitment of Resources;

Section 4.8, Impacts of Potential Loss of Institutional Actions; and Section 4.9, Short-Term Uses and Long-Term Productivity.

4.2 SUBUNIT A

4.2.1 Analysis of Alternative 0A - No Action

The no-action alternative is retained throughout the FS process as required by the NCP (40 CFR 300.430[e][6]). This alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken. In the no-action alternative, the material is considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. The contents of Silos 1 and 2 and the remaining sludges in the decant sump tank would remain in place. Alternative 0A does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and Alternative 0A does not provide for access control actions taken to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

4.2.1.1 Overall Protection of Human Health and the Environment

The no-action alternative does not meet the remedial action objectives for Subunit A. The Baseline Risk Assessment, previously summarized in Section 1.6.3, presented information on the risks to a number of representative receptors for the no-action alternative under varied land use assumptions. Upon comparison of the results of the Baseline Risk Assessment with the generally accepted risk range of 10^{-4} to 10^{-6}, the no-action alternative would not be adequately protective of human health under all evaluated land use scenarios, except current land use conditions with continuation of access controls. For these land use scenarios, at least one receptor receives risks which are calculated to exceed 10^{-4}.

4.2.1.2 Compliance with ARARs

With no further action, certain ARAR/TBCs would not be met. Eventual failure of the silos would result in exceedances of radon release limits under 40 CFR 61 Subpart Q, and release of material from the silos that would violate State of Ohio water quality standards for receiving surface waters, and exposure limits to the public from radionuclides established under DOE Order 5400.5. Drinking water MCLs and MCLGs would most likely be exceeded if the released material were to migrate into groundwater of the Great Miami Aquifer.

Other ARARs, such as the location-specific siting of a solid waste landfill, and the action-specific closure performance standard under RCRA for a disposal vault, would not be met by this alternative. In addition, design standards for a RCRA solid or hazardous waste disposal vault, or for intruder protection from direct radiation hazards associated with radioactive waste disposal would not be met.

CERCLA Section 121 cleanup standards, including compliance with ARARs, apply only to remedial actions EPA determines should be taken under CERCLA Sections 104 and 106 authority. A no-action decision can only be made when no remedial action is necessary to reduce, control, or mitigate exposure because the site is already protective of human health and the environment. If the alternative passes the protectiveness threshold criteria, then compliance with ARARs is not pertinent to the selection of Alternative 0A.

4.2.1.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

This alternative does not provide a long-term solution that is effective and permanent, as previously identified in the Baseline Risk Assessment. Under the no-action alternative, continued deterioration of the containment system for Silos 1 and 2 and the decant sump can be expected. In the event DOE or other responsible parties do not control this deterioration, it is reasonable to expect the existing silo domes to collapse and the decant system to corrode. This loss of containment would lead to increased infiltration of stormwater and increased infiltration from the silos to the underlying perched groundwater zone. Increased contamination levels in the perched zone will consequently lead to higher concentrations of contaminants in Paddys Run surface water and sediment, and the Great Miami aquifer. Additionally, radon flux rates could be expected to increase, leading to increased ambient radon concentration in the surrounding atmosphere and increased plateout of radon daughters in the berm and surface soils. These increased concentrations of contaminants in the environmental media surrounding Operable Unit 4 would lead to additional overall risks to human and environmental receptors.

As previously discussed, the risks due to carcinogenic and non-carcinogenic contaminants present within Operable Unit 4 exceed generally accepted regulatory levels for all foreseeable future land use scenarios.

Adequacy and Reliability of Controls

Deterioration of residue containment systems could be expected to increase the concentration of contaminants in surface water reaching adjacent biotic resources. The existing Waste Pit Area Stormwater Runoff Control System currently limits such discharges. Additionally, the current level of radon exposures to biological receptors could be expected to increase with the loss of containment on Silos 1 and 2. Current levels of radon exposures to species near Operable Unit 4 are near background levels. No threatened and endangered species or critical habitats for these species occur in or adjacent to Operable Unit 4 and, thus, are unaffected by the conditions within the study area.

Long-Term Environmental Impacts

Alternative 0A would not be protective of human health and the environment in the long term because it does not protect against the potential exposure to waste materials and the possibility of silo collapse. Silo collapse and subsequent loss of containment could lead to increased contamination levels in the perched groundwater zone and in surface water and sediment in the 100- and 500-year floodplain, i.e., Paddys Run and the 0.36 ha (0.76 acre) wetland south of Silos 1 and 2.

4.2.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reduction of toxicity, mobility or volume through treatment is not applicable to Alternative 0A, No Action, because this alternative does not include treatment.

4.2.1.5 Short-Term Effectiveness

This evaluation criteria addresses the effectiveness of the alternative during the construction and implementation of the remedial action. Under the no-action alternative, no remedial action will be taken; therefore, there will be no increase in short-term risks.

4.2.1.6 Implementability

Under the no-action alternative, no remedial action would be taken; therefore, there would not be any difficulties or uncertainties with construction. The no-action alternative is included in the detailed analysis of alternatives for a baseline comparison.

4.2.1.7 Cost

There are no costs associated with Alternative 0A-No Action.

4.2.2 Analysis of Alternative 2A/Vitrification

This alternative requires the removal of Silos 1 and 2 contents and the remaining sludge from the bottom of the decant sump tank, stabilization of the materials by vitrification, and on-property disposal of the treated materials. The silo contents and decant sludge would be retrieved with a hydraulic mining device introduced through manways in the structures. The equipment would be supported from a work platform that spans the silos. The material would then be transferred to a processing facility for vitrification. The treated material would then be placed in an above-grade disposal vault constructed on property. Treated residues may be staged and/or placed into interim storage, as required pending availability of on-site disposal capacity. The above-grade disposal vault would feature an inadvertent intrusion barrier and a radon barrier. The contaminated debris from the dismantlement of the material processing facility, the hydraulic removal device, and the work platform would be dispositioned consistent with the selected remedy for Subunit C. Approximately 3785 liters (1000 gal.) of sludge from the decant sump tank would be mixed with the silo contents and vitrified. The alternative would include the placement of markers to define waste disposal areas, the use of deed restrictions, and the provision of continued federal ownership of the property to preclude drilling or residential development.

Site Preparation and Construction

Site preparation would begin with the clearing and grubbing of vegetated areas near the silos and to the east. In preparation for the construction of the material processing facility, the packaging pad for the removed berm material, the material slurry transfer trench, and the construction of roads and equipment staging areas, approximately 3.2 ha (8 acres) would be cleared and grubbed. In addition to the clearing and grubbing activities, the southern area of the remediation site would be filled, as required, to level the site. The volume of fill soil is estimated to be approximately 11,500 m^3 (15,000 yd^3), which could be obtained from excess unaffected soil removed from the silo berms.

The site preparation activities would also include the installation of roadways, site fencing, site lighting, process water piping, sewer lines, power poles, and the extension of site power to the processing elements requiring service.

Processing elements to be constructed include the work platform with an underlying foundation (used during removal of the material), a material processing facility for vitrification, and the above-grade disposal vault.

The material removal work platform would be a reusable, rail-mounted, 54-m (180-ft) structure truss bridge that will span the silos (Figure 4-1). The placement of the rail system would require the removal of part of the berms. The work platform would support the hydraulic mining device and allow the placement of the mining device into each of the four perimeter manways and the center manway in each silo. The work platform would be built between Silos 3 and 4 rather than directly over either Silo 1 or 2 to minimize the risk of a construction accident impacting a silo dome. Following the removal of Silo 1 contents, the platform will be moved to Silo 2.

The processing facility would be a preengineered metal building structure built approximately 75 m (250 ft) east of the silos and measuring 36 m by 36 m by 9 m (120 ft by 120 feet by 30 ft). The processing facility would house all material treatment and material product sampling activities and equipment and administrative activities relating to material processing and equipment maintenance. The administrative areas and the outside would be shielded from the material processing areas. Negative pressure and a separate ventilation system would be used. See Figure 4-2 for a depiction of the site layout.

Removal

A slurry pump with a jetting ring would be used to dislodge and transport the materials, in slurry form, to the processing facility. The slurry pump jetting ring would be introduced through the silo and tank manways and would be remotely operated from a shielded control station adjacent to the work platform. As the contents are removed from the silos, the berm material opposite the silo wall would be removed to ensure the forces are balanced. Both the silo contents and the berm material would be removed in equal layers. Because of the removal-by-layer method and because of the configuration of the silo, silo contents may not be accessible to the slurry pump jetting ring through a single manway. The removal device could be moved from manway to manway or through enlarged manways, until all of the contents have been removed evenly.

During normal operations, personnel would be required on the silo domes once a week for approximately 2 hours to reposition the slurry pump jetting ring. Other than this weekly activity and required monitoring activities, personnel would not work above the silo domes. Material removal operations would take place 8 hours/day, 7 days/week, and 3 weeks/month. The fourth week of every month would be used for equipment maintenance and repairs. An estimated 18 months would be required to remove the Silo 1 contents, 16 months to remove the Silo 2 contents, and 1 week to remove the decant sump tank sludge.

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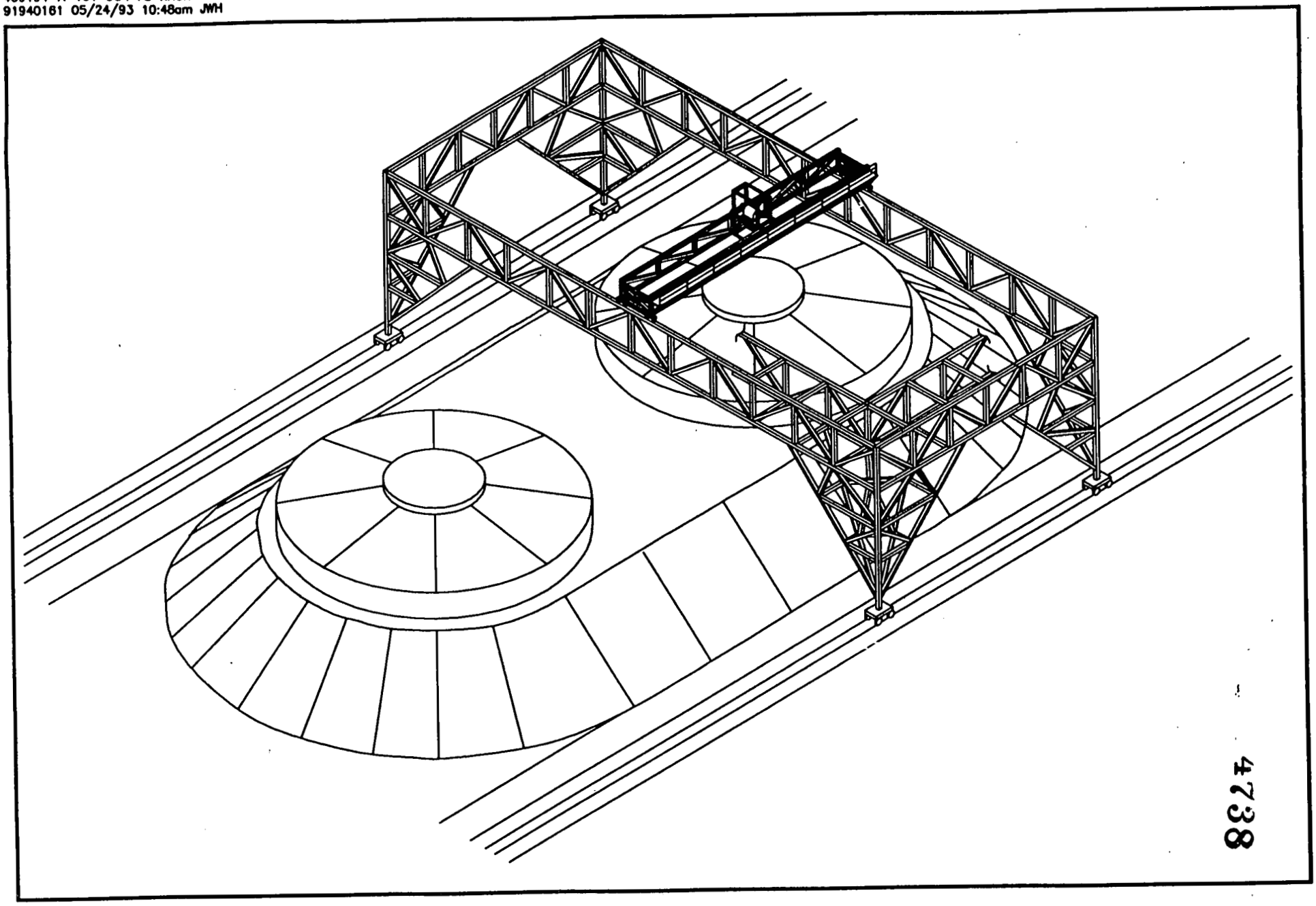

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FIGURE 4-1. SILO MATERIAL REMOVAL WORK PLATFORM

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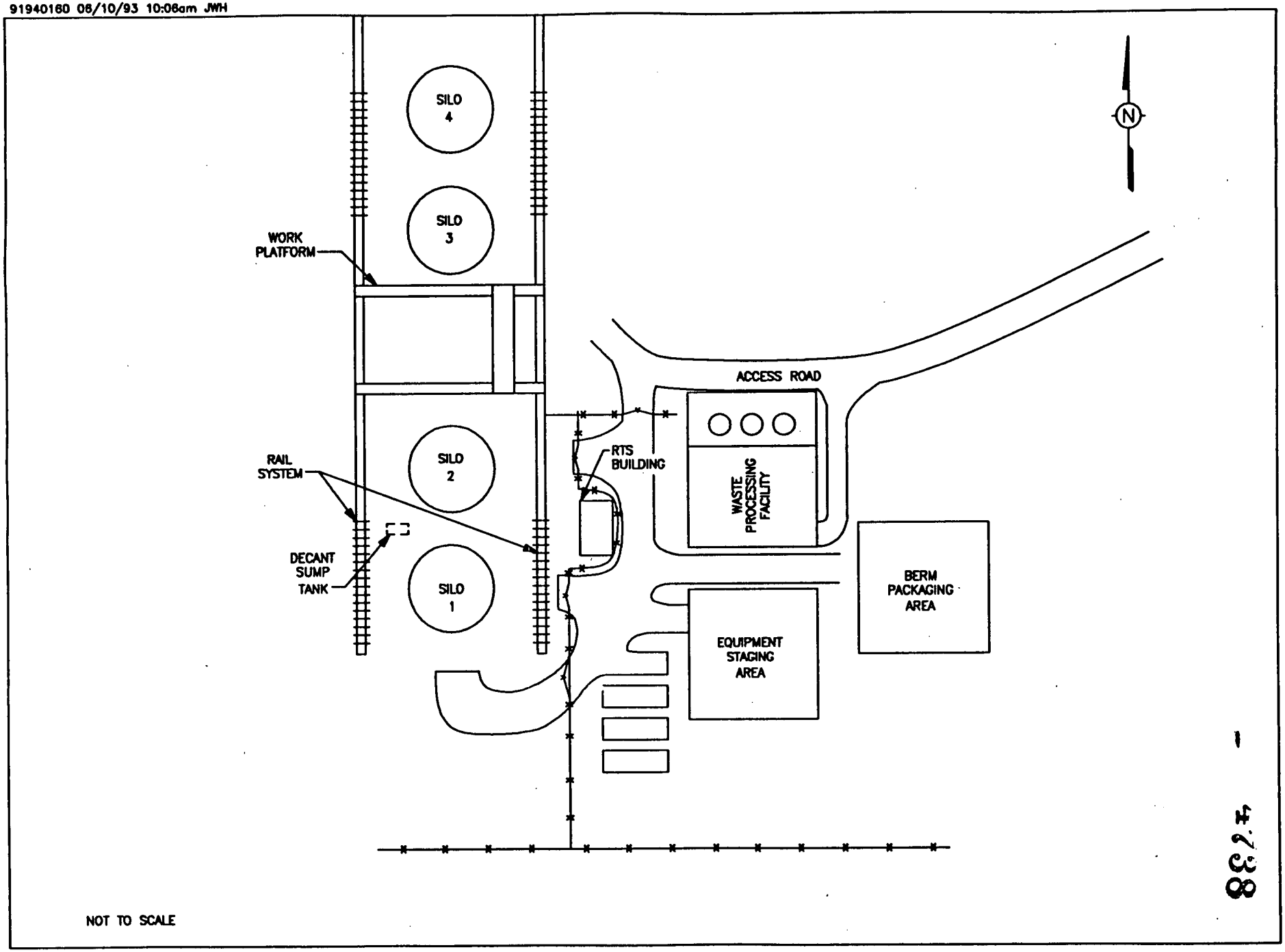

FIGURE 4-2. SITE LAYOUT-ALT. 2A-3A.1

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The silos and decant sump tank would have a recirculating RTS that would maintain the silo atmosphere in a state of negative pressure (see Figure 4-3). The RTS would be operational during material removal and before personnel are sent over the silo domes to reposition the slurry pump jetting ring and conduct repairs or maintenance. The system and procedures would be designed to minimize exposure to personnel over the work areas and to prevent the escape of radon and radioactive particulates from the silos and the decant sump tank. The RTS would use calcium sulfate dehumidification media, carbon absorbers, and HEPA filters. The RTS would be housed in a building adjacent to the silos.

A glove bag would be used at the slurry pump jetting ring/manway interface to function as a part of the containment along with the vessel. The setup, along with procedural compliance and an operational RTS, would be designed to prevent the release of radon or radioactive particulates.

Material Processing

The silo contents and decant sludge would be removed as a slurry with a water content of 80 percent. The slurry would be pumped through double-walled piping to the processing facility. The slurry transfer piping would be contained in an enclosed concrete trench placed just below grade. After the slurry enters the processing facility, it would be dewatered with a horizontal belt filter to reduce its water content to the level required for vitrification. The filtrate would pass to a filtrate recycle tank and be pumped back to the vessels for reuse in the hydraulic removal operations. The dewatered residues and sludge would then pass to a surge tank, which is required because material removal operations would occur 8 hours/day and material processing would occur 24 hours/day. The surge tank would be continuously emptied by the material processing operations and filled during the removal operations.

For the vitrification process (Figure 4-4) the dewatered slurry would be mixed with the glass-forming agents, sodium carbonate and carbon, and melted in a joule-heated melter. The molten glass would be poured directly into DOT specification 7A Type A packaging and placed in the storage room until the form has cooled and been sampled. Due to the high temperatures required for vitrification (1350°C [2460°F]), significant quantities of superheated steam and volatilized matter would be produced. This off-gas would contain water, radon, lead, radium, and other materials. An off-gas treatment system (Figure 4-5) would use scrubbers to treat the gases for lead, radium, and other miscellaneous nongaseous material; carbon absorbers would be used to treat the gases for radon, and

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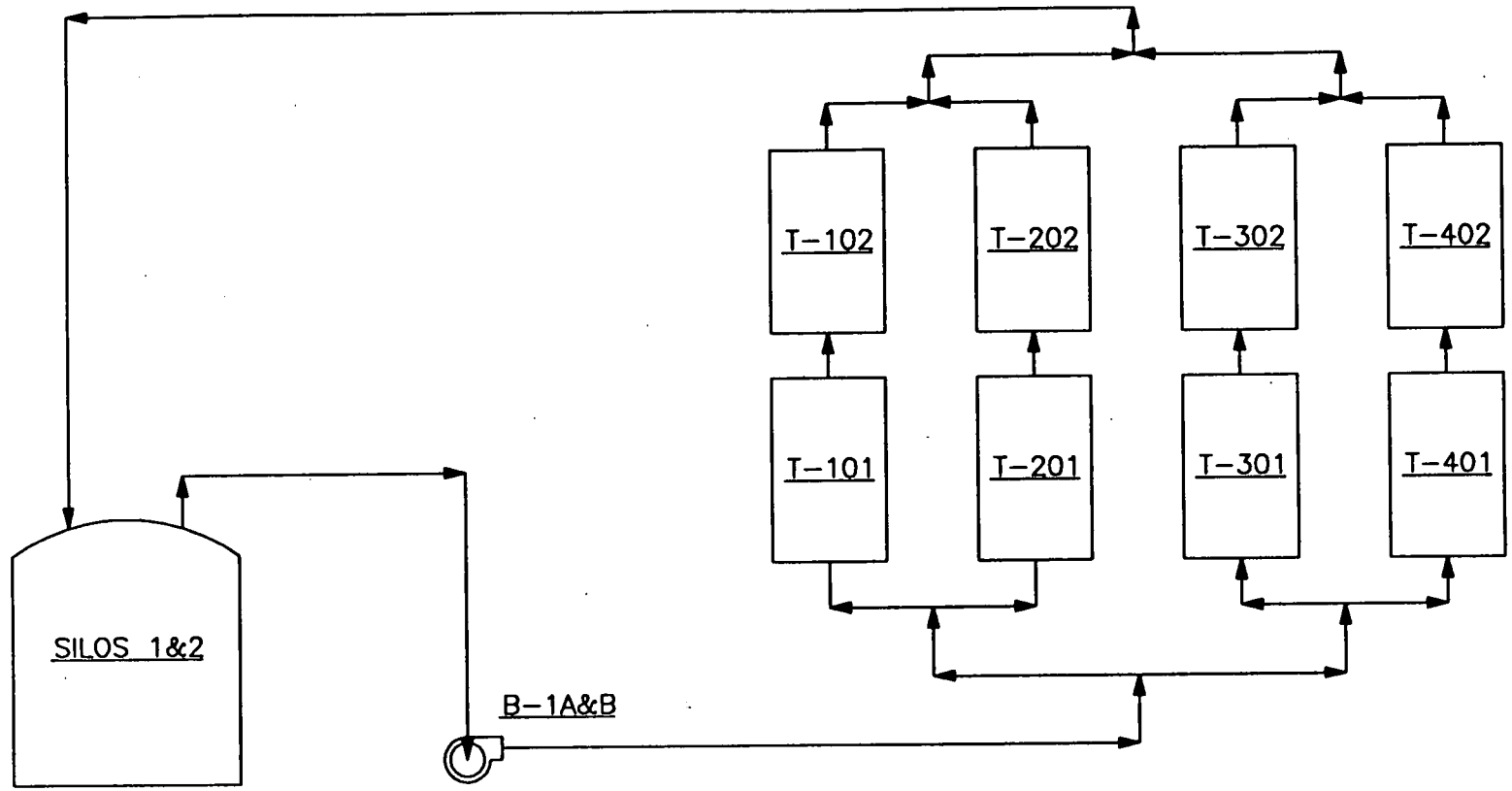
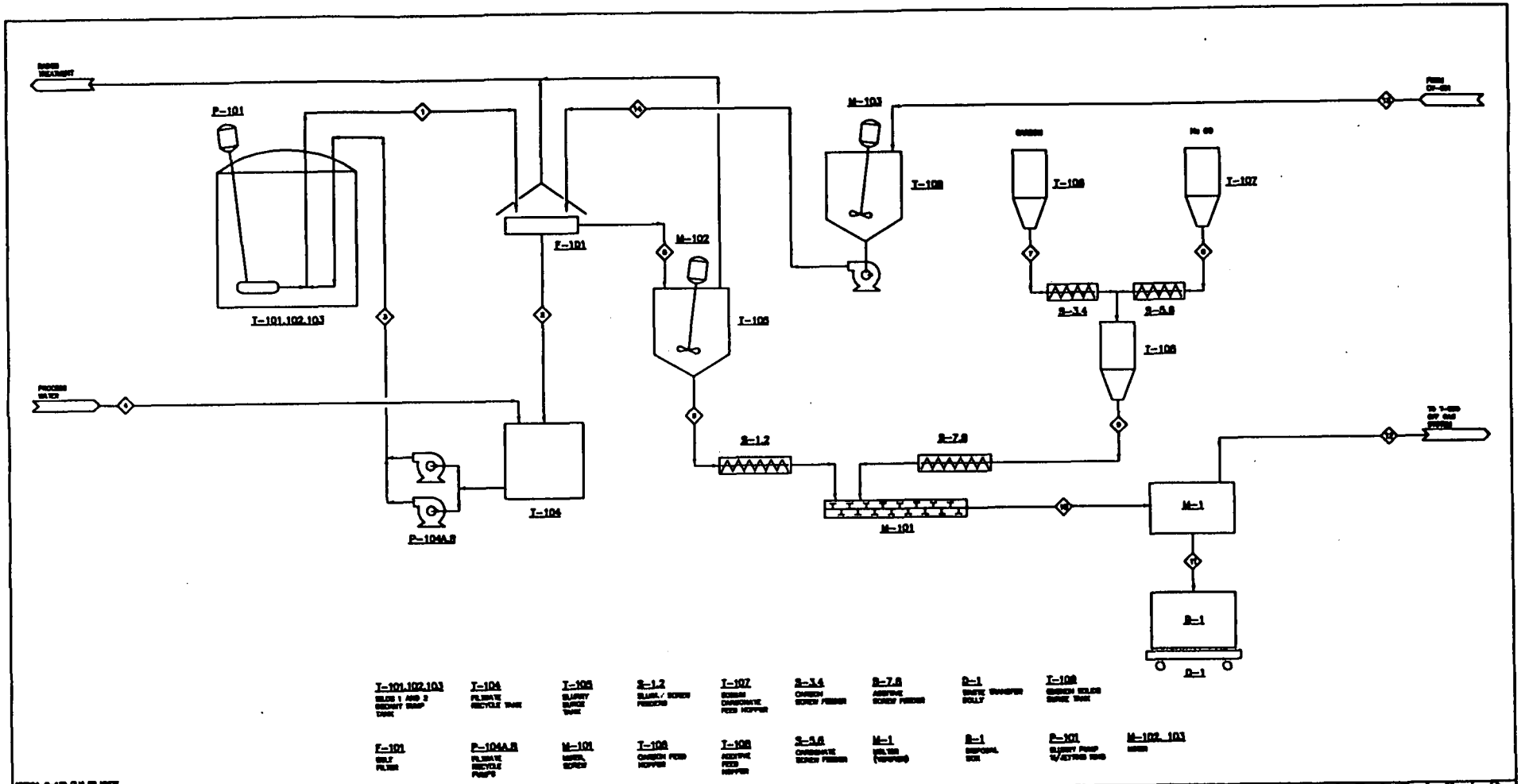


B-1A&B
RTS BLOWER
1500 CFM CAPACITY (EA.)

T-102 thru 402
CARBON ABSORBERS
1500 CFM CAPACITY (EA.)

T-101 thru 401
DRIERS
1500 CFM CAPACITY (EA.)

FIGURE 4-3. RADON TREATMENT SYSTEM FOR SILOS 1 & 2



STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
BASE FLOW (lb/hr)	14639	10146	11044	1798	6336	5639	8.4	249	242	3844	1370	1369	638	5884
SOLIDS (lb/hr)	2889				3349	1103	8.4	249	242	1007	1369		119	294
WATER (lb/hr)	11044	10146	11044	1798	2988	1077	-	-	-	1007	1370		719	5879
CARBON (lb/hr)							8.4		8.4	8.4				
SODIUM CARBONATE (lb/hr)								249	249	249				
GLASS														
% SOLIDS	20				40	40	100	100	100	80	100		0.3	
FLOW (gpm)			26	3.8									100	
HOURS/DAY	8	8	8	8	8	24	24	24	24	24	24	24	24	8
DAYS/WEEK	7	7	7	7	7	7	7	7	7	7	7	7	7	7

ALTERNATIVES 2A/VIT, 3A.1/VIT
VITRIFICATION
PROCESS FLOW DIAGRAM
FIGURE 4-4

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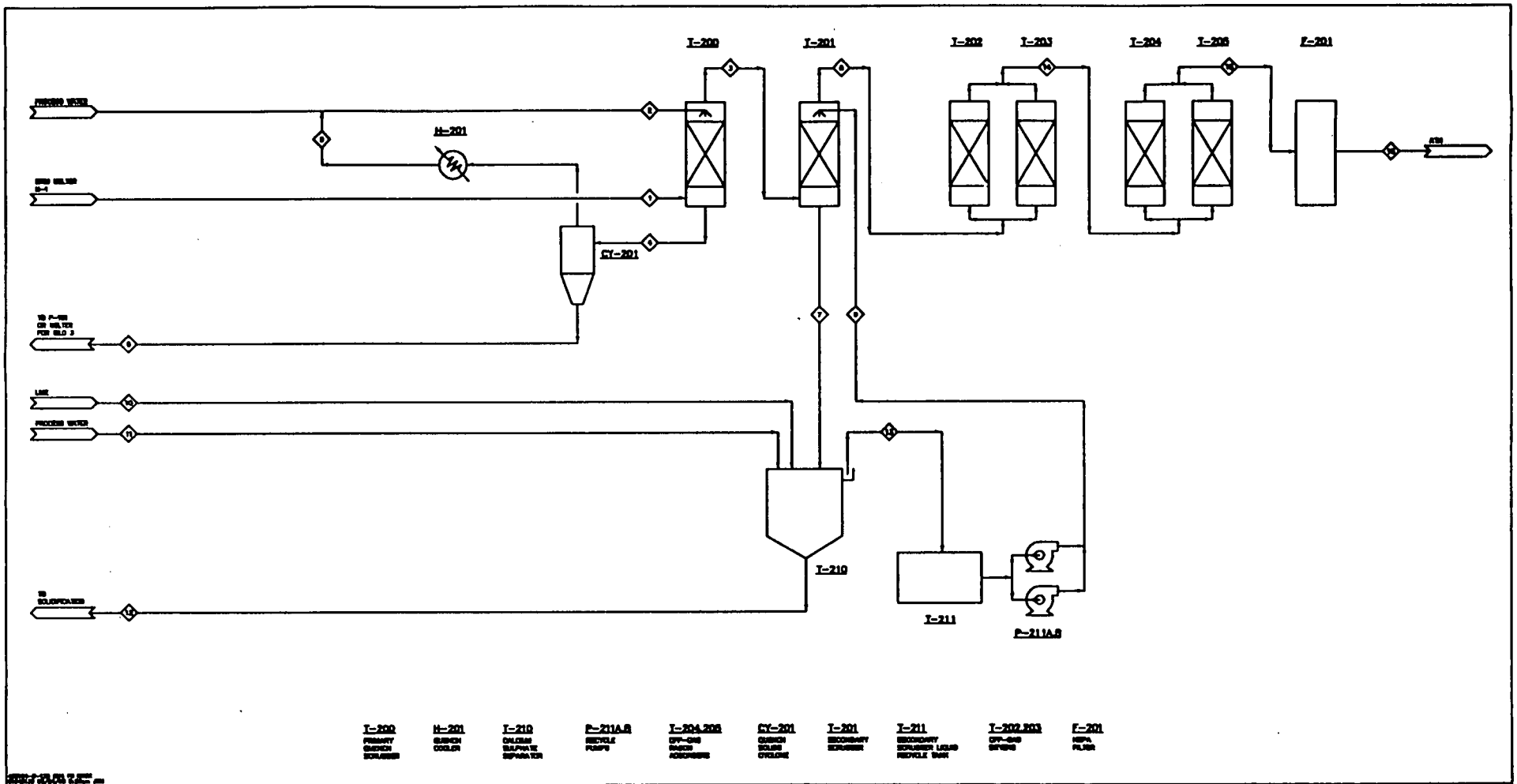


STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MASS FLOW (lb/hr)	1300	50,000	500	51,300	500	50,000	5010	404	2300	10.7	40	50	2000	404	404	404
SOLIDS (lb/hr)				110	110	10.7	10		10.7	10.7		10.7	10.7			
WATER (lb/hr)		50,000		51,210	710	50,000	5000		2300		40	40	2000			
GAS (lb/hr)	1300		500					404						404	404	404
FLOW (acfm)	1903		129					113						113	113	113
FLOW (gpm)		101		103		101	6.3		6				6			
% SOLIDS	0	0	0	.2	16							20				
HOURS/DAY	24	24	24	24	24											
DAYS/WEEK	7	7	7	7	7											

ALTERNATIVES 2A/VIT, 3A.1/VIT
OFF-GAS TREATMENT SYSTEM
PROCESS FLOW DIAGRAM
FIGURE 4-5

HEPA filters would be used for the remaining airborne particulates.

All process vessels containing the slurry would be vented to an RTS separate from that used for the silos and decant sump tank. The process piping/vessels design, the process vessel headspace RTS, and operational procedures would be designed to minimize emissions.

Decontamination and Decommissioning

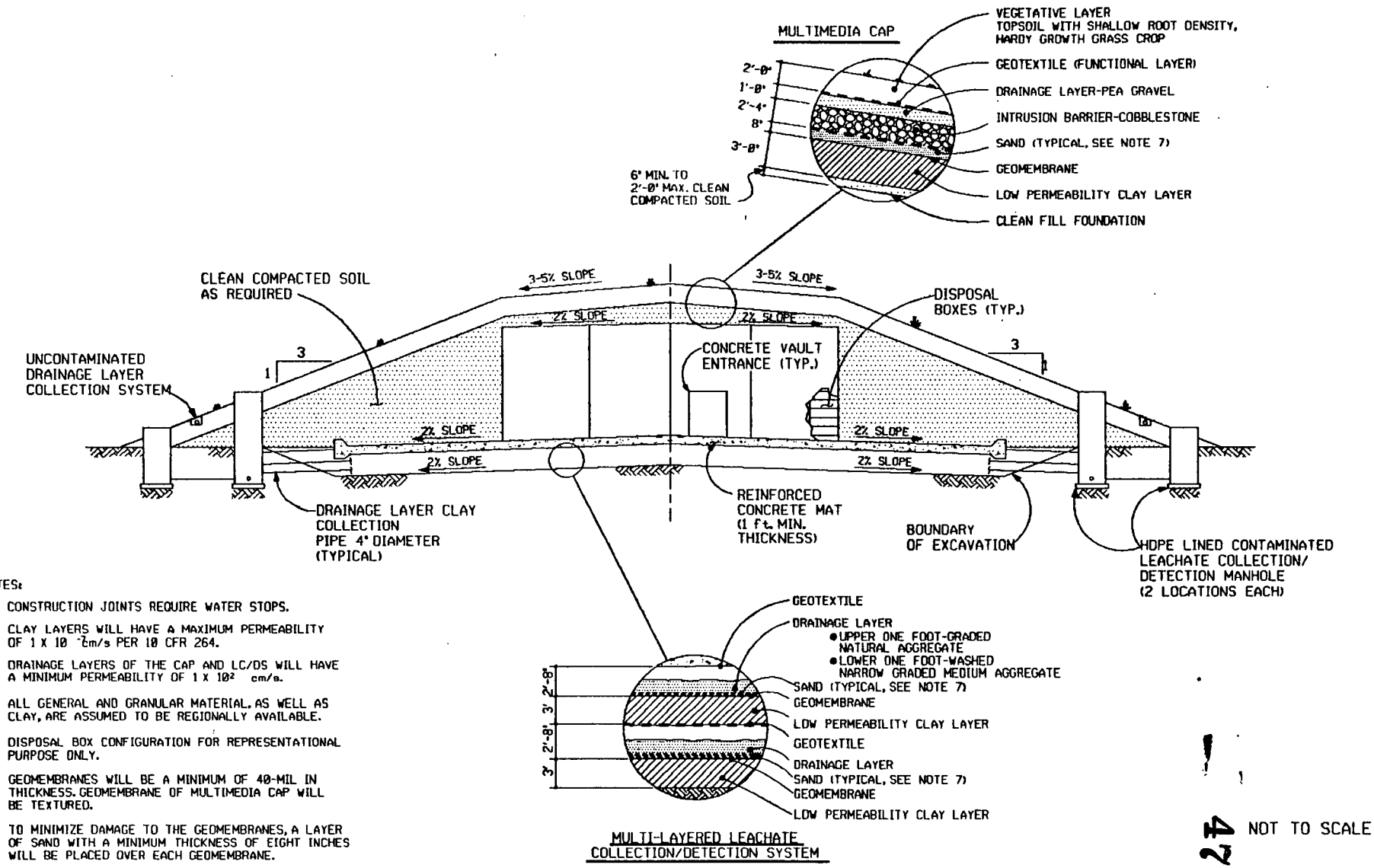
All facilities and equipment installed and used by this alternative would be disassembled, decontaminated (if necessary), and disposed of appropriately. Conventional D&D techniques and equipment would be employed. The debris that cannot be decontaminated, an estimated 1070 m^3 (1400 yd^3), would be dispositioned as part of Subunit C. It is assumed that none of the contaminated material/equipment would be reused with restrictions. The remaining uncontaminated materials can be released for unrestricted use or for disposal in an industrial landfill.

On-Property Disposal

The vitrified product would be disposed of in an above-grade disposal vault. Figure 4-6 provides a cross-sectional view of the vault and the underlying, multimedia LC/DS. Final closure would be completed by the construction of a multimedia cap over the vault. Figures 4-7 and 4-8 depict the proposed on-property location of the vault and plan view of the vault with institutional controls, respectively.

The concrete vault would have a service opening to allow access for the placement of DOT specification 7A Type A packaging. The floor of the vault would have a minimum slope of 2 percent to facilitate any leachate collection and monitoring. The roof of the vault would also have a minimum slope of two percent to allow storm water runoff. As each vault is filled to capacity, all equipment and temporary utilities would be removed and the vault sealed before the multimedia cap is installed.

The vault would be constructed on a reinforced concrete mat with a minimum thickness of 0.3 m (1 ft). The perimeter of the mat would be bounded by a curb with embedded pipes that are connected to the manholes of the underlying multimedia LC/DS to facilitate the collection of any contaminated leachate after final closure. The LC/DS would be composed of alternating composite soil liners and drainage layers to minimize the potential release of contaminated leachate to the groundwater and the underlying Great Miami Aquifer.



NOTES:

1. CONSTRUCTION JOINTS REQUIRE WATER STOPS.
2. CLAY LAYERS WILL HAVE A MAXIMUM PERMEABILITY OF 1×10^{-7} cm/s PER 10 CFR 264.
3. DRAINAGE LAYERS OF THE CAP AND LC/DS WILL HAVE A MINIMUM PERMEABILITY OF 1×10^{2} cm/s.
4. ALL GENERAL AND GRANULAR MATERIAL, AS WELL AS CLAY, ARE ASSUMED TO BE REGIONALLY AVAILABLE.
5. DISPOSAL BOX CONFIGURATION FOR REPRESENTATIONAL PURPOSE ONLY.
6. GEOMEMBRANES WILL BE A MINIMUM OF 40-MIL IN THICKNESS. GEOMEMBRANE OF MULTIMEDIA CAP WILL BE TEXTURED.
7. TO MINIMIZE DAMAGE TO THE GEOMEMBRANES, A LAYER OF SAND WITH A MINIMUM THICKNESS OF EIGHT INCHES WILL BE PLACED OVER EACH GEOMEMBRANE.

FIGURE 4-6. ABOVE GRADE DISPOSAL VAULTS

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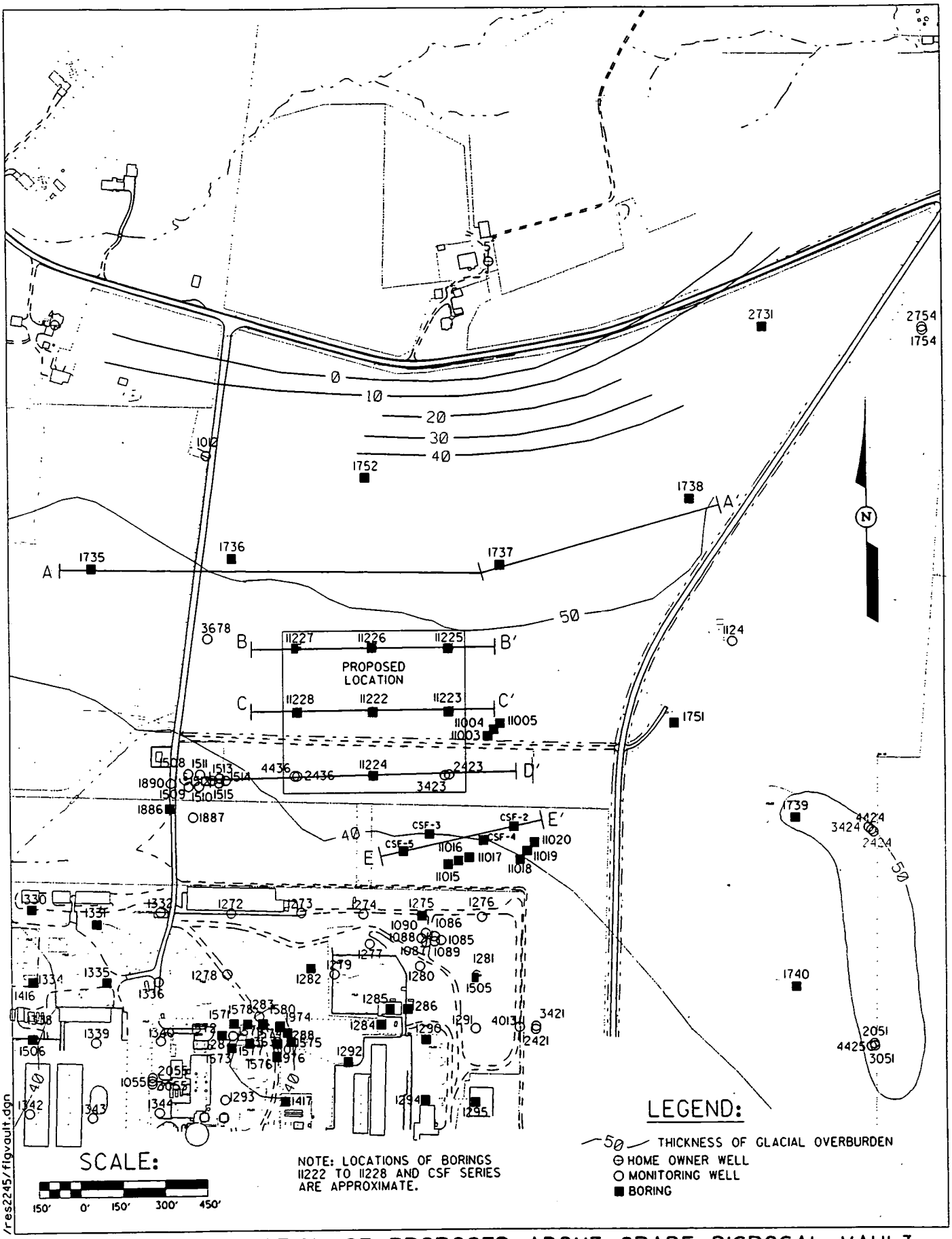


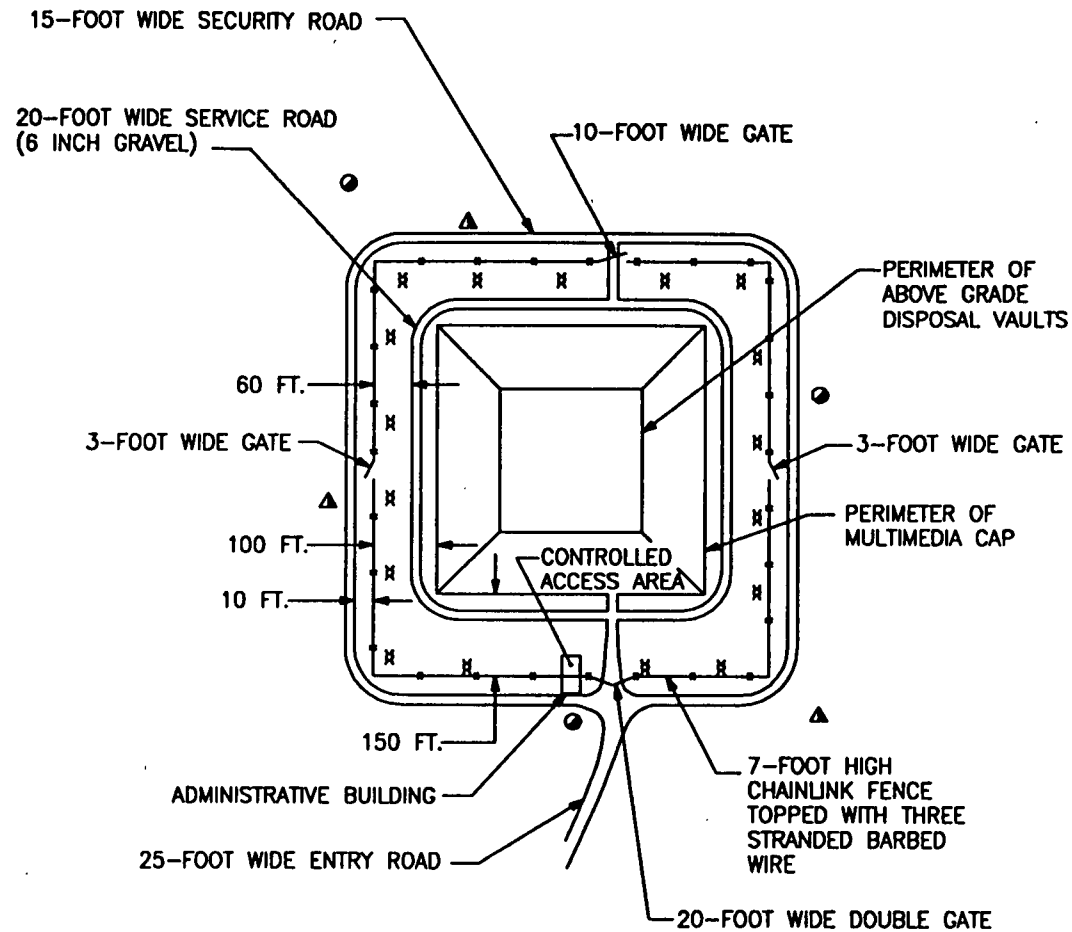
FIGURE 4-7 LOCATION OF PROPOSED ABOVE GRADE DISPOSAL VAULT

NOTES:

1. PERIMETER OF INSTITUTIONAL CONTROL VARIABLE BASED UPON CHOSEN ALTERNATIVE.
2. ACTUAL MONITORING WELL LOCATIONS ARE DEPENDENT ON FINAL REGIONAL GROUNDWATER FLOW DIRECTIONS
3. SEE FIGURE 4-8 FOR DETAILS OF ABOVE GRADE DISPOSAL VAULTS.

LEGEND:

- DEEP MONITORING WELL
- SHALLOW MONITORING WELL
- 20-FOOT HIGH 150 W SODIUM VAPOR MAST MOUNTED LIGHTS 3 PHASE ON WOODEN POLES



NOT TO SCALE

FIGURE 4-8
PLAN VIEW OF ABOVE GRADE DISPOSAL VAULTS WITH INSTITUTIONAL CONTROL

The soil of the composite liners would be constructed of a natural, compacted clay with a maximum permeability of 1 x 10^{-7} cm/s. The layers would be a minimum of 0.9 m (3 ft) thick. To improve the performance of the clay, a geomembrane of at least 40 mil in thickness would be placed over the surface of the clay, which has been smooth-rolled to ensure good hydraulic contact. To minimize damage to the geomembrane during construction, a sand layer with a minimum thickness of 20 cm (8 in.) would be placed over the geomembrane of the LC/DS.

Between the composite soil liners, drainage layers would be installed to intercept any leachate that may be generated. The drainage layers would be a minimum of 0.6 m (2 ft) each in thickness. The upper 0.3 m (1 ft) of each layer would be a graded natural aggregate and the lower 0.3 m (1 ft) would be a narrow-graded medium aggregate to provide a minimum permeability of 1 x 10^{-2} cm/s. A geotextile membrane would be placed on the upper surface of each drainage layer to prevent the migration of fines from overlying material.

During placement of the aggregate, 10 cm (4 in.) diameter pipes would be installed within the aggregate to collect and direct any leachate to a series of manholes lined with HDPE. The leachate would then be removed from the manholes by vacuum truck for treatment at the FEMP site AWWT facility.

A multimedia cap constructed of five distinct layers of media would provide final closure of the vault. The upper layer of the cap would be a vegetative layer consisting of topsoil with a hardy, shallow-root grass cover. This layer would be noncompacted and have a minimum thickness of 0.6 m (2 ft) to support plant growth. The vegetative layer would inhibit erosion and allow runoff during storm events. A drainage layer would be beneath the vegetative layer to intercept infiltrating precipitation. The layer would consist of 0.3 m (1 ft) of pea gravel that would provide a minimum permeability of 1 x 10^{-2} cm/s. A geotextile membrane would be placed between the vegetative layer and the top surface of the drainage layer to prevent the migration of granular fines from the vegetative layer to the drainage layer.

A layer of cobblestone with a minimum thickness of 0.7 m (2.3 ft) would be beneath the drainage layer to serve as an inadvertent intrusion barrier. Beneath the cobblestone would be a composite soil liner to impede downward moisture movement from the drainage layer. The soil of this layer would be natural, compacted clay with a maximum permeability of 1 x 10^{-7} cm/s. The layer would be 0.9 m (3 ft) thick to ensure the isolation of the disposal containers. A geomembrane at least 40 mil in

thickness would be placed over the surface of the clay, which is smooth-rolled to ensure good hydraulic contact, and thus improving the performance of the clay. To minimize slippage of the overlying layers due to interfacial shearing characteristics, the geomembrane would be textured. Similar to the composite soil liners of the LC/DS, a layer of sand would be placed over the geomembrane to minimize damage during construction. The foundation of the multimedia cap would be clean, compacted soil. This layer would be a minimum of 15 cm (6 in.) to a maximum of 0.6 m (2 ft) in thickness above the vault. All general and granular material, as well as clay, are assumed to be regionally available.

Upon completion of the multimedia cap, fencing, permanent markers and deed restrictions would be instituted. To provide assurance against inadvertent intrusion of the wastes, the alternative also provides for continued federal ownership of the FEMP property. Under this ownership, the federal government is assumed to not provide active controls, but to continue to exercise its rights of ownership to preclude further site development. Monitoring wells would be appropriately located to evaluate the effectiveness of the above-grade disposal vault in ensuring the protection of human health and the environment. The on-property above-grade disposal vault would cover approximately 2.8 ha (6.9 acres).

4.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2A/Vit meets the remedial action objectives for Subunit A. Implementation of this alternative would prevent direct access to waste materials and would mitigate the migration of contaminants to the air, soil, and groundwater. Exposure to direct radiation above protective levels also would be prevented. Three primary actions would be used to meet the remedial action objectives, thereby providing adequate protection to human health and the environment. These actions are treatment through vitrification, containment in above-grade disposal vault) and implementation of institutional control measures.

Treatment of Subunit A materials through vitrification would reduce contaminant toxicity, mobility, and volume. The leaching rate of the treated waste would be reduced, enhancing the protection of the underlying Great Miami Aquifer. Treatment of the material prior to disposal would provide additional protection in the event that the disposal vault begins to degrade, allowing increased infiltration and subsequent leachate formation. However, beyond the 1,000 year expected design life of the disposal vault, continued protection becomes less certain as a result of possible degradation of

the vitrified material itself and subsequent increased leachability. As demonstrated by treatability studies, the leaching rate of the treated material is much slower than untreated material.

Containment of the treated material form in an on-site, capped engineered disposal vault would provide additional control of contaminant migration to human and environmental receptors. The disposal vault would also prevent direct radiation from the treated waste material and radon (minor contribution). The vault design would include an intruder barrier and markings to inhibit purposeful or inadvertent human intrusion of the facility's engineered protective features. The vault would be designed for a life of 1,000 years with no active maintenance. As discussed above, continued long-term effectiveness of the vault cap and leachate collection system is uncertain and eventual degradation could lead to an increased rate of infiltration, leachate formation, and release. Fate and transport modeling using conservative assumptions supports the conclusion that long-term protection of human health and the environment would still be achieved, based on the slow rate of deterioration of the disposal vault.

Institutional control measures would be employed to supplement the treatment and containment actions in order to provide additional assurance that overall protection would be maintained as engineered components degrade. Institutional controls include the adoption of long-term federal government ownership of the FEMP site. Continued federal ownership of the site would preclude future on-site residential and farming land uses which could result in direct exposure to the waste materials through intrusive actions or facility degradation. The use of institutional controls is also consistent with an ARAR for the on-site engineered disposal vault. To comply with ORC 3734.02 (H), hazardous and solid waste disposal facilities must include in any conveyance deeds a protective covenant to restrict future mining, drilling, and residential uses of the active disposal areas. In accordance with this requirement, a deed restriction would be placed on the FEMP site property detailing these restrictions. The uncertainty associated with very long-term institutional control periods includes a possible loss of federal ownership and the loss of administration of the property records containing the deed restrictions.

Loss of institutional controls in combination with disposal vault failure over the long term (more than 1,000 years) could result in potential contaminant migration or direct exposure to the vitrified material by future human and ecological receptors. Exposures to receptors through these pathways (groundwater, air, etc.) in the event of disposal vault failure would be expected to be minimal due to

the positive attributes of the treated wastes. Direct radiation exposure could be significant in the 4738 event the disposal vault is breached, due to the presence of significant activity concentrations of the long-lived gamma emitting radionuclides. Ultimately, the risks from complete failure of the alternative could approach baseline risk conditions. However, both engineering controls and institutional controls would have to fail before unacceptable risks to human health and the environment would occur.

There are no unacceptable short-term risks from Alternative 2A/Vit. There are increased worker risks over the no-action alternative due to radiation exposure during removal treatment, and packaging. However, through the use of remote removal, shielding, and implementation of a worker health and safety plan in compliance with 29 CFR 1910.120, these exposures would be kept to ALARA levels and would comply with DOE Orders.

4.2.2.2 Compliance with ARARs

Alternative 2A/Vit would comply with all pertinent ARAR/TBC requirements identified and discussed in Tables F-1.1 through F-1.3 of Appendix F and summarized in matrix form for Subunit A in Table F-2. Compliance or noncompliance with the principal chemical-, location-, and action-specific ARARs presented in these tables is discussed below. Detailed documentation of compliance with ARARs for Alternative 2A/Vit is presented in Appendix F and in the detailed risk assessment presented in Appendix D.

Chemical-Specific ARAR/TBCs

A set of the identified ARAR/TBCs provides chemical-specific and dose-based requirements for the protection of groundwater. Regulations providing prescriptive chemical-specific limitations include the Maximum Contaminant Levels (MCLs) defined in 40 CFR 141.11 (et al.) and 40 CFR 141.61 for inorganics and organics, respectively (Safe Drinking Water Act). These concentration-based limits are presented in numerical form in Table F-1.1. Additional concentration-based limits for chemicals in drinking water at TSD facilities are prescribed in 40 CFR 264.94 (RCRA Subtitle C). A recent rule-making by EPA has proposed concentration-based limitations for certain previously unregulated radionuclides, including uranium. Where these proposed limitations are more restrictive than existing promulgated standards they have been adopted as TBC requirements. Additionally, dose-based requirements for the protection of potential public receptors using affected groundwaters are defined in DOE Order 5400.5 and 40 CFR 191.16. DOE Order 5400.5 limits the allowable annual effective dose equivalent, from all pathways including groundwater, to any member of the public from

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exceeding 100 mrem. As specified in 40 CFR 191.16, the annual dose equivalent to the whole body or critical organ is limited to 4 mrem, assuming the consumption of 2 liters per day of potable groundwater.

Groundwater compliance is typically demonstrated by fate and transport modeling. Guidance is provided in 40 CFR 257.3-4 and 40 CFR 264 Subpart F as to the point of compliance for demonstrating whether the groundwater protection requirements for inorganic and organic contaminants would be attained. The most restrictive groundwater requirements for these constituents appear in 40 CFR 264.94 which requires the disposal vault to meet the concentration-based limits in the uppermost aquifer underlying the waste management area at the point of compliance, which is a vertical surface located at the hydraulically down-gradient limit of the waste management area (pending the specific establishment of an alternative boundary). The uppermost aquifer and point of compliance is the Great Miami Aquifer. This definition of the uppermost aquifer and assignment of the point of compliance is supported by the technical discussions in Section 3.2.2.1, and in general is based upon the following factors specific to the proposed disposal vault location:

- Zones of saturation in the glacial overburden have very low yields and are not viable sources of groundwater for domestic or agricultural use, particularly in comparison to the underlying Great Miami Aquifer;
- Zones of saturation in the glacial overburden do not have significant hydraulic connections to the underlying Great Miami Aquifer;
- The glacial overburden is infrequently used for groundwater supplies relative to the Great Miami Aquifer.

The petition for sole source aquifer designation of the GMA (OKI, 1988) stated that, regionally, till is generally not used for water supplies because it infrequently yields enough water even for domestic purposes. OKI's regional analysis holds true with respect to the till depositional unit over which the FEMP site is built. There are no known groundwater supply wells completed in the till downgradient of the FEMP site. All local downgradient users of groundwater use wells that are completed in the GMA. All well locations downgradient of the FEMP site that have till contiguous with the FEMP are underlain by the Great Miami Aquifer. It is reasonable to assume that all future groundwater users will continue to use the GMA for groundwater supplies, because the glacial overburden, particularly in the vicinity of the proposed disposal vault, is not a viable domestic or agricultural groundwater source.

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FEMP Operable Unit 5 is, at the time of printing of this report, is conducting slug tests and yield tests in a number of monitoring wells completed in the glacial overburden. Preliminary results have shown potential sustained yields ranging from less than 1 gpm to approximately 3 gpm. These yields are 50 to 100 times less than the yields typically obtained from water supply wells completed in the GMA (see Section 3.2.2.1).

Zones of saturation in the glacial overburden do not have significant hydraulic connections to the underlying Great Miami Aquifer. The zones of saturation are relatively small and isolated within a low permeability matrix of clay and silt. The till, with its high clay and silt content, is a natural barrier to groundwater migration. The low hydraulic conductivity of the till produces very slow groundwater velocities.

The specified 1000-year fate and transport modeling of uranium, the principal groundwater constituent of concern, indicates the uranium concentration would not exceed the proposed 20 ug/L MCL defined in 40 CFR 141, at the point of compliance (See Appendix D for a description and results of this modeling and the discussion of the Long-Term Effectiveness in Section 4.2.2.3). The modeled releases for the contaminants of concern would all be within the concentration- and dose-based regulatory limits.

Airborne emissions, soil-related exposures, and penetrating radiation would be controlled with engineered features. The most critical chemical-specific ARAR/TBC for airborne releases for this alternative relates to radon. The maximum permissible surface release rate of radon-222, as specified in 40 CFR 61 Subpart Q, is 20 pCi/m^2/s, surface averaged. This requirement is supplemented by 40 CFR 192.02(b) which requires that the concentration of radon-222 in air at or above any location outside the disposal site not increase the annual average by more than 0.5 pCi/L. Similar TBC requirements are contained in DOE Order 5400.5 Chapters III and IV. Requirements for other radionuclides are established in 40 CFR 61 Subpart H and DOE Order 5400.5 Chapter III. The atmospheric release of radionuclides (including radon) from the surface of the disposal vault would be essentially eliminated by the multiple barriers due to the treated non-porous (vitrified) waste form, the engineered concrete disposal vault liner [over 3 m (9 ft) thick], and the multi-media engineered cover [at least 3 m (9 ft) thick]. On the basis of available treatability data (further discussed under Reduction of Toxicity, Mobility, and Volume), the vitrification of the Subunit A materials decreases the radon flux rate from the untreated waste to below the required or emission rate limits. The application of the multi-media capping system to the engineered disposal vault would further reduce,

or essentially eliminate, any potential above background releases of radon and other airborne contaminants from the waste disposed in the unit. Given these multiple barriers to the release of radionuclides, the 40 CFR 61 Subpart Q release rate and the other identified chemical-specific public dose and airborne concentration limits would be met. ARARs associated with fugitive dust and particulates would also be met.

All surface water releases (originating from the vault leachate collection/detection system) would be directed to the FEMP site AWWT Facility for treatment prior to release. Since the AWWT Facility would be subject to the NPDES permit issued by the State of Ohio, any contaminants in this waste stream would be removed or treated to acceptable levels prior to discharge. The Ohio Water Quality Standards for surface water (i.e., for a warm water aquatic life habitat) would also be attained by this treatment. Restrictions on uncontrolled discharges to surface water bodies would be met through designed engineered controls, and procedures such as Best Management Practices (BMPs).

Location-Specific ARAR/TBCs

Location-specific requirements associated with this alternative relate to the protection of four principal natural features or resources: floodplains, wetlands, endangered species, and the sole source aquifer underlying the FEMP site. Restrictions on activities conducted in floodplain areas are specified in 40 CFR 257.3-1, 264.18, 6.302, and 10 CFR 1022. Compliance with these requirements would be met through appropriate planning, siting, design, and operational procedures. Restrictions on activities conducted in wetland areas are presented in 40 CFR 258.12 and 10 CFR 1022. Compliance with these requirements would be met through appropriate siting of facilities and operations, the prior assessment of potential impacts associated with activities conducted in these locations, and the development of an impact mitigation plan. Protection of endangered species is mandated by 50 CFR 200 and 204. The proposed location of the disposal vault has been determined not to jeopardize endangered or threatened species or their habitat. Alternative 2A/Vit would, therefore, comply with these identified location-specific ARAR/TBC requirements.

The State of Ohio's solid waste disposal design criteria considerations are found at OAC 3745-27-07. Embodied within these requirements are restrictions pertinent to the siting of the on-property disposal vault. Through the definition of an Area of Contamination for Operable Unit 4, which includes the area encompassing the Operable Unit boundary and any proposed on-property treatment and disposal areas, these OAC requirements would be considered relevant and appropriate to the implementation of this alternative. The location of the disposal vault would be sited to meet the specific set back

requirements as defined in the above citation including the distance from the property line and the distance from the disposal vault to the nearest domicile or water supply well. As previously discussed in Section 3.2.2.1, the proposed siting location also attains the 4.5 m (15 ft) isolation distance required in the OAC citation regarding the distance between the bottom of the liner system and the top of the uppermost aquifer underlying the disposal vault.

OAC 3745-27-07 (B)(5) specifically prohibits solid waste disposal facilities from being constructed over sole source aquifers. Exemptions have been granted to this requirement on the basis of technical considerations which are defined in "Guidance on Solid Waste Siting Criteria: Sole Source Aquifer (Guidance No. GD0202.101, May 6, 1991)". These technical considerations include the following:

- There is a significant thickness of low permeability material between the disposal vault liner and the aquifer
- There is no significant interconnection between the aquifer and any significant saturated zones that exist above the aquifer
- No adverse impact to human health or safety or the environment will occur as a result of granting the exemption

The disposal vault, as proposed, meets the technical considerations used to grant exemptions: approximately 30 feet of low permeability glacial till lies beneath the proposed liner, saturated zones in the glacial till have no significant hydrologic connections with the underlying aquifer, and fate and transport modeling predicts that potential future releases to the aquifer from the facility will not exceed MCLs or lead to an incremental lifetime cancer risk (ILCR) greater than 1×10^{-6}. The following is a summary discussion of the technical considerations and employs data from Section 3.2.2.1 and Appendix D.

The geologic data presented in Section 3.2.2.1 and shown in Figures 3-4 to 3-8 demonstrate that there is greater than 9 m (30 ft) of low permeability, grey till between the proposed facility liner and the top of the sand and gravel of the GMA. The glacial till does contain erratically distributed pockets and lenses of sand. However, data from both the FEMP site and proposed disposal vault site indicate that movement of groundwater within these units is limited due to the small areal and vertical extent of the lenses. Consequently, the dominant groundwater flow path through the till is vertical.

The till, with its appreciable silt and clay content, is a high quality natural barrier to groundwater migration. The low hydraulic conductivity of the clay and silt strata produces very low groundwater

velocities. The proposed vault location does not currently have a significant hydraulic connection between perched groundwater in the till and the GMA. Limited lateral transport is presumed to be possible within the till, such as in sand lenses. Engineered measures such as removal or grouting of lenses will mitigate potential lateral transport. Additionally, the engineered measures would further retard the already slow vertical transport.

Fate and transport modeling for the specified 1000-year time frame predicts that no adverse impact to human health or the environment will occur for Alternative 2A/Vit (groundwater fate and transport model results are presented in Appendix D). The incremental lifetime cancer risk (ILCR) is less than $1x10^{-6}$ for all receptors and all land use scenarios. Predicted concentrations in the Great Miami Aquifer at the point of compliance are all less than MCLs, proposed MCLs, non-zero MCLGs, and dose limits that have been identified as ARARs and TBCs for Alternative 2A/Vit.

In consideration of these hydrogeologic factors, design, and impact prevention and mitigation capabilities, an exemption to allow the construction of a disposal vault over the sole source aquifer at this location at the FEMP site could be technically justified, and the requirements of OAC 3745-27-07 relating to the sole source aquifer would be met for Alternative 2A/Vit.

Action-Specific ARAR/TBCs

Alternative 2A/Vit would comply with all pertinent action-specific ARARs identified in Appendix F. The engineered above-grade disposal vault system incorporates the design requirements for the disposal of uranium mill tailings (40 CFR 192), hazardous waste under RCRA (i.e., the TSDF requirements for land disposal facilities under 40 CFR 264), and the intruder protection requirements under 10 CFR 61. The following features would be incorporated into the overall design for Alternative 2A/Vit: (a) waste treatment through vitrification; (b) an engineered concrete vault with intrusion barrier; (c) a multi-layer leachate collection/detection system; and (d) a 3 m (10 ft) thick multi-media cap. The technical elements of this design are described in Section 4.2.2.

Pursuant to Section 3734.02 (H) of the Ohio Revised Code, building and drilling activities are prohibited on land where hazardous or solid waste facilities were operated, without the prior approval of the Director of the Ohio EPA. Additionally, requirements under 40 CFR 264.310 provide that all disposal vault systems be protected and benchmarks be used to mark the location of waste cells. Compliance with these ARARs would be achieved through design and the implementation of institutional controls at the disposal vault. These controls would be maintained through the use of

fences, sign posting, deed restrictions, and continued federal ownership of the FEMP site. As a result of the elevated direct penetrating radiation associated with the vitrified residues, the prescriptive intruder protection requirements established in 10 CFR 61.7 wastes have been adopted for the on-property disposal of the residues. These requirements include a minimum cover thickness of 5 m (15 feet) above the wastes or the use of specially designed intruder barriers to preclude inadvertent intrusion for at least 500 years. These requirements have been incorporated into the disposal vault conceptual design and would be adopted as a remedial design requirement for Alternative 2A/Vit. In addition, the Alternative 2A/Vit engineered disposal system has been evaluated and would satisfy the 100 mrem public dose limit for radiation exposure from all pathways as established by DOE Order 5400.5 Chapter II (see Appendix D for the presentation of the analysis). The total exposure to radiation from all potential pathways associated with this alternative would be less than 1 mrem/yr.

The design of the on-property disposal vault also would include engineered features that satisfy the requirements of the Clean Water Act (40 CFR 125.100, .104, and 122.26, and the Ohio Water Quality Standards), and RCRA Subtitle C for hazardous waste facilities. 40 CFR 264 Subpart F requirements mandate groundwater monitoring, detection, and a program to initiate corrective action, if necessary. 40 CFR Part 264 Subpart G requires facility closure in a manner that minimizes the release of hazardous constituents. Compliance with these RCRA requirements is met with the incorporation of the appropriate design features. Operational requirements for disposal facilities, such as those specified in 40 CFR 241 Subpart B, and 40 CFR 264 Subparts B, C, and D would also be complied with through planning and the implementation of appropriate procedures.

During implementation of the remedial action (including facility construction and waste treatment), appropriate engineered features and procedures would be implemented to comply with the Ohio requirements for fugitive dust control (OAC 3745-17-08), and the control of emissions of particulates (OAC-3745-17-07 and OAC-3745-17-11).

An action-specific ARAR/TBC requirement particular to on-property disposal of Subunit A material at the FEMP site is 40 CFR 191 (Standards for the Management, and Disposal of Spent Nuclear Fuel, High Level and Transuranic Radioactive Wastes). In October 1990, EPA directed DOE to consider 40 CFR 191 Subpart A (dealing with the storage and management of waste) as relevant and appropriate to the on-site portions of remedial activities involving the K-65 residues, and to consider Subpart B (pertaining to waste disposal) as a TBC requirement for the on-site Subunit A disposal

alternatives. This direction resulted primarily from EPA's concerns about the potential for inadvertent intrusion into the disposed residues due to conditions present at the FEMP site.

40 CFR 191 Subpart A specifies a public dose limit during waste storage and remedial operations. This requirement would be met through the use of engineered features that would prevent exposures, or the uncontrolled release of radioactive waste material. Estimates of the dose to the public calculated for the short-term risk assessment indicate that exposures would be less than 1 mrem/yr (see Appendix D), which is well below the dose rate standard.

40 CFR 191.13 sets forth containment requirements which mandates that the disposal system must consider during design to provide a reasonable expectation that specified cumulative radionuclide-specific release limits will not be exceeded for 10,000 years. More specifically, the disposal system must limit releases such that there is less than 1 chance in 10 of exceeding the following quantities of activity (based on Table 4-3 of the Remedial Investigation Report Operable Unit 4, August 12, 1993) over 10,000 years as the result of man-made and natural events (or less than 1 chance in 1000 of exceeding 10 times these quantities):

- Ra-226 - 0.450 Ci
- Th-232 - 0.045 Ci
- U-235 - 0.450 Ci
- Th-230 - 0.045 Ci
- U-234 - 0.450 Ci
- U-238 - 0.450 Ci

In order to demonstrate compliance with this requirement, a probabilistic assessment of all events that could result in a release of waste material from the disposal vault would need to be undertaken, along with an assessment of the impact each identified release would have on the accessible environment (i.e., the Great Miami Aquifer). These results would then need to be appropriately summed according to their relative likelihood. The application of such probabilistic modeling techniques is beyond the scope of a CERCLA Feasibility Study. In a January 21, 1991 letter, EPA questioned the application of these release limits to the on-site disposal alternatives, but reiterated their concern about the need to provide for the long term protection of inadvertent intruders for 10,000 years.

In order to demonstrate compliance with these limitations it would require that no more than 1374 kilograms (3000 pounds) of uranium-238 or 0.45 grams (1/1000th of a pound) of radium-226 would be released from the disposal vault over the 10,000 year period. In the case of uranium, this

corresponds to an average of 137 grams (4.8 ounces) released per year. For radium, the quantity is 4.5 x 10^{-5} grams (1 x 10^{-7} pound) per year. An ability to confidently demonstrate that such ~~minute~~ quantities of material would not be released over so long a period of time is well beyond current modeling abilities. On this basis, the likely compliance or noncompliance of Alternative 2A/Vit with the cumulative release limits of this TBC requirement could not be assessed. However, in response to EPA's letter and the reasonable expectation that CERCLA risk goals would be attained for the 1000 year modeling horizon, the uncertainty as to compliance with the aforementioned limits was not used as a basis for screening the alternative from further evaluation.

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40 CFR 191 Subpart B also contains many requirements that are equivalent or similar to those contained in other ARAR requirements for this alternative that have already been discussed. These include 10 CFR 61 (Low-Level Radioactive Waste); 40 CFR 192 (Uranium Mill Tailings); 40 CFR 61 Subpart Q (Radon Standard); and 40 CFR 141.16 (Safe Drinking Water Standards). Additional consideration of the adequacy and reliability of the engineering controls to provide for the long-term protection of the inadvertent intruder are discussed as a part of the evaluation of the long-term effectiveness of this alternative. All other provisions of 40 CFR 191 would be attained by Alternative 2A/Vit.

4.2.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 2A/Vit reduces the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6}. Figure 4-9 is a conceptual site model for the various action alternatives considered. It is presented to illustrate the potential long-term exposure pathways. These pathways represent the realm of potential exposures which could occur after remediation is completed. Some of the pathways can only occur with failure of the engineered or institutional controls (indicated with a dashed line). Some of the pathways will occur to some extent as part of the alternative (indicated by a solid line). Residual risk will only be through completed pathways. The basis of the risk evaluation is presented in Appendix D. Each of these concerns is addressed through the primary components of Alternative 2A/Vit; treatment, isolation in an engineered disposal vault, and the application of institutional controls.

Vitrification significantly reduces the mobility of the COCs and the radon emanation rate. While the direct radiation fields remain unchanged after vitrification, the disposal vault design supplemented by

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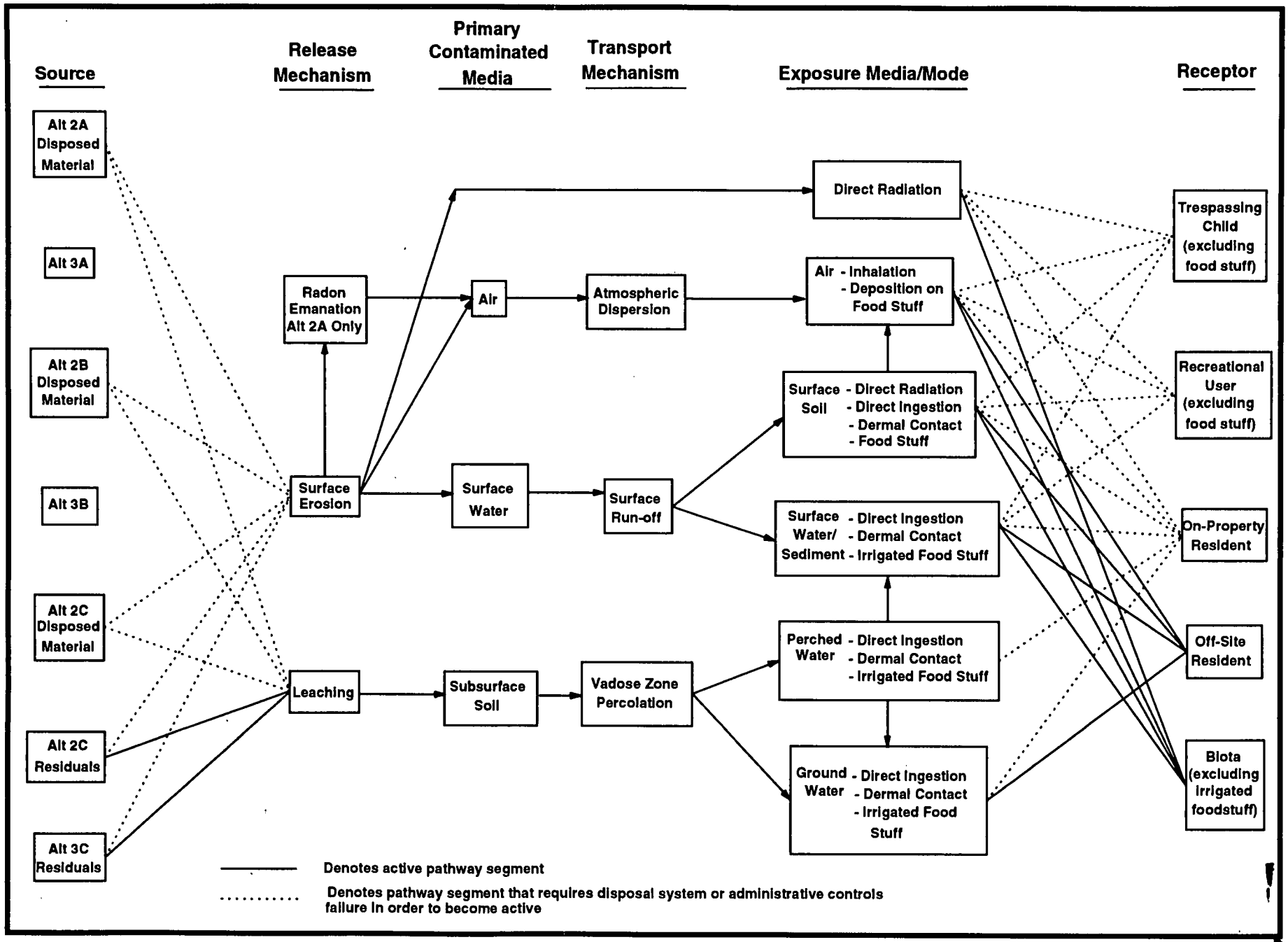

FIGURE 4-9 LONG-TERM RISK CONCEPTUAL SITE MODEL

institutional controls precludes contact to or direct radiation exposure from the treated waste by a recreational user. The disposal vault also contributes to a significant reduction in leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude access to the waste material by an on-site resident.

Because 2A/Vit includes the on-site disposal of treated residues, the 5-year CERCLA review process to ensure continued performance of the disposal system would be part of this alternative.

Adequacy and Reliability of Controls

As previously indicated, the projected residual excess cancer risk to viable receptors, which is attributable to Alternative 2A/Vit, is less than 10^{-6}. The on-site disposal unit uses proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low level radioactive waste under both DOE and NRC programs, and uranium mill tailings under the DOE Uranium Mill Tailings Radiation Control Program (UMTRCA) and the Formerly Utilized Sites Remedial Action Program (FUSRAP). Fate and transport modeling to assess the most likely release mechanism under degradation of the facility, leaching, is completed. The results were based on the assumption that components of the system slightly degrade over 1000 years and that infiltration rates (and consequently exfiltration rates) increase to 1.3 cm/yr (based on the HELP model). Also, the leachability of the treated material was assumed to be the same as that indicated in the treatability study results. Under these assumptions, the leaching of contaminants would not pose a risk to off-site receptors. Even if these input parameters were increased to 15 cm/yr (highest possible with no infiltration barrier) and the leachability of the untreated material were used, the overall result would not change. The leaching of the contaminants would result in a risk to off-site receptors of approximately 10^{-6}.

Vitrification is an innovative technology has not been previously applied to the stabilization of waste materials at the scale contemplated under Alternative 2A/Vit. From 1989 to 1993, the FEMP site has conducted a series of bench scale treatability tests to examine the performance of the vitrification technology on K-65 residues. The tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics (see Appendix C). An ongoing glass optimization program underway for the K-65 residues has identified a relatively wide envelope of operating parameters (temperature, additive rate, and waste composition) under which the vitrification system could perform to produce an acceptable product. Additionally, the use of vitrification provides added operational flexibility to recycle glass product not meeting performance based requirements through

the glass melter. On this basis, there is a high probability that the vitrification treatment system would attain the required glass product performance requirements.

As a result of the significant direct radiation field associated with the treated K-65 residues and to the long half-life gamma emitting radionuclides present, there is concern for ensuring the long-term protection of the inadvertent intruder or on-site resident (in the event of institutional control failure). Employing the 95 percent upper confidence limit activity concentration of 890,000 pCi/g of Ra-226, with a density of 1.8g/cm^3 and a dose conversion factor of 8.56 mrem/hr/pCi/cm^3, the maximum expected effective dose equivalent associated with the treated K-65 residues would be 1.5 rem/hr. Actual values would be expected to be significantly less than this due to the range of Ra-226 concentrations in the residues. The location and physical site conditions associated with the FEMP produce significant uncertainties as to the ability to maintain appropriate long term controls to mitigate potential exposures to potential intruders.

Consistent with DOE Order 5400.5, 40 CFR 264.114 Subparts F and G, 40 CFR 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required 5-year CERCLA review. As a result of the findings of the review, there is a potential that the disposal system may require maintenance, modification, or replacement. The risks associated with maintenance activities would be generally limited to direct radiation to on-site workers. Consistent with DOE Order 5480.11, these potential exposures would be kept as low as reasonably achievable (ALARA) and within regulatory limits.

Long-Term Environmental Impacts

The following paragraphs discuss the long-term impacts of the Alternative 2A/Vit on the environment. Section 4.7 provides a discussion of the irreversible and irretrievable commitment of resources associated with Alternative 2A/Vit.

Soil and Geology

Construction of the disposal vault would result in the permanent disruption of 2.8 ha (6.9 acres) of land. The disposal vault configuration would prevent erosion of waste material that could result in surface soil contamination and would prevent leaching that would contaminate subsurface soil. Uncontaminated soil would be used as fill. Borrow pit soil for construction would be obtained from clearing and grubbing and clean berm soil.

The regional geology of the FEMP site and surrounding area would not be affected by implementation of Alternative 2A/Vit. Geological conditions are important in terms of site suitability for construction of an on-property disposal vault . Because the K-65 material would be vitrified and the appropriate design factors (e.g., depth of cover material) would be incorporated into the disposal vault, the proposed on-property location would be suitable from a geologic standpoint. The design would also incorporate appropriate protection against seismic damage. A review of local conditions suggests the soil beneath the location of the proposed vault is not susceptible to liquefaction or seismically induced settling.

Water Quality and Hydrology

A system to monitor long-term water quality would be implemented by installing monitoring wells around the perimeter of the disposal vault . No significant long-term hydrological impacts to the surrounding area are expected to result from changes to the site. However, after 1,000 years, some degradation could occur. Run-on and runoff controls would be used at the disposal vault and the remaining areas of the site would be regraded to approximate original contours; surface runoff would be directed by engineered controls to existing on-property drainageways for proper treatment prior to release.

Final grading would ensure that the site is well drained to prevent any potential impacts to the above-grade disposal vault. The above-grade disposal vault would be actively monitored and maintained. Periodic monitoring of nearby surface water and groundwater would continue and periodic site inspections would be carried out to identify any damage to the disposal vault or other areas of the site from the erosive forces of heavy rains and wind, biointrusion, or severe natural phenomena (e.g., earthquake or tornado). Maintenance would be performed as necessary.

Air Quality

Following implementation of Alternative 2A/Vit, the air quality at the FEMP site would be similar to current conditions. There would be no long-term impacts on air quality because the depth and material of the cap on the disposal vault, and the non-porous nature of the vitrified waste would limit radon emissions. Disturbed areas would be revegetated which would minimize release of fugitive dust and other particulates.

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Biotic Resources

Long-term impacts may include displacement of potential threatened and endangered species habitat. No critical habitat for threatened and endangered species has been identified in areas to be impacted by Alternative 2A/Vit activities. However, the potential for threatened and endangered species to temporarily reside in the disposal area does exist. State threatened and endangered species observed in or near the disposal location include: the Northern junco (Junco hyemalis), which does not breed in this area but is a common winter migrant. High densities of the bird were surveyed in the areas affected by the proposed action during the winter of 1987 (Facemire et. al., 1990). One endangered Northern harrier (Circus cyaneus) was observed outside the ungrazed pasture census plot established by Facemire (1990). This bird prefers the conditions that may be found in palustrine deciduous forested wetland; however, the Northern harrier does not breed in this area, but is a common spring and fall migrant. One threatened Red-shouldered hawk (Beuto lineatus) was seen outside the proposed area in 1986 (Facemire, et al. 1990). This bird prefers woodlands and the wetter conditions that may be found in the palustrine deciduous forested wetland. The endangered Mountain bindweed (Polygonum cilinode) surveyed in the northern pine plantation and riparian areas in 1986 (Facemire et al. 1990) is found in openings of forested areas. State threatened and endangered species not observed in or near the proposed area, but possibly present because of suitable habitat include the sharp-shinned hawk and the Northern waterthrush; implementing Alternative 2A/Vit would result in the loss of 2.8 ha (6.9 acres) of potential habitat, for these species. Following completion of construction and excavation activities, disturbed areas would be backfilled, regraded, and revegetated with native grass species.

Wetlands and Floodplains

A wetlands delineation for the FEMP site was conducted in December 1992 (Ebasco Environmental 1993) and is currently pending COE approval. The delineation identified approximately 12 ha (29 acres) of jurisdictional wetlands in the northern part of the site. Efforts were made to site the disposal vault in areas not containing jurisdictional wetlands. However, the siting of the facility for Alternative 2A/Vit would result in the loss of approximately 5.0 ha (12.35 acres) of forested wetlands. A wetlands assessment pursuant to the requirements of 10 CFR 1022 has been prepared (Appendix J) for the leading remedial alternative and other alternatives evaluated.

The 100-yr and 500-yr Paddys Run floodplains are located near Silos 1 and 2 and the support facilities. However, these areas would not be permanently altered as a result of implementing Alternative 2A/Vit.

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Socioeconomics and Land Use

The area of the disposal vault is estimated at less than 0.1 percent of the site. However, the presence of the permanent disposal vault would result in future limitations for use of the site. No change would be expected in the local population growth, nearby industrial and commercial operations, or noise level. The net long-term impact of Alternative 2A/Vit on these socioeconomics is expected to be positive because the silo contents and sludge would be isolated and controlled. However, aesthetic perceptions to a visitor or passerby could be altered due to the controls required for the disposal vault. A fenced area topped with barbed wire would be used for restricting access to the material disposal area. These controls could result in noticeable attention drawn to the disposal area.

Cultural Resources

A site-wide archaeological survey would be performed for the areas to be impacted by Alternative 2A/Vit. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of National Historic Preservation Act (NHPA), Ohio Historic Preservation Office (OHPO), American Indian Religious Freedom Act (AIRFA), and Native American Graves Protection and Repatriation Act (NAGPRA). Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2A/Vit uses vitrification to treat all of the wastes making up the contents of Silos 1 and 2 and the K-65 sludge in the decant sump tank. A remedy selection treatability study was conducted with Operable Unit 4 materials to compare the performance of vitrification to other remediation technologies. The criteria upon which this comparison was based were the leachability of the waste form, the material volume reduction achieved, and the reduction in radon emanation from the material (Appendix C - Section C.3.0).

The chemical and physical properties of Subunit A wastes were determined and used in developing glass formulas for the bench-scale treatability study tests (Appendix C, Tables C.3-1 to C.3-10). Data from the study revealed that the radon emanation rate from the vitrified K-65 material ranged from 0.01 to 0.06 pCi/m^2/s, more than two orders of magnitude less than the EPA limit of 20 pCi/m^2/s for radon emanation from uranium mill tailings. Based on an emanation rate ranging from 1,985 to 7,314 pCi/m^2/s for the untreated K-65 material, a reduction of radon emanation by a factor of approximately 500,000 was obtained in the bench-scale vitrification tests (Appendix C, Figure C.3-

1). The measured radon emanation rate from the treated waste form is approximately equal to the emanation rate from natural building materials such as brick and concrete, even though the radium content of the waste glass is 10^3 to 10^6 times greater than that of natural building materials.

Data from the treatability study revealed that significant volume reductions could be achieved through vitrification. As shown in Table C.3-13, the reduction in volume of material ranged from 50.3 to 68 percent. Thus, the final volume was approximately 41 percent of the untreated material volume. This result corresponds to a total estimated treated volume of 2770 m^3 (3645 yd^3).

The vitrified residue from all tests was RCRA nonhazardous, as determined by the TCLP test. Thus, TCLP test results (through the leachate concentration) for the treated waste form demonstrated the effectiveness of vitrification as a treatment process for Subunit A wastes. Previous TCLP testing conducted during the RI for Operable Unit 4 indicated that untreated K-65 material exceeded RCRA toxicity characteristic thresholds for lead. Leachate concentrations were below TCLP regulatory limits for all of the glasses produced in these tests (Table C.3-14 of Appendix C). Lead concentrations in the leachate from the treated material were reduced by a factor of about 500 relative to the untreated K-65 material. Table C.3-18 presents a comparison of the leachate activity from the untreated wastes to the leachate activity from the vitrified wastes.

A wide variation in leaching of the various radionuclides achieved through vitrification was observed. While leaching of Ac-227 from the untreated waste is reduced by a factor of thousands through vitrification, leaching of some radionuclides such as Ra-226, Ra-228, Th-228, Th-230, and Th-232 was unchanged. The low ratios observed of the activity in the leachate from the untreated waste to the activity in the leachate from the vitrified waste do not necessarily indicate that radionuclides are immobilized, but rather, the ratios show that some radionuclides are not leached as readily as others from the untreated waste. For example, while nearly 9 percent of the Pb-210 in the K-65 material is leached from the untreated waste, only 0.45 percent of the Ra-226 and 0.01 percent of the Th-230 are leached. Such variations can arise because of differences in solubility among the elements for the conditions encountered in the leachate. Some radionuclides, particularly Ra-226, were found to leach from the treated material samples at the same rate as the major glass constituents, indicating the absence of selective leaching of radionuclides.

A measure of the stability of the vitrified K-65 waste form is to compare it to leach rate standards which have been developed for high-level vitrified materials. The normalized leach rates observed during the treatability study indicated that all glass formulas exhibited exceptional durability comparable to glasses developed from vitrified high-level wastes. The normalized leach rates were an order of magnitude less than the Defense Waste Processing Environmental Assessment (EA) glass rates (Jantzen et al. 1992) and are comparable to those measured for simulated high-level waste glasses (Piepel et al. 1989). The EA glass is designed to be a standard representing the maximum acceptable leach rate for high-level waste glasses; therefore, the K-65 glasses are substantially more durable than the minimum standard for high-level waste glasses.

Another observation of the treatability tests was that the TCLP will leach the glass more aggressively than the Product Consistency Test (PCT). The PCT is a 7-day static leach test developed for the high-level waste vitrification program. The test uses deionized water at 90°C (194°F) to leach a glass sample which has been crushed and sieved to a size fraction of -100/+200 mesh. The TCLP employs acid, rather than water, to leach the vitrified waste material. The PCT leach testing demonstrated a high degree of durability for the vitrified K-65 materials.

The viscosity and electrical conductivity of the vitrified materials were measured as a function of temperature. The viscosity data show the glass from various tests (Sequences A, C, and D) had reasonable viscosities for processing within the temperature range reported, but the glass from Sequence B was too viscous in this temperature range. The higher viscosity for Sequence B glass resulted from the high alumina content in the BentoGrout mixed with the waste materials, and can be brought to within acceptable levels by increasing the fluxing additives or reducing the BentoGrout content of the waste mixture. The conductivity values for all glasses were close to typical ranges for glass processing. Therefore, the results show that the K-65 material can be made into glasses with reasonable conductivity and viscosity by processing in a joule-heated ceramic melter; however, it is also evident that further development for optimization of glass formulas is needed.

The operating temperature considered for the vitrification design (1350°C [2460°F]) would destroy any organic compounds present in the residues and fix metals into the nonleachable stabilized melt. Hazardous inorganic constituents actually become part of the chemical structure of the glass matrix, and not merely encapsulated. Treatability tests demonstrate that the vitrified product effectively immobilizes the RCRA-defined hazardous elements and reduces their release to levels below the regulatory limits. Additional remedial design treatability studies would be conducted to further

determine the factors that affect the destruction and removal efficiencies for the contaminants during vitrification and the extent of partitioning of undestroyed contaminants between the vitrified material and the off-gas treatment system. The results of these studies will be used to develop appropriate glass formulations, provide data necessary for sizing and design of the full-scale continuous melter system, and to determine the configuration of the final off-gas treatment system for removal of radon.

Literature data on the leachability of the vitrified product from a variety of waste types indicate similar leach resistance; all vitrified material tested to date has passed the RCRA TCLP test. Contaminant release from a vitrified product is controlled by diffusion and is governed by the same factors that affect release from a chemically stabilized/solidified product. The leachability of the vitrified product could be impacted by the development of immiscible phases in the melt because of the variable chemical composition of the waste; however, the short residence time in the melter would minimize the potential for immiscible phase development.

The weathering behavior of volcanic glass (a natural analog to the vitrified product) can provide some measure of the long-term stability and durability of the vitrified product. Only very thin weathering rinds develop on volcanic glass over a period of several million years. The slowness in the overall degradation of a glass grain suggests that the diffusion coefficient or leachability index would remain relatively unchanged over time. Data on the long-term stability of vitrified material are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates. On the basis of the longevity of volcanic glass and diffusion calculations, the vitrified product would be expected to withstand environmental exposure for thousands of years.

Treatment residual of the vitrification process would be produced from the off-gas treatment system. Off-gases containing particulate and other pollutants would be captured and treated using conventional air pollution control equipment (e.g., scrubbers). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary for an adequate design to reduce the amount of fugitive emissions. Scrubber residuals would be recycled through the vitrification process until all the residual waste is contained in the glass matrix. Furthermore, the effects of vitrification as a treatment are essentially irreversible.

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4.2.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Through a combination of engineering controls and access controls, Alternative 2A/Vit would be protective of the community during implementation. Figure 4-10 illustrates that radon release during material removal and direct emissions from being near the untreated material are the release mechanisms that could potentially impact the community during remediation activities. Potential radon exposures would be minimized through the use of engineering controls. The silo headspace would be kept under negative pressure to prevent the release of radon during removal of material. Additionally, the installation of a RTS would capture released radon and remove it from the air stream. Gas collection and treatment systems operated during vitrification of the material would also minimize radon and other gaseous contaminant releases. It has been estimated that during implementation of Alternative 2A/Vit, fenceline radon exposure levels for the off-site public would be indistinguishable from background levels, less than 0.5 pCi/L.

There is the potential for dust created during berm excavation and disposal vault construction to be slightly contaminated. To control migration of the dust off site, a variety of dust suppression methods would be considered during the design. Controlling the dust would provide protection to the community.

Through access to the site during remediation, there is the potential for a trespasser to be exposed to direct radiation from the waste material along with radon, gases, or dust. In addition to the engineering controls that would be implemented to limit the release of contaminants, access controls would also be used during remediation. Through the use of fences and guards, access to the materials by the public would be limited. Access controls are effective, especially in the short term. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 2A/Vit is effective in protecting the community in the short term.

Protection of Workers During Remedial Action

There are no unacceptable risks to workers as a result of implementation of Alternative 2A/Vit. This alternative involves the handling of the waste materials and, therefore, there are several potential exposure pathways for workers. Both the release of radon and exposure to direct radiation from the waste could create a risk to workers. It has been estimated that with appropriate protection, the removal and treatment of materials would result in an excess cancer risk level to remediation workers

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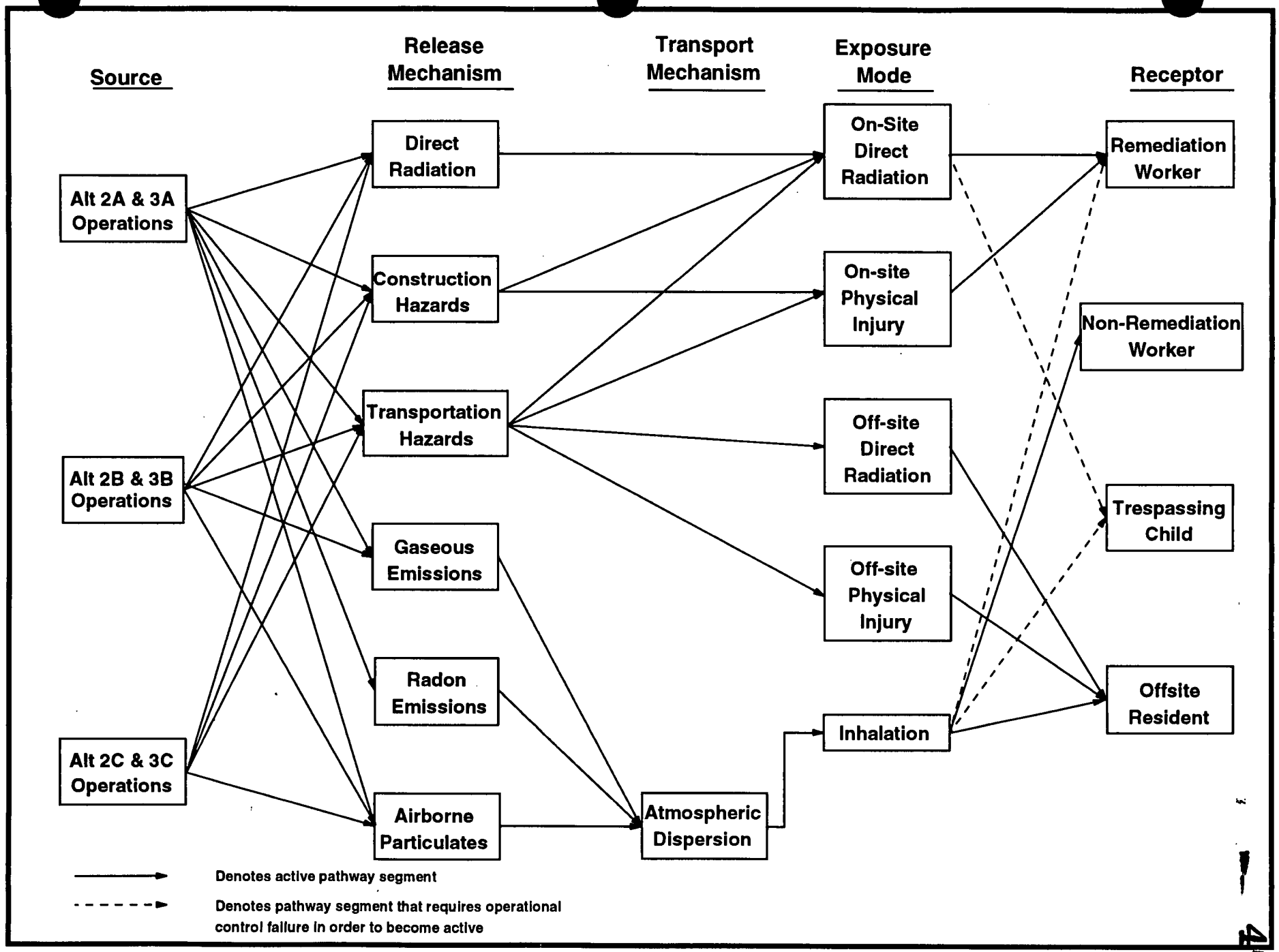

Figure 4-10 SHORT-TERM RISK CONCEPTUAL SITE MODEL

of $4x10^{-4}$ (see appendix D), well within the occupational standards required by DOE Orders. Most of this risk would occur during handling of the untreated waste. As appropriate, workers would wear protective clothing. Shielding would also be used, along with remote activities where needed.

With the negative headspace pressure in the silos and the RTS, it is estimated that there would be no additional risk from radon to remediation or non-remediation workers. However, there may be some additional risk from dust particles released during berm excavation to non-remediation workers who are assumed to not be in protective equipment. Although below occupational limits, the non-remediation worker could experience an incremental lifetime cancer risk level of $7.6x10^{-7}$ from dust inhalation. This estimate is very conservative and assumes that dust is always present. Dust control would significantly reduce this risk.

There are safety issues associated with the removal and vitrification process. The high temperatures and power of vitrification results in an unquantifiable added risk over cement stabilization. There are also safety issues with constructing the on-site disposal vault. There may be accidents bringing the material on site or heavy equipment accidents. Without considering the nature of the activity, it has been estimated, based solely on labor hours, that the removal, treatment, and on-site disposal of Alternative 2A/Vit could have 7.7 injuries during remediation and 0.13 deaths. All remediation activities would be conducted in accordance with a health and safety plan developed to meet 29 CFR 1910.120(b)(4). Training and procedures would assure that worker exposure would be ALARA.

Short-Term Environmental Impacts

Soil and Geology

Soil disturbance during implementation of Alternative 2A/Vit would result primarily from preparation of disposal vault location and construction of access roads, a treatment/packaging area, a staging area, and support facilities. Construction and excavation activities could disturb a total of approximately 4.3 ha (10.6 acres) of the site. [Note: These acreages could increase up to 2.8 ha (7 acres) to accommodate interim storage needs due to delays in transportation or disposal.] These same activities could also result in the erosion of exposed soil areas. Erosion controls such as straw bales and berm would be used to minimize potential erosion. Measures for reducing fugitive dust generation such as surface wetting or using dust suppressants would be used in exposed soil areas as appropriate. Following completion of all construction and excavation activities, disturbed areas would be filled with clean backfill and topsoil and revegetated with native grasses.

Water Quality and Hydrology

Through erosion control and dust suppression, contaminants disturbed during remediation would not be transported to adjacent surface water bodies. These measures include: surface grading, using berms and silt fences; covering surfaces with straw, mulch, riprap, or geotextile membranes; and using revegetation mats in areas with high water velocity. Surface water near the site would be monitored during remediation in accordance with the existing water discharge permit to assess potential impacts to the water from remediation.

Operation of the waste treatment facility would result in the generation of filtrate water, dewatered residues and sludge. These waste streams will be recycled and utilized during waste processing operations (i.e., vitrification) to minimize wastes generated. However, the operation of the vitrification process would result in the generation of a limited amount of wastewater which would require treatment by the FEMP AWWT prior to discharge.

Remediation would not increase the release of contaminants to the groundwater since the material would always be contained. Groundwater concerns in the short term would be addressed by implementing source control actions (i.e., removing the sources of groundwater contamination, and by monitoring to ensure initiation of a timely response) if needed. A monitoring well network is currently in place at the FEMP site. Existing monitoring wells would be sampled to provide information on groundwater quality to: (1) establish baseline conditions, (2) monitor groundwater elevations and concentrations during source removal, and (3) evaluate the effect that remedial activities have on groundwater.

The monitoring frequency is expected to be location specific, depending on the amount of material to be excavated, the level of contamination, and the characteristics of the overburden at each source area. As part of the final monitoring design, Paddys Run and other drainageways would be monitored to assess changes in water quality during source removal activity.

Air Quality

Ambient air quality in areas accessible to the public is regulated by both state and federal standards. There are three potential sources of air emissions; 1) dust from construction and earth-moving activities, 2) radon and gas releases during removal and treatment, and 3) heavy equipment exhaust. Dust would be controlled as discussed in the soil section. With the appropriate dust suppression,

excavation activities are not expected to negatively impact the air quality. The exhaust emissions from heavy equipment are not expected to impact air quality either.

Silo headspace would be kept under negative pressure to prevent the release of radon and a RTS would be installed to remove any released radon from the air stream. Radon and other gaseous emissions would be controlled through collection and treatment during both removal and waste treatment. Therefore, fenceline radon exposure concentrations for the off-site public are expected to be consistent with background levels (less than 0.5 pCi/L).

Biotic Resources

The short-term disturbance of on-property vegetation and wildlife habitat under Alternative 2A/Vit would result primarily from activities associated with 1) construction of the on-site disposal vault and other facilities, 2) excavation of berm soils, and 3) installation of electric power lines, transformers, process water and sewer lines, and material slurry transfer lines. Approximately 4.3 ha (10.6 acres) of local biota (wildlife and wildlife habitat) would be temporarily displaced along with potential threatened and endangered species habitat due to increased noise and vehicular activity. However, these impacts would be temporary and permanent habitat losses are not expected.

There also is the potential for impact to biota from contaminant releases such as through erosion, dust emissions, radon and gas releases. The releases would be minimized through engineering controls such as erosion control, dust suppression, radon and gas collection and treatment, and shielding of waste materials. There should be no negative exposure impact on biota during implementation of Alternative 2A/Vit. Accidental spills of petroleum products (e.g., diesel fuel and oil) or excavated materials could result in the exposure of site contaminants to local biota and water quality degradation. Response actions would be in place for responding to accidental spills to minimize any potential impacts.

Wetlands and Floodplains

A site-wide wetlands delineation has identified several areas of wetlands in or adjacent to areas that could be impacted by the implementation of Alternative 2A/Vit. Wetlands north and south of the treatment facilities are not expected to be affected; however, there would be disturbance of wetlands during the construction of the on-site disposal vault. Approximately 5.0 ha (12.35 acres) of forested wetlands could be affected in the northern part of the site. Engineering controls through the site

activities, such as silt fences and straw bales, would be used to minimize the migration of eroded soil to wetland areas.

The 100-year and 500-year Paddys Run floodplains are located immediately west of Silos 1 and 2. Alternative 2A/Vit activities are not planned to occur within the floodplains and contaminant migration during remediation would be controlled through engineered erosion controls to minimize impacts on the floodplains.

Socioeconomics and Land Use

Short-term impacts to socioeconomics and land use would be minor. Employment needed to implement Alternative 2A/Vit would require 180 workers and approximately 20 trucks making 30 one-way trips per working day. It is assumed for this analysis that many of the workers needed for the remedial activities already work at the site; consequently, the relocation of additional workers to the area would not have a significant impact on public facilities within the Cincinnati Metropolitan Statistical Area (CMSA).

The implementation of this alternative would require the acquisition of resources such as steel and concrete. These resources are readily available in the region around the FEMP site. In addition, it is expected that most of the resources such as sand and soil would be available from excavated areas within the site boundary. Implementation of this alternative would not result in the consumption of large quantities of geological resources. However, due to the requirements for high temperatures associated with the vitrification process, the implementation of Alternative 2A/Vit would require fairly large quantities of electricity.

To better assess economic impacts, it is assumed for this analysis that all resources needed for remedial activities would be purchased within the CMSA. Rather than addressing each individual county and the resources they are capable of supplying, a total budget figure for all counties has been derived from each county's operating budget for the fiscal year 1992 to 1993. The total operating budget for the CMSA 1992-1993 was approximately $805,000,000. The collective revenue for the CMSA would increase by 4.7 percent. The additional expenditures would be spent over approximately 6 years of implementation. Therefore, only minor economic impacts are expected for the CMSA as a result of implementing Alternative 2A/Vit.

The land adjacent to the FEMP site is primarily devoted to open land use such as agriculture and recreation. Commercial activity is generally restricted to the village of Ross, approximately 3.2 km (2 miles) northeast of the FEMP site, and along State Route 128, just south of the village. More than 160 ha (400 acres) of the open land on the FEMP site are leased to a nearby dairy farmer, who allows livestock to graze on the property. Pine plantations are located to the northeast and southwest of the former Production Area. Because the area had been extensively used for agricultural purposes prior to the establishment of the FEMP site, there is no land on or in the vicinity of the site where a predevelopment natural environment remains intact. The land closest to this description is the recreated prairie lands on the Miami Whitewater Forest property, located several miles south of the site.

Cultural Resources

The NHPA (36 CFR 800, Section 106) requires federal agencies to protect properties on or eligible for inclusion on the National Register of Historic Places. This list includes undiscovered resources, districts, sites, buildings, structures, or objects that may be eligible for inclusion on the National Register of Historic Places. There are currently no areas identified at the FEMP site that are eligible for inclusion on the National Register.

To avoid impacts on undiscovered cultural resources, a site-wide archeological survey will be performed by a professional firm approved and managed by DOE. An ethnographic survey will be conducted by a professional anthropologist to determine the presence of Indian sacred sites and burial grounds. These cultural resources, if present, would be protected in accordance with the American Indian Religious Freedom Act (AIRFA) and the Native American Graves protection and Repatriation Act (NAGPRA). If possible, impact area boundaries should be designated so as to avoid cultural resources; however, if this is not feasible and cultural resources are affected, they would be evaluated to determine the appropriate treatment. In situ cultural resources would be preserved through agreement with the OHPO and other interested parties. Should it be agreed that cultural resources are to be removed, the following steps would be followed; 1) archaeological excavation, 2) laboratory treatment of cultural resources recovered at the site, and 3) curation of any recovered artifacts. If final in situ preservation of on-property artifact(s) is chosen (the artifacts remain in place), the plan for preservation would have to be compatible with remedial alternatives selected for the area in which the artifact(s) is located (Luce 1987).

Duration of Remedial Activities

Remedial action activities under Alternative 2A/Vit are expected to be completed in approximately 6 years. Construction, testing, and startup of the material processing could require at least 3 years, with the possibility of a longer period depending on the difficulties encountered. Material removal activities would require approximately 3 years, assuming 8 hours/day, 7 days/week, and 3 weeks/month. The treatment would operate concurrently with removal for 3 years assuming that operations would be conducted 24 hours/day, 7 days/week, and 3 weeks/month. The time to implement the treatment component of this alternative could be prolonged if pilot-scale testing and full-scale testing of the vitrification resulted in scale-up and operational difficulties because of the innovative nature of this treatment technology. Physical, substantial, and continuous on-site activities would be initiated within 15 months after the ROD is approved by the EPA.

4.2.2.6 Implementability

Technical Feasibility

Technical feasibility, construction, and operation of the material removal component of Alternative 2A/Vit would be reliable. Hydraulic removal is a standard technology that is normally reliable and readily available. Although hydraulic removal has not been used before on this type of material, it has been used to remove material of similar consistency. Because the silo domes have questionable structural integrity, extreme caution must be exercised when removing the silo contents. In case of silo dome failure and the subsequent implementation of the emergency response plan, all silo contents removal would stop until an assessment of the failure and any impacts is complete. Upon completion of the assessment, the steps required to continue removal of the silo contents would be determined.

Construction and operation of the disposal component of this alternative would be reliable. Components of the design have been used at numerous other sites. Readily available resources and standard procedures would be used for the construction and operation of the above-grade disposal vault. About 2.8 ha (6.9 acres) would be required for the above-grade disposal vault. If disposal volumes are greater than anticipated, the above-grade disposal vault would be increased to accommodate the additional capacity.

The technical feasibility of the vitrification facility construction is expected to be moderately straightforward, but a full-scale facility for the vitrification of materials similar to those in Silos 1 and 2 and the decant sump tank has never been built. However, remedial design treatability studies (bench- and pilot-scale) would be performed to address specific design requirements for Subunit A

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wastes. The necessary equipment would be modified from available equipment used in the glass making industry. An electrical substation also would be built in the vicinity to supply the power required for vitrification.

The vitrification technology for Alternative 2A/Vit would require engineering scale-up to be implemented full scale. Pilot testing, detailed design, fabrication, installation, and full scale operation would be needed to optimize the treatment process. The construction of a vitrification facility is expected to be relatively straightforward, but a full scale facility for the vitrification of hazardous or radioactive waste similar to that at the FEMP site has not yet been constructed elsewhere. The necessary equipment could be modified from available equipment used in the glass-making industry. Construction of a vitrification facility at site would include construction of an electrical substation. Operation of the vitrification facility would be somewhat difficult. The vitrification system consists of three basic circuits: a feed preparation circuit, a melter circuit, and an off-gas treatment system. The feed preparation circuit would be used to remove water from the slurry material prior to vitrification. The equipment needed for this circuit is readily available because this component of the process is widely used in industry. Joule-heated ceramic melters have been used to vitrify liquid high-level radioactive material, radioactively contaminated soil, and waste contaminated with heavy metals in quantities ranging from 4540 to 408,460 kg/d [5 to 450 tons per day (TPD)]. The conceptual design for the Operable Unit 4 treatment system specifies a 13 TPD melter with a slurry feed.

A trained process engineer would be needed to operate both the physical pretreatment and melting circuits of the ceramic melter and to act as supervisor of the melter circuit. Operators and maintenance personnel, laborers, laboratory technicians, and administrative personnel would also be needed. Industrial work experience would be required for the system operators and maintenance personnel. The number of operators and maintenance personnel with previous experience in the vitrification of hazardous waste is limited, but these personnel could be drawn from the commercial glass-making industry or the high-level radioactive waste vitrification industry. The melter system could be designed to operate largely by computer, with a combination of human and computerized oversight. Start-up of the vitrification would require at least 4 months; however, because the melter system has not been previously used at the scale required for the site, operational problems might develop during start-up that could impact the processing schedule and costs.

Potential operational problems in the melter circuit include temperature variation, incomplete melting, immiscible phase development, and thermocouple or heat sensor failure. Refractory failure is not

anticipated to be a problem because the design life of the melter operation is less than the design life of the refractory at anticipated operating temperatures. Temperature variation and improper control could result in the incomplete melting of feed material. Temperature fluctuations could also cause phase immiscibility. The use of electricity allows for almost immediate control over melt temperatures and thus would aid in controlling temperatures continuously monitored by thermocouples and heat detectors. These thermocouples would probably be prone to failure at the high operating temperatures, necessitating the placement of redundant thermocouples at critical locations in the system and routine replacement and repair as part of maintenance activities. Any product from the vitrification system that was incompletely melted or contained immiscible phases would be returned to the system until an acceptable product was produced.

The reliability of the melter system for waste treatment is not well established because this system has not yet been implemented at full scale or continuous operation. Similar melting systems used in commercial glass-making report a 90 percent continuous operation efficiency.

The off-gas treatment system would use standard air pollution treatment and control devices. The capabilities of the individual off-gas treatment devices are known and reliable with regard to linking multiple treatment devices together to treat the off-gas stream expected from vitrification of the Silos 1 and 2 contents and decant sludge at full scale. The off-gas treatment system would use standard components, but the selected devices and their configuration will have to be explicitly defined, tested, and optimized through bench-scale and pilot-scale testing.

The limited experience in developing the required off-gas treatment system could result in schedule delays or cost increases because more time and personnel might be needed to bring the system on-line. Operators and repair personnel would probably be drawn from the incineration industry because of their experience in operating and maintaining off-gas treatment systems. The likelihood of operational problems would increase as the complexity of the off-gas treatment system increased. It is possible that a complex linkage of treatment devices could lead to operational difficulties with individual devices, and the potential for effects from failure of individual devices could be exacerbated in downstream devices and result in an overall problem with system operations and collection and removal efficiencies. If the off-gas emissions exceeded applicable requirements, delays would result. Failure of monitoring devices or inadequate test results from a full-scale off-gas system could also cause delays until corrections could be implemented. Additional conceptual design and

testing would be required to identify and resolve the potential difficulties in designing and operating an off-gas treatment system for a vitrification system.

Operational problems that could develop in the off-gas treatment circuit include production of large amounts of particulate that require secondary handling, added treatment requirements for the scrub solution prior to disposal, monitoring device calibration, maintenance requirements, and exacerbation of operational problems in downstream control devices resulting from failure of an upstream device. The off-gas treatment system would require testing and optimization to resolve these potential problems.

The effectiveness of the main components of the treatment process for Alternative 2A/Vit would be regularly monitored. The off-gas treatment system effluent would be monitored to determine the off-gas composition and ensure compliance with applicable requirements. The effectiveness of the vitrification process would be monitored by regular testing of the treated material. If a sample fails the determined leachability criteria, additional samples would be collected, and these samples would be tested and analyzed to determine the cause of the problem. The failed treated material would be revitrified if necessary, and the process modification will be instituted. Any leachate generated from the treated material placed in the above-grade disposal vault would be captured by the LC/DS. A radon monitoring system would be used to detect any radon emissions to verify the integrity and effectiveness of the multimedia cap. Groundwater monitoring wells would be located to detect changes in groundwater quality. The monitoring system associated with the above-grade disposal vault would provide the information needed to determine if corrective action should be taken to prevent the migration of materials into the environment.

The implementation of Alternative 2A/Vit would not adversely impact the performance of additional remedial actions at the FEMP site. For example, the presence of the above-grade disposal vault would not affect the ability to remediate groundwater beneath the vault. Migration and exposure pathways would be addressed through active sampling and analysis during on-site activities.

Administrative Feasibility

No permits or licenses would be required, but permit information summary packages may be necessary. The substantive technical requirements of air emissions permits would also need to be demonstrated, and may include calculating estimated emissions, providing air emissions controls, developing a sampling and analysis plan to monitor air emissions, and air sampling. Coordination

with OEPA would be necessary to ensure that the substantive technical requirements for siting the above-grade disposal vault would be met.

Availability of Services and Materials

Although it is technically feasible to design, construct and operate a vitrification facility, a full-scale facility for the vitrification of materials similar to those within Operable Unit 4 has never been built. Remedy-selection treatability studies have been completed and remedial design treatability studies (bench- and pilot-scale) would be performed to address site-specific design requirements. Necessary equipment would be modified from available equipment in the glass-making industry. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel would be trained as required. There would be sufficient disposal capacity for the vitrified waste.

The activities involved in Alternative 2A/Vit include: construction of the rail system for the work platform, the work platform and hydraulic mining device, clearing and grubbing of areas around the silos and at the location of the material processing facility, construction of access roads, fencing, lighting, water, sewer, and electrical services, construction of an above-grade disposal vault, construction of a new Radon Treatment System (RTS), construction of a materials processing facility including a belt filter and vitrification unit, and construction of a multimedia cap.

The construction of the rail system, a work platform, and hydraulic mining device would involve the purchase of materials and services which are standard in the construction industry.

The clearing and grubbing, and construction of roads, fencing, lighting, sewers, and electrical services would involve the use of standard construction equipment and trades, the use of a fence installation contractor, and the purchase of appropriate materials. These are all readily available.

The construction of an above-grade disposal vault would require the use of standard construction equipment and trades. Materials needed to construct the vault would be purchased. These services and materials are available locally.

The construction of a materials processing facility would involve the purchase of a pre-engineered building, the process equipment, the process chemicals/materials, electrical transformers and transmission lines, and the instrumentation and controls. It would also involve the use of standard

construction equipment and services. Some engineering would be required during construction, start-up, and debugging of the process equipment. Qualified personnel would be needed to operate and maintain the facility. Of these, only the operator may be difficult to retain.

The construction of the multimedia cap would require the acquisition of material for a geotextile liner, a clay layer with a permeability of $1x10^{-7}$ cm/s, a 40-mil textured geomembrane, and clean soil for the foundation. As shown in a survey, these materials would be readily available. Standard construction equipment, operators, and trades would be required. The installation of membranes and liners would require specialized equipment and personnel to lay the material and seal the seams.

Finally, it will be necessary to ensure that EPA, OEPA, and the local community are fully involved in the development of remedial design and remedial action work plans. Close coordination with the regulatory agencies and the community prior to and during remedial activities is essential to successful implementation.

4.2.2.7 Cost

The total present worth cost of Alternative 2A/Vit is $43.6M. A detailed breakdown of the cost is provided in Table 4-2.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and hydraulic removal/transfer system for transfer of the residues, purchase of vitrification equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-2. More detailed information is provided in Appendix E.

The largest component of the capital cost is the construction of the hydraulic removal/transfer system. This represents approximately 40 percent of the total capital costs. Most of the expense of this component is due to construction of the steel superstructure that supports the hydraulic system. The second largest element of the capital costs (13 percent) is the purchase of vitrification equipment.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

TABLE 4-2

COST ESTIMATE FOR ALTERNATIVE 2A/VIT

ALTERNATIVE 2A: REMOVAL, STABILIZATION W/VITRIFICATION, ON-PROPERTY DISPOSAL			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
SITE PREPARATION	$768,600	$660,000	$1,428,600
WASTE PROCESSING	$1,008,500	$1,065,000	$2,073,500
VITRIFICATION	$2,935,500	$1,703,600	$4,639,100
HYDRAULIC REMOVAL/TRANSFER SYSTEM	$6,655,400	$7,797,800	$14,453,200
DISPOSAL VAULT	$937,100	$1,595,500	$2,532,600
PACKAGING (2,412 PKGS. @ $955/PKG.)	$636,800	$1,666,700	$2,303,500
TOTAL CAPITAL	$12,941,900	$14,488,600	$27,430,500
ESCALATION (11.0% OVER 2 YEARS)	$1,423,600	$1,593,700	$3,017,300
SUBTOTAL	$14,365,500	$16,082,300	$30,447,800
CONTINGENCY (20.0%)	$2,873,100	$3,216,500	$6,089,600
TOTAL ESTIMATED INSTALLED COST	$17,238,600	$19,298,800	$36,537,400
OPERATION AND MAINTENANCE (O&M) COSTS			
DURING CONSTRUCTION			$11,692,500
POST-REMEDIATION			$3,425,400
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$43,601,900

NOTES:

Costs are order of magnitude costs (-30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during construction (years): 3
Post-remediation O&M (years): 30

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, the roads, and the equipment staging areas. The basis of estimate includes the following assumptions:

- An area of approximately 2.8 ha (6.9 acres) would be cleared and grubbed.
- Filling would be performed where necessary. The volume of fill was estimated to be 11,500 m^3 (15,000 yd^3). It was assumed that this soil could be obtained from excess onsite soil.
- New fencing would be added across the southern end of the remediation area, around the interim storage area, and between the proposed parking area and the equipment staging area. Fencing would be 2 m (7 ft) high, barbed wire topped chain link fence. Approximately 550 linear meters (1,800 linear ft) would be required. It is assumed that seven gates would be required, each 4.5 m (15 ft) wide and 2 m (7 ft) high, and topped with barbed wire.
- An equipment staging area would be added to the north end of the remediation site. This area would consist of 15 cm (6 in) of crushed stone [2.54 cm (1 in) maximum diameter] applied over an area 45 m (150 ft) by 60 m (200 ft) [2700 m^3 (30,000 ft^2)].
- Approximately 450 m (1,500 ft) of 6 m (20 ft) wide roads would be constructed in the remediation area. The roads would be constructed of 15 cm (6 in) deep crushed stone [2.54 cm (1 in) maximum diameter].

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the radon treatment system. Costs were estimated based on the following assumptions:

- The waste processing facility would be a modified, two-story, pre-engineered building built on slab. The first floor would provide approximately 1350 m^2 (14,400 ft^2) and the second floor would have 50 m^2 (500 ft^2). The waste facility would be fully insulated and would have a 10-year design life span.
- The walls of the processing rooms and the storage room will be shielded with 0.6 m (2 ft) thick concrete.
- Approximate dimensions of the various areas of the building were estimated to be as follows: processing area - 820 m^2 (8,800 ft^2), administrative/personnel area - 300 m^2 (3,200 ft^2), miscellaneous equipment area - 450 m^2 (4,800 ft^2), and storage area - 220 m^2 (2,400 ft^2).
- The ventilation system for the general process area would operate continuously, and would either recirculate or exhaust to atmosphere. This system would not be designed to remove radon.

- The general process area ventilation would provide seven air changes per hour. The system would include a 1135 m^3/min (40,000 cfm) blower and HEPA filter, and 91 m (300 ft) of 1.5 m (5 ft) diameter ductwork with dampers and fittings. A second redundant train would be installed.

- A separate ventilation train would be used in the event radon is detected in the process area. The general process area ventilation system would shut down if radon is detected in the general process area.

- The radon treatment system for process air would consist of a 30 m^3/min (1,000 cfm) blower, a calcium sulfate media dehumidification vessel, a carbon adsorption canister, a HEPA filter, and approximately 61 m (200 ft) of 25 cm (10 in) diameter ductwork (with dampers and fittings). This system would be rated for 30 m^3/min (1,000 cfm), and the system would exhaust to atmosphere. A second redundant train would be installed.

Vitrification

This cost item includes the cost of the vitrification equipment, radon treatment system, and off-gas system, and is estimated based on the following:

- The vitrification equipment would operate 24 hours/day and would be designed to treat of 11,800 kg/day (13 tons/day) of material.

- Vitrification equipment includes a horizontal belt filter for sludge dewatering, filtrate recycle tank, surge tank, sodium carbonate and carbon storage/feed facilities, process piping, pumps, mixers, and a joule-heated melter.

- The off-gas treatment system would be rated at 4 m^3/min (150 cfm). It would consist of blowers, scrubbers, carbon adsorbers, and HEPA filters.

- A radon treatment system (RTS) for the headspace for Silos 1 and 2 and the decant sump would be provided.

- The radon treatment systems would each be rated at 40 m^3/min (1,500 cfm). It would consist of a blower, carbon adsorbers, and driers.

Hydraulic Removal/Transfer System

This cost component includes the support superstructure and work platform, rail trolleys, an enclosure for the hydraulic equipment, a concrete material transfer pit, an RTS and building for the silo structures, and the hydraulic removal equipment. Assumptions used for the cost estimate include:

- The work platform would be a rail-mounted, 54 m (180 ft) structure truss that would span the silos.

- A 2.4 m (8 ft) wide by 2.4 m (8 ft) long by 9 m (30 ft) high, 1.3 cm (0.5 in) thick plexiglass enclosure would be provided for the drive unit of the hydraulic removal equipment.

- The silo RTS would be as described for the vitrification system RTS for the silo headspace. The RTS equipment building would be 6 m (20 ft) long by 9 m (30 ft) wide by 3 m (10 ft) high, with 0.3 m (1 ft) thick concrete walls.

- The hydraulic removal equipment would consist of a slurry pump.

- A 60 m (200 ft) long, below-grade concrete pit with a removable concrete lid would be constructed between the silo and the waste processing facility. This pit would contain the double-walled material transfer piping and serve as a secondary containment for the piping.

Disposal Vault

The cost of the disposal vault was estimated as follows:

- Cost for the on-property, above-grade disposal vault was estimated at a unit cost of $939/m^3$ ($718/yd^3$).

- The unit cost estimate is based on a conceptual design for a vault consisting of individual modular cells, each capable of holding 3400 m^3 (120,000 ft^3) of material. As additional disposal volume space is required, additional modular cells were added for cost estimating purposes. Cell numbers were estimated by rounding up to the nearest whole number.

- The size of the disposal vault was based on the number of packages noted below, assuming each package occupies 2 m^3 (64 ft^3) of space, and was estimated as 4372 m^3 (154,368 ft^3). Assuming a cell size of 3400 m^3 (120,000 ft^3), two cells would be required [1394 m^2 (15,000 ft^2) vault footprint area).

- The design of the vault includes a multimedia cap, liner, intruder barrier, and LC/DS.

- The vault would cover approximately 2.8 ha (6.9 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation. Estimated cost is based on the following:

- Packages would be DOT specification 7A-Type A containers with exterior dimensions of 1.2 m (4 ft) width by 1.2 m (4 ft) length by 1.2 m (4 ft) depth. Interior dimensions would be 1.1 m (3.5 ft) width by 1.1 m (3.5 ft) length by 1.1 m (3.5 ft) depth, providing 1.2 m^3 (43 ft^3) of storage per package.

- Total volume that would be packaged was based on 3636 m^3 (4,756 yd^3) and 3158 m^3 (4,130 yd^3) of untreated Silos 1 and 2 material, respectively. Final packaging

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volume, assuming a 59 percent volume reduction due to the vitrification process, was 2770 m^3 (3,643 yd^3).

- Packaging and disposal of materials generated during D&D operations are not included in this cost, but are included in the costs for Subunit C.
- Total packaging cost was estimated assuming 2,412 containers.
- A unit cost of $955 per container was determined based on a material cost of $650 per unit and a labor cost of 16 man-hours per unit for handling, filling, and documentation.

O&M Cost

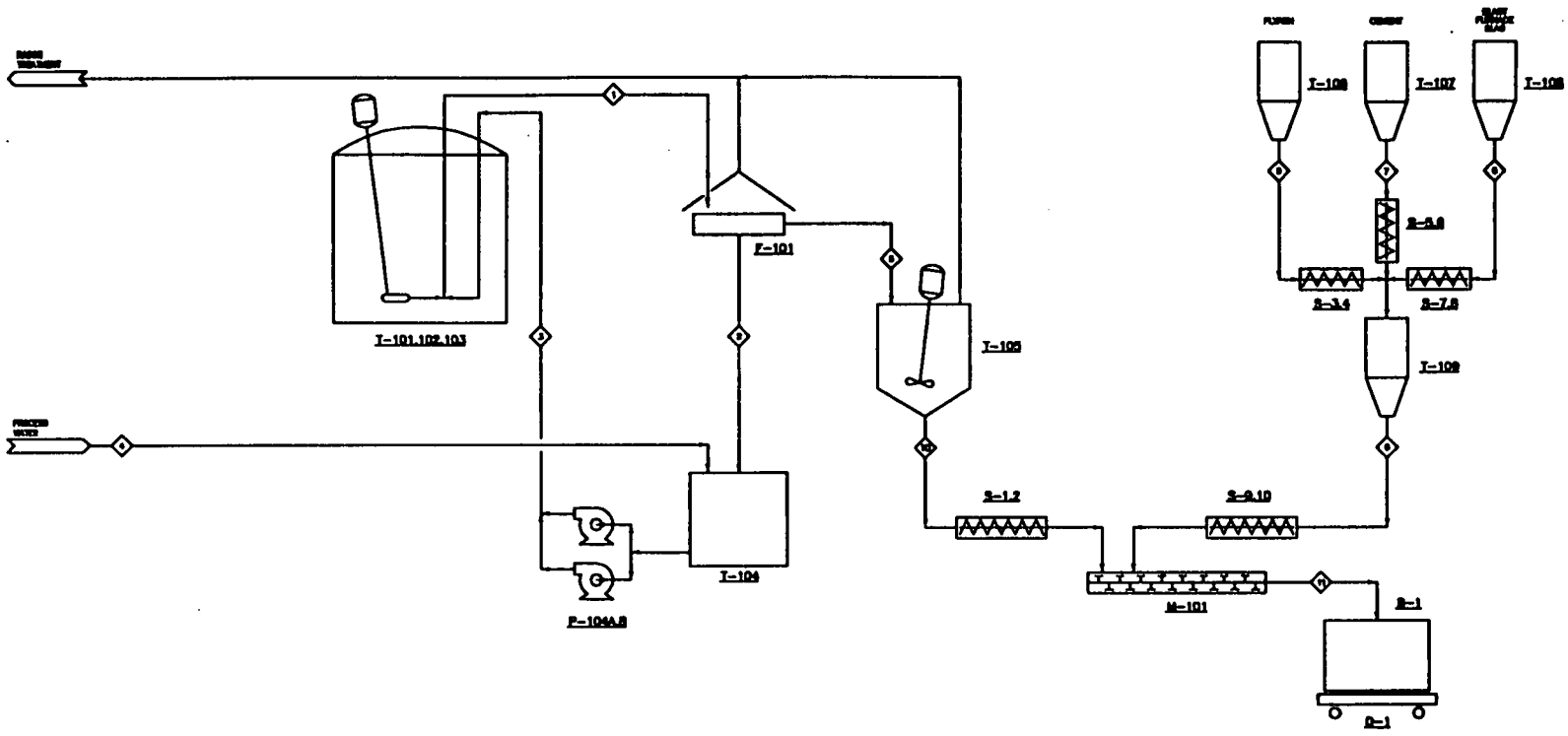
Short-term O&M costs incurred during remediation, and long-term O&M costs are $11.7M and $3.4M, respectively (not considering present worth). Long-term O&M costs include the maintenance and monitoring which would be conducted until FEMP site-wide remedial action objectives are attained, i.e., for a period of approximately 30 years. The monitoring would support the required CERCLA five-year reviews.

4.2.3 Analysis of Alternative 2A/Cementation

This alternative is identical to Alternative 2A/Vit with the exception of the stabilization process option (Figure 4-11). Alternative 2A/Cem would use the same site preparation/construction, material removal, and on-property above-grade disposal vault process options as Alternative 2A/Vit (Section 4.2.2); however, Alternative 2A/Cem would use cement stabilization in place of vitrification as the treatment process option. Also, because cement stabilization results in a greater quantity of treated material than vitrification, the on-property above-grade disposal vault for the treated material is estimated at 4.3 ha (10.6 acres).

Material Processing

The Subunit A material would be removed as described in Alternative 2A/Vit (Section 4.2.2). Cement stabilization involves pumping the slurried silo contents and decant sludge from the slurry surge tank through a screw feeder to a stabilization mixer, to which the additives (flyash, cement, and blast furnace slag) are added with the appropriate amount of water. After the contents are thoroughly mixed with the additives, the mixture would be pumped directly into DOT specification 7A Type A packaging and transported to a nearby curing area. After the treated material has cured, it would be tested and transported to the above-grade disposal vault (see Figure 4-6).



T-101, 102, 103	SLUG 1 & 2 CEDWIT SLURP TANK
T-104	FLYWASH RECYCLE TANK
T-105	SLURRY SURGE TANK
S-1,2	SLURRY SCREW FEEDERS
T-107	CEMENT HOPPER
S-3,4	FLY ASH SCREW FEEDER
S-7,8	BLAST FURNACE SLAG SCREW CONVEYOR
S-9,10	ASBESTOS SCREW FEEDER
D-1	WASTE TRANSFER SKILLY
F-101	BELT FILTER
P-104A,B	FLYWASH RECYCLE PUMPS
M-101	STABILIZATION MIXER
T-106	FLYWASH HOPPER
T-108	BLAST FURNACE SLAG HOPPER
S-5,6	CEMENT SCREW FEEDER
T-109	STABILIZATION FEED HOPPER
R-1	DISPOSAL SITE

STREAM NO.	1	2	3	4	5	6	7	8	9	10	11
MASS FLOW (lb/hr)	14020	7063	11044	3981	6967	221	774	300	1304	2302	3606
SOLIDS (lb/hr)	3066	119	119		3066	221	774	300	1304	995	2299
WATER (lb/hr)	11044	7063	11044	3981	3901					1307	1307
FLYWASH (lb/hr)						221			221		
CEMENT (lb/hr)							774		774		
SFS (lb/hr)								300	300		
% SOLIDS	20	0	0	0	43	100	100	100	100		
FLOW (gpm)		18.0	24	8							
HOURS/DAY	8	8	8	8	8	24	24	24	24	24	24
DAYS/WEEK	7	7	7	7	7	7	7	7	7	7	7

ALTERNATIVES 2A/CEM, 3A.1/CEM
CEMENT SOLIDIFICATION
PROCESS FLOW DIAGRAM
FIGURE 4.2.11

4.2.3.1 Overall Protection of Human Health and the Environment

Alternative 2A/Cem meets the remedial action objectives for Subunit A. As with Alternative 2A/Vit, Alternative 2A/Cem meets the objectives through treatment, containment in an on-site engineered above-grade vault, and implementation of institutional control measures. The difference between the two alternatives is the treatment method used.

Treatment of Subunit A material through cement stabilization would reduce contaminant mobility but would increase the volume of contaminated material. The leaching rate of the treated waste form would be reduced enhancing the protection of the underlying Great Miami Aquifer. As with Alternative 2A/Vit, treatment of the material prior to disposal would also provide additional protection in the event that the vault begins to degrade. Similar to Alternative 2A/Vit, continued protection by Alternative 2A/Cem is uncertain as a result of the possible degradation of the stabilized material and subsequent increased leachability.

The containment features of Alternative 2A/Cem include the above-grade vault and provide additional control of contaminant migration along with prevention of direct access to the waste. Uncertainties exist in long-term reliability of the vault although fate and transport modeling results show Alternative 2A/Cem to be protective even with slight degradation of the disposal vault.

Both 2A alternatives use institutional controls to provide protection to human health in the event of failure of the engineering controls and to provide an added measure of protection against destruction of the vault. Additionally, under ORC 3734.02, a restrictive covenant limiting site use is required for any disposal vault. As with the other components of these two alternatives, the long-term reliability of institutional controls is uncertain.

Exposures to receptors from pathways resulting from the vault failure would be expected to be minimal due to the positive attributes of the treated material. However, direct radiation exposure could be significant. Eventually, failure of both the engineered controls and the institutional controls could result in human health and environmental risks approaching baseline conditions.

Short-term risks for Alternative 2A/Cem would be almost the same as for Alternative 2A/Vit. While the difference in hazards between the two treatment process options is not quantifiable, cement stabilization probably poses slightly lower risks because it does not employ the high voltages and temperatures that vitrification does.

4.2.3.2 Compliance with ARARs

Alternative 2A/Cem is identical to Alternative 2A/Vit with the exception of the process option used to treat the Subunit A wastes. In this alternative, cement stabilization would be used in place of vitrification. Because cement stabilization results in a greater quantity of treated material than vitrification, the on-property disposal vault for Alternative 2A/Cem would be proportionately larger than the disposal vault required under Alternative 2A/Vit. This difference is insignificant for compliance with potential ARAR/TBC requirements (see Table F-2 in Appendix F). Compliance of this alternative would be substantially identical to that of Alternative 2A/Vit presented in Section 4.2.2.2. The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 2A/Cem would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those standards associated with meeting drinking water MCLs and MCLGs requirements, the groundwater protection requirements, radon-222 airborne release requirements, other radionuclide release requirements for water and air, and their resulting doses to the public. Appendix D contains the description and results of the analyses supporting these assessments for Alternative 2A/Cem. Additional documentation of compliance of Alternative 2A/Cem with the identified ARARs is presented in Appendix F (Table F-2).

Location-Specific ARAR/TBCs

Alternative 2A/Cem would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands, endangered species, and the sole source aquifer underlying the FEMP site. Despite the larger footprint of the on-property disposal vault associated with this alternative, the Alternative 2A/Cem disposal vault would have adequate locational setbacks to comply with these distance requirements. As was noted, compliance with the OAC 3745-27-07 prohibition on siting a solid waste disposal vault over a sole source aquifer would be based on demonstrating the substantive technical requirements for an exemption to this requirement as discussed in Section 4.2.2.2.

Action-Specific ARAR/TBCs

Alternative 2A/Cem would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.3). Included would be those standards associated with the design of the multi-barrier engineered above-grade disposal vault system and operational requirements under RCRA, UMTRCA, and the NRC. As was discussed for Alternative 2A/Vit, Alternative 2A/Cem would comply with 40

CFR 191 Subpart A (a relevant and appropriate requirement) and would comply with most of the requirements in 40 CFR 191 Subpart B (a TBC requirement). In addition, Alternative 2A/Cem would comply with ARARs associated with the Clean Air Act, Clean Water Act, and RCRA requirements for management and treatment of hazardous waste by incorporating sound engineering features and best management practices into the remediation and operation of the unit. Additional supporting documentation to justify that Alternative 2A/Cem would comply with the identified ARARs is presented in Appendices D and F (Table F-2).

4.2.3.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 2A/Cem reduces the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6}. Since the only difference between Alternatives 2A/Cem and 2A/Vit is the treatment technology applied and since the magnitude of the residual risk under an effective alternative does not depend in this case on the type of treatment technology, the residual risk from both alternatives would be the same.

Adequacy and Reliability of Controls

The projected residual excess cancer risk attributable to Alternative 2A/Cem for viable receptors is less than 10^{-6}. The on-site disposal unit is the same as that for Alternative 2A/Vit and therefore has the same adequacy of controls and the same degree of reliability. Fate and transport modeling of the leaching pathway is completed. The assumptions were the same as for Alternative 2A/Vit except that the leachability of the treated material was assumed to be that of the treatability results for cement stabilization. The results were the same as for Alternative 2A/Vit, leaching of contaminants would not pose an unacceptable risk to off-site receptors.

Cement stabilization is a proven technology that has been previously applied to the stabilization of similar waste materials as those contemplated under Alternative 2A/Cem. Additionally, over the period of 1989 to 1993, the FEMP site has conducted a series of bench scale treatability tests to examine the performance of the cement stabilization technology on K-65 residues. The tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics (see Appendix C). On this basis, there is a high probability that the cement stabilization treatment system would retain the required product performance requirements.

Consistent with DOE Order 5400.5, 40 CFR 264.114 and 40 CFR 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required 5-year CERCLA review.

Long-Term Environmental Impacts

With the exception of the area disturbed, Alternative 2A/Cem has the same long-term environmental impacts as Alternative 2A/Vit. Alternative 2A/Cem would permanently disturb 4.3 ha (10.6 acres) of land as a result of construction of an on-site disposal vault.

4.2.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2A/Cem uses cement stabilization to treat the contents of Silos 1 and 2 and the K-65 sludge in the decant sump tank. Cement stabilization reduces the mobility of contaminants by binding them into a cement mixture. As a result of the additives used in the process, the volume increases. There is no reduction in toxicity. A remedy selection treatability study was conducted with Operable Unit 4 materials to compare vitrification and cement stabilization. The criteria for the comparison included leachability of the treated waste form, the material volume reduction achieved, and the reduction in radon emanation from the material (Appendix C-Section C1.0 and Appendix H).

The chemical and physical properties of Subunit A wastes were determined and used in developing the bench-scale treatability studies. Data from the study revealed that the radon emanation rates from the treated K-65 material did not pass the 20 $pCi/m^2/s$ criteria established for DOE in 40 CFR 61. The rates exceeded 200 $pCi/m^2/s$. The cementation process is effective in reducing radon emanation by an average of 78 to 87 percent; however, significant levels of radon continue to be emitted after cement stabilization.

The amount of volume increase caused by the addition of cementatious material varied greatly. For Subunit A material, the increase varied from 136 to 216 percent as a result of the heterogeneity of the waste. Assuming an average increase of 169 percent, there would be a total estimated treated material volume of 18,166 m^3 (23,903 yd^3) for Alternative 2A/Cem.

The stabilized material from all tests were RCRA nonhazardous, as determined by the TCLP test. Thus, TCLP test results (through leachate concentration) for the treated waste are the basis for the demonstration of the effectiveness of cement stabilization as a treatment process for Subunit A waste. A formulation including blast furnace slag, cement, and flyash was the most effective even though

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reductions in contaminant concentrations in the leachate were not achieved for all parameters. The percent reduction for lead in leachate was typically above 99 percent. High percent reductions for uranium were demonstrated while Ra-228 exhibited mean reductions from 48 to 57 percent. The mean reduction of Ra-226 ranged from 53 to 84 percent.

Durability was measured by freeze-thaw and wet-dry testing and comparison to ASTM standards (30 percent weight loss) and EPA guidance of 15 percent weight loss. No average weight losses for Subunit A material exceeded 15 percent. Durability was also measured using the unconfined compressive strength (UCS) test on the durability samples. The comparison of the UCS results is used to indicate how the physical properties of the stabilized material changes as a result of the simulated climatic stress. None of the Subunit A treated waste degraded to the extent that it had no resistance to compressive stress. However, degradation and leachability results for some contaminants indicate that cement stabilization is not an irreversible treatment process.

Residuals from the stabilization process would be generated from the off-gas treatment system. Off-gases containing particles and other pollutants would be removed and treated using conventional air pollution control equipment (e.g., scrubbers). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary to adequately reduce the amount of fugitive emissions. Scrubber residuals would be recycled through the stabilization process until all were contained in a cementatious form.

4.2.3.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Alternative 2A/Cem provides the same degree of short-term protection of the community as Alternative 2A/Vit (Section 4.2.2.5) using the same engineering and access controls.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and non-remediation workers are the same for Alternatives 2A/Vit and 2A/Cem. Although cement stabilization is inherently less dangerous than vitrification, the increase in labor hours results in an estimate of 9.9 injuries and 0.15 deaths during remediation activities.

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Short-Term Environmental Impacts

The short-term impacts associated with Alternative 2A/Cem are essentially the same as those for Alternative 2A/Vit short-term disturbances would involve 5.8 ha (14.3 acres) of land at the FEMP site. In addition, 230 workers and approximately 25 trucks, making 21 one-way trips per working day, would be required to implement remedial activities. For this analysis, it is assumed that all expenditures would take place within the CMSA in which case the implementation of Alternative 2A/Cem would increase revenues by 6.7% over a 6-year period.

Duration of Remedial Activities

The duration of Alternative 2A/Cem is the same as Alternative 2A/Vit.

4.2.3.6 Implementability

Technical Feasibility

The technical implementability, construction, and operation of Alternative 2A/Cem would be reliable and straightforward and, except for the treatment component, the same as Alternative 2A/Vit.

The cement stabilization facility would be reliable and straightforward to construct and operate. All of the necessary equipment would be readily available because the process is widely used in the construction and mining industries. It is also used frequently in hazardous material treatment applications. The treatment system would consist of a standard configuration of industrial equipment. The cement stabilization process would require a supervisor and general laborers with industrial work experience, as well as maintenance personnel. After remedial design treatability studies further defined and optimized the reagent to material blend, the plant supervisor would be able to respond to operational problems that could arise during processing. Continual testing of treatment batches during operation would determine required modifications to the standard blend to optimize product and immobilization of contaminants.

The benefits of cement stabilization technology are the moderate processing costs, the compatibility with a wide variety of disposal options, and the ability to meet stringent processing and performance requirements. The associated increase in volume caused by adding dry materials could be minimized through encapsulation of the solids and evaporation of associated water. However, water evaporation increases the complexity and cost of the treatment.

Administrative Feasibility

The administrative feasibility for Alternative 2A/Cem is the same as for 2A/Vit.

Availability of Services and Materials

Alternative 2A/Cem would involve the same activities as Alternative 2A/Vit, with the exception of cement stabilization being utilized in place of vitrification. Since cement stabilization is a commonly utilized technology, the availability of vendors to provide service and materials would be adequate.

The construction of a cement stabilization facility involves the same steps as described in Section 4.2.2 with the substitution of cement stabilization equipment and materials for vitrification equipment and materials.

4.2.3.7 Cost

The total present worth cost of Alternative 2A/Cem is $74M. A detailed breakdown of the cost is provided in Table 4-3.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and hydraulic removal/transfer system for transfer of the residues, purchase of cement stabilization equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-3. More detailed information is provided in Appendix E.

The largest component of the capital cost is the disposal vault, which represents approximately 30 percent of the total capital cost. This is due to the increase in volume of the cement-stabilized material over that of the untreated material. Construction of the hydraulic removal/transfer system and packaging are the next largest components of the costs, each representing approximately 27 percent of the total capital cost.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

TABLE 4–3

COST ESTIMATE FOR ALTERNATIVE 2A/CEM

ALTERNATIVE 2A: REMOVAL, CEMENT STABILIZATION, ON–PROPERTY DISPOSAL			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
SITE PREPARATION	$768,600	$660,000	$1,428,600
WASTE PROCESSING	$1,008,500	$1,065,000	$2,073,500
CEMENT STABILIZATION	$2,590,500	$2,843,300	$5,433,800
HYDRAULIC REMOVAL/TRANSFER SYSTEM	$6,655,400	$7,797,800	$14,453,200
DISPOSAL VAULT	$5,830,979	$9,928,517	$15,759,496
PACKAGING (15,009 PKGS. @ $955/PKG.)	$3,962,400	$10,371,200	$14,333,600
TOTAL CAPITAL	$20,816,379	$32,665,817	$53,482,196
RISK BUDGET (11.0%)	$2,289,800	$3,593,200	$5,883,000
SUBTOTAL	$23,106,179	$36,259,017	$59,365,196
CONTINGENCY (20.0%)	$4,621,200	$7,251,800	$11,873,000
TOTAL ESTIMATED INSTALLED COST	$27,727,379	$43,510,817	$71,238,196
OPERATION AND MAINTENANCE (O&M) COSTS			
DURING CONSTRUCTION			$11,715,700
POST–REMEDIATION			$3,582,000
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$74,038,600

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during construction (years): 3
Post–remediation O&M (years): 30

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads and equipment staging areas. The basis of estimate is the same as that discussed for Alternative 2A/Vit.

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the radon treatment system. Costs were estimated based on the same assumptions as for Alternative 2A/Vit.

Cement Stabilization

This cost item includes the cost of the cement stabilization equipment and was based on the following:

- The cement stabilization equipment would operate 24 hours/day and would be designed to treat 11,800 kg/day (13 tons/day) of waste material.
- Cement stabilization equipment includes a surge tank, screw feeder, stabilization mixers, flyash, cement, and blast furnace slag storage/feed facilities, process piping, pumps, and mixers.

Hydraulic Removal/Transfer System

This cost component includes the support superstructure and work platform, rail trolleys, an enclosure for the hydraulic equipment, a concrete material transfer pit, an RTS and building for the silo structures, and the hydraulic removal equipment. System components and cost are the same as for Alternative 2A/Vit.

Disposal Vault

Assumptions used to estimate the disposal vault cost are the same as those described for Alternative 2A/Vit, except for the following:

- The size of the disposal vault was based on the number of packages noted below, assuming each package occupies 2 m^3 (64 ft^3) of space, and was estimated as 27,204 m^3 (960,576 ft^3). Assuming a vault size of 3400 m^3 (120,000 ft^3), nine cells would be required [6270 m^2 (67,500 ft^2) vault footprint area].
- The vault would cover approximately 4.3 ha (10.6 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation, and was estimated as described for Alternative 2A/Vit, with the following differences:

- Total volume that would be packaged was based on 3636 m^3 (4,756 yd^3) and 3158 m^3 (4,130 yd^3) of untreated Silos 1 and 2 material, respectively. Final packaging volume, assuming a 169 percent volume increase due to the cement stabilization process, was 18,274 m^3 (23,903 yd^3).

- Total packaging cost was estimated assuming 15,009 containers.

O&M Cost

Short-term O&M costs incurred during remediation and long-term O&M costs are $11.7M and $3.6M, respectively, not considering present worth. Long-term O&M costs include maintenance and monitoring until all FEMP site-wide remedial action objectives are attained, i.e., in an estimated 30 years. The monitoring would support the required CERCLA five-year reviews.

4.2.4 Analysis of Alternative 3A.1/Vitrification

Alternative 3A.1/Vit will use the same site preparation, construction, removal, material processing, as Alternative 2A/Vit (Section 4.2.2). The difference between these two alternatives is that Alternative 3A.1/Vit will dispose of the treated material off site at NTS.

Off-site disposal for this alternative involves the packaging, loading, and shipping of the treated material to the Low-Level Radioactive Disposal Site at NTS. Shipping of the treated material to NTS will involve rail transportation from the FEMP site through East St. Louis on the CSX rail lines. From St. Louis, the treated material will be transported on the Union Pacific (UP) rail lines through North Platte, Nebraska, and Salt Lake City, Utah. Currently there are no direct rail lines to NTS. Presently, the treated material would be transported to either a point near Las Vegas, Nevada or one of the areas north of Las Vegas. From either location, the containers carrying the treated material will be transferred to trucks for transportation over roads to NTS. If a direct rail line to NTS becomes available before this alternative is implemented, it should be used in lieu of shipping the treated material by truck on the last leg of its trip. Treated material may be staged and/or placed into interim storage, as required, in response to interruptions in the availability of disposal capacity.

4.2.4.1 Overall Protection of Human Health and the Environment

Alternative 3A.1/Vit meets the remedial action objectives for Subunit A. As with Alternative 2A/Vit, Alternative 3A.1/Vit prevents direct contact with waste material and mitigates the migration of contaminants to the air, soil, and groundwater. This is accomplished with two components, treatment and off-site disposal.

Similar to Alternative 2A/Vit, treatment of the Subunit A materials through vitrification would reduce contaminant toxicity, mobility, and volume. Treatment through vitrification will enable the treated waste form to meet acceptance criteria at NTS. This is due to the fact that the vitrified material does not exhibit RCRA hazardous waste characteristics. In addition, the treatment of the material prior to disposal would provide additional long-term protection in the event the off-site disposal vault were to degrade.

The removal of the contaminants and their disposal off site provides the final element of protectiveness for Alternative 3A.1/Vit. The off-site disposal vault will provide protection by eliminating access to the waste and preventing migration of contaminants out of the waste similar to the on-site disposal vault under Alternative 2A/Vit. The off-site NTS disposal vault is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant release, migration, and direct contact with contaminants. The long-term effectiveness of the necessary institutional controls at the NTS disposal vault is believed to be very reliable.

Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. Further, the climatic (low average annual precipitation) and hydrogeologic (depths to groundwater ranging from 157 - 600 m [515 - 2000 ft] below-ground surface) characteristics would tend to mitigate impacts to human health and the environment in the event that engineering and institutional controls fail.

There are no unacceptable short-term risks from Alternative 3A.1/Vit which for removal and treatment processes pose the same risks as Alternative 2A/Vit. Additional risk is associated with transportation accidents. Radiation exposure to workers and the public as a result of the transportation is expected to be minimal.

4.2.4.2 Compliance with ARARs

Issues related to ARAR compliance for Alternative 3A.1/Vit are similar to Alternative 2A/Vit with the exception of the disposal of Subunit A treated material at a DOE-owned off-site facility. Alternative 3A.1/Vit meets all ARARs. Because Alternative 3A.1/Vit consists of off-site disposal of the treated material, the State of Ohio disposal vault siting criteria and disposal requirements would no longer be applicable nor relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3A.1/Vit concentrate on waste management and treatment and are similar to the ARARs for Alternative 2A/Vit (see Table F-2 in Appendix F). Consequently, the discussion of compliance for those common ARARs would be identical to that presented in Section 4.2.2.2. The applicable findings of that discussion are summarized below. Additional documentation of compliance of Alternative 3A.1/Vit with the identified ARARs is presented in Appendix F (Table F-2).

Chemical-Specific ARAR/TBCs

Alternative 3A.1/Vit would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those requirements associated with meeting Ohio water quality standards, control of radon-222 airborne releases, and control of other radionuclide releases to air and water, and their resulting doses to the public.

Location-Specific ARAR/TBCs

Alternative 3A.1/Vit would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands, endangered species and their habitats during the on-site treatment of the waste material. As noted above, disposal vault siting criteria and disposal requirements would no longer be applicable nor relevant and appropriate to this alternative because of the proposed use of an off-site disposal vault.

Action-Specific ARAR/TBCs

Alternative 3A.1/Vit would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.3). As was discussed for Alternative 2A/Vit, Alternative 3A.1/Vit would comply with 40 CFR 191 Subpart A (a relevant and appropriate requirement), as well as ARARs associated with the Clean Air Act, Clean Water Act, and RCRA requirements for management and treatment of hazardous waste. Off-site disposition will require shipment of materials. Hazardous waste transport requirements will be complied with by following the regulations under 40 CFR 262 and the appropriate DOT shipping requirements under 49 CFR 172 and 173.

4.2.4.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementability of Alternative 3A.1/Vit would reduce the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6}. Because all of the material is removed from the site, there is no residual risk from Subunit A residues at the FEMP site. Residual risk at NTS is limited by the facility institutional controls, the characteristics of the vitrified materials, and the arid environment.

Adequacy and Reliability of Controls

The reliability of the vitrification of Subunit A material for Alternative 3A.1/Vit is the same as that for Alternative 2A/Vit (Section 4.2.2.3). Off-site disposal at NTS has enhanced reliability because the facility is currently used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate maintenance are likely to be reliable at NTS. Additionally, if there is a release at NTS, the climate, hydrologic conditions and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density would also reduce the potential for direct contact in the event of disposal vault failure.

Long-Term Environmental Impacts

The long-term environmental impacts of removal and treatment actions of Alternative 3A.1/Vit are the same as for Alternative 2A/Vit (Section 4.2.2.3). The discussion below focuses on impacts to the NTS site.

Soil and Geology

Approximately 5.0 ha (12.35 acres) of soil at NTS would be permanently disturbed for the disposal of the Subunit A materials. Borrow material from NTS may be required to accommodate disposal at the NTS . The geology of NTS has been determined to be suitable for disposal of LLRW (DOE 1991). NTS is characterized by great depths to the groundwater table. As stated previously, depths to groundwater beneath NTS vary from about 155 m (515 ft) to more than 600 m (2000 ft) (DOE 1991). Groundwater movement in the saturated and unsaturated zones is very slow and there is an extremely low potential for transport of contaminants to off-site areas. These parameters make the geology of NTS very suitable for long-term disposal activities.

Water Quality and Hydrology

The disposal of treated material at NTS under this alternative is not expected to have significant 4738 impacts on water quality or hydrology. There are no continuously flowing streams on NTS. Stream beds carry water only during unusually intense or persistent rains. Rainfall (which averages 1 cm [0.4 in] per year) infiltrates quickly into moisture deficient soil. These parameters, coupled with very suitable geology, would help minimize long-term impacts to water quality. Engineered controls (capping) and ongoing monitoring activities would also be used to control and minimize water quality impacts.

Air Quality

Following implementation of Alternative 3A.1/Vit, the air quality at the NTS site would be similar to current conditions. There would be no long-term impacts on air because the capping system on the disposal vault would prevent radon emissions and because disturbed areas would be revegetated.

Biotic Resources

Most of NTS is vegetated by various desert shrubs. There are 711 types of vascular plants within or near the boundaries of NTS (DOE 1991). Several mammal species on NTS (e.g., feral horses, burros, kit foxes) have been placed on the protected classification list by the State of Nevada. The desert tortoise (Gopherus agassizii) is federally-listed as a threatened species and is present in some of the areas of NTS. The disposal activities at NTS related to Alternative 3A.1/Vit are not expected to impact the habitat of the desert tortoise or displace any other species at NTS.

Wetlands and Floodplains

No wetland areas have been delineated at NTS (DOE 1991). In addition, no floodplain areas are located near the disposal areas of NTS.

Socioeconomics and Land Use

NTS encompasses about 3500 square km (km^2) [1350 square miles (mi^2)], an area larger than the State of Rhode Island. Since 1951, primary land use on NTS is nuclear weapons testing and LLRW disposal for on-site and off-site DOE-affiliated generators. NTS is surrounded on the east, north, and west sides by public access exclusion zones (e.g., Nellis Air Force Base Bombing and Gunnery Range). This area provides a buffer zone between the test areas and public lands of 24 to 105 km (15 to 65 mi). The population density within a 150-km (93-mi) radius of NTS is about 2.8 persons per km^2 (7.2 per mi^2). In comparison, the 48 contiguous states (1990 census) had a population density of approximately 29 persons per km^2 (75 per mi^2). The off-site areas adjacent to NTS are predominantly

rural; hence, aesthetic impacts would not be expected to change. Hence, treated material disposal activities (associated with this alternative) would not impact socioeconomics or land use at NTS.

Cultural Resources

A site-wide archaeological survey would be performed for the areas to be impacted by Alternative 3A.1/Vit. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, OHPO, AIRFA, and NAGPRA. Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site. Archaeological sites have been surveyed and inventoried at NTS and currently, disposal activities are avoided in those areas.

4.2.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reductions in constituent toxicity, mobility, or volume would be the same for Alternative 3A.1/Vit as for Alternative 2A/Vit, based on application of the same treatment technology (Section 4.2.2.4).

4.2.4.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Alternative 3A.1/Vit provides the same level of short-term protection of the community during removal and treatment as does Alternative 2A/Vit (Section 4.2.2.5). There is added risk to the public through transporting the treated material off site. The estimate of public radiation exposure, expressed in terms of ILCR, along the route to NTS is 8.3×10^{-10}, far below the target risk range of 10^{-4} to 10^{-6}. It is estimated that 0.16 injuries and 0.039 deaths may occur due to transportation accidents. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 3A.1/Vit is effective in protecting the community in the short term. The basis for these estimates is provided in Appendix D.

The disposal of FEMP materials at NTS would not be expected to exceed protective levels for the community around NTS over the short term. The vitrified materials would meet NTS waste acceptance criteria and, therefore, would be managed within the bounds of the NTS facility's protectiveness criteria.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers during removal and treatment are the same for Alternatives 3A.1/Vit as for 2A/Vit. There are additional radiation exposure risks to the worker resulting from transporting the material to NTS. The excess ILCR is estimated at 2.8×10^{-6}, near EPA's target risk level of 10^{-6}. The estimate of the occurrence of injuries during remediation activities is 2.0 and indicates the incidence of deaths is 0.029. The risk to workers due to radiological exposures during off-loading activities at NTS is conservatively assumed to be similar to the estimated ILCR risk level of 4.0×10^{-6} during treatment/construction activities at the FEMP site. There is uncertainty for some additional risk due to exposure to wastes already present at NTS in the vicinity of off-loading operations for FEMP materials.

Short-Term Environmental Impacts

The short-term environmental impacts at the FEMP site for removal and treatment of materials under Alternative 3A.1/Vit are the same as those for Alternative 2A/Vit (Section 4.2.2.5). The total area disturbed at the FEMP site for Alternative 3A.1/Vit is 1.5 ha (3.0 acres). Since Alternative 3A.1/Vit involves off-site disposal of the treated waste form at NTS, short term environmental impacts for that facility are summarized below. Relevant information on NTS environmental impacts is also provided under Section 4.2.4.3, Long-Term Effectiveness and Permanence.

Soil and Geology

Soils at NTS would be disturbed during disposal activities. Appropriate mitigative controls (e.g., cover and grading) would be used at NTS to control erosion, the off-site transport of waste material, and radon release. Groundwater at NTS would not be impacted in the short term by disposal of Subunit A material due to the treated form of the waste, disposal under a cover system and depth to groundwater. Ongoing monitoring would identify any unacceptable releases, with maintenance occurring to minimize the potential for release.

Water Quality and Hydrology

The implementation of 3A.1/Vit is expected to have minor impacts on the surface water hydrology at NTS. The NTS lies in an arid region with little rainfall. There are no continuously flowing streams on NTS.

Air Quality

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Shipping treated material for disposal would result in minor increases in emissions related to vehicle exhaust. Short-term impacts would be negligible.

Biotic Resources

Disposal activities would disturb portions of NTS. However, habitat at NTS in the disposal area is limited (DOE 1991) and little displacement of species would occur.

Wetlands and Floodplains

No wetland or floodplain areas exist at NTS (DOE 1991).

Socioeconomics and Land Use

Short-term disposal activities for this alternative would not impact socioeconomics at NTS.

The implementation of Alternative 3A.1/Vit would have minimal short-term impacts on socioeconomic and land use at and around the FEMP site. Remedial activities would require 110 workers and approximately 20 trucks making 3 one-way trips per day. Relocation of workers and their families are not expected to impact public facilities.

Synonymous with the other alternatives, it is assumed for this analysis that all resources needed for remedial work would be purchased within the CMSA. This would increase the collective revenue of the CMSA by 4.8 percent over seven years. This would have a minimal economic impact on the thirteen surrounding counties. Furthermore, the removal of the Subunit A material would help eliminate any impacts on future population and economic growth in the area.

Transportation

The implementation of Alternative 3A.1/Vit would result in minor increases in traffic flow (3.0 truck trips per working day) on and around the FEMP site. Temporary increases in deliveries and workers to the FEMP site are not expected to result in any significant impact to traffic patterns or roadways. It was determined that an additional 300 to 400 vehicles a day would be required to impact traffic patterns. The implementation of Alternative 3A.1/Vit would result in an increase of only a fraction of those numbers. Due to the fewer worker hours associated with this alternative, fewer worker injuries should occur compared to Alternative 2A/Vit.

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Treated material would be transported first by rail, and then transferred to trucks for transport to NTS. Environmental impacts from shipping and disposing of treated material are expected to be minimal from normal transportation because all procedures would be in compliance with applicable Department of Transportation (DOT) requirements and DOE Orders. However, added risk to the public from transporting off site would increase public radiation exposure along the route to NTS to 8.3×10^{-10}, still far below the target range. More information on the risk to workers and the public associated with the transportation of treated material is addressed in Appendix D and Section 4.2.2.5.

Duration of Remedial Activities

The duration of remedial activities is assumed to be the same as for Alternative 2A/Vit. There is more uncertainty in the remedial activity schedule estimate since transportation or waste acceptance problems could cause delays in the shipping schedule.

4.2.4.6 Implementability

Technical Feasibility

The technical feasibility of implementing the removal and treatment components of Alternative 3A.1/Vit would be the same as described for Alternative 2A/Vit (Section 4.2.2.6). The technical feasibility of implementing the disposal component of Alternative 3A.1/Vit depends on the implementability of both transport of the treated material to NTS and disposal at that site.

Off-site transport of the treated material to NTS would consist of rail transport from the FEMP site to within 483 km (300 mi) of NTS. Currently NTS is not accessible by rail; therefore, the treated material would be transferred to trucks and transported to NTS. Equipment, facilities, and the required personnel for truck and rail transport would be readily available. The treated material would be placed in appropriate containers that meet all transportation and disposal requirements.

Administrative Feasibility

NTS is a DOE-owned facility; thus, no special permits would be required. However, an addendum to the FEMP site's current waste shipping application would be required for this new waste stream. This alternative would require agency approvals and coordination for the interstate shipment of the material. Many states require advance notification and permitting for shipments of radioactive material entering their state. All material shipments would be required to meet applicable federal and state regulations. The public and regulatory agencies from the states located within the transportation

route from FEMP Site to NTS are likely to oppose transport; thus, some coordination work would be required to obtain these approvals.

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Availability of Services and Materials

The availability of services and materials for Alternative 3A.1/Vit is the same as for Alternative 2A/Vit, with the exception of the disposal vault. NTS currently accepts LLW and it has adequate facilities to accept the Alternative 3A.1/Vit treated material. Transfer areas, storage areas, decontamination facilities, and a laboratory are available at NTS. The treated material form would be tested to ensure that it complies with NTS waste acceptance criteria.

4.2.4.7 Cost

The total present worth cost of Alternative 3A.1/Vit is $42.2M. A detailed breakdown of the cost is provided in Table 4-4.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing and hydraulic removal/transfer system for transfer of the residues, purchase of vitrification equipment, packaging of material for disposal, transportation, and disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-4. More detailed information is provided in Appendix E.

This alternative includes identical cost components as Alternative 2A/Vit (Section 4.2.2.7), except off-site transportation and disposal replace the on-property vault that was included in Alternative 2A/Vit. As with Alternative 2A/Vit, the largest component of the capital cost is the construction of the hydraulic removal/transfer system, representing approximately 53 percent of the total capital costs.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads and equipment staging areas. The basis of estimate is the same as that discussed for Alternative 2A/Vit (Section 4.2.2.7).

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TABLE 4–4

COST ESTIMATE FOR ALTERNATIVE 3A.1/VIT

ALTERNATIVE 3A.1: REMOVAL, STABILIZATION W/VITRIFICATION, OFF–SITE DISPOSAL AT NTS			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
SITE PREPARATION	$768,600	$660,000	$1,428,600
WASTE PROCESSING	$1,008,500	$1,065,000	$2,073,500
VITRIFICATION	$2,935,500	$1,703,600	$4,639,100
HYDRAULIC REMOVAL/TRANSFER SYSTEM	$6,655,400	$7,797,800	$14,453,200
TRANSPORTATION	$1,268,100		$1,268,100
DISPOSAL	$1,302,500		$1,302,500
PACKAGING (2,412 PKGS. @ $955/PKG.)	$636,800	$1,666,700	$2,303,500
TOTAL CAPITAL	$14,575,400	$12,893,100	$27,468,500
RISK BUDGET (11.0%)	$1,603,300	$1,418,200	$3,021,535
SUBTOTAL	$16,178,700	$14,311,300	$30,490,035
CONTINGENCY (20.0%)	$3,235,700	$2,862,300	$6,098,000
TOTAL ESTIMATED INSTALLED COST	$19,414,400	$17,173,600	$36,588,035
OPERATION AND MAINTENANCE (O&M) COSTS			
DURING CONSTRUCTION			$11,692,500
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$42,229,400

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on following time periods:
Construction (years): 3
O&M during construction (years): 3
Post–remediation O&M (years): 0

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the radon treatment system. Costs were estimated based on the same assumptions as for Alternative 2A/Vit (Section 4.2.2.7).

Vitrification

This cost item includes the cost of the vitrification equipment, radon treatment system, and off-gas system, and is estimated based on the same assumptions discussed for Alternative 2A/Vit.

Hydraulic Removal/Transfer System

System components and cost are the same as for Alternative 2A/Vit (Section 4.2.2.7).

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2A/Vit Section 4.2.2.7). The same number of containers (2,412) required for Alternative 2A/Vit are required for Alternative 3A.1/Vit.

Transportation

This cost item includes transportation of the packaged material, and is based on the following assumptions:

- Packages would be transported by rail to within 483 km (300 mi) of the disposal vault (NTS) and then transported by truck the remainder of the distance.
- Rail costs were estimated using a unit rate of $3.97 per railcar per mile. Railcars were assumed to weigh 8165 kg (180,000 lbs) each.
- Truck costs were estimated using a unit rate of $0.53 per kg ($0.24 per pound) [for the total 483 km (300-mile) trip].

Disposal

- Treated material would be disposed at NTS.
- Unit disposal cost was estimated as $353 m^3 ($10/ft^3).

O&M Cost

Short-term O&M costs incurred during remediation are the same as for Alternative 2A/Vit ($11.7M, not considering present worth). There are no long-term O&M costs associated with this alternative because no material would remain at the FEMP site.

4.2.5 Analysis of Alternative 3A.1/Cementation

This alternative will use the same site preparation, construction, removal, and D&D process options as Alternative 2A/Vit (Section 4.2.2). The treatment process option for this alternative is cement stabilization and would be the same as described for Alternative 2A/Cem (Section 4.2.3). The off-site disposal at NTS would use the same transportation route as discussed in Alternative 3A.1/Vit (Section 4.2.4). The volume of cement stabilized material to be disposed of would be more than for the vitrification alternative.

4.2.5.1 Overall Protection of Human Health and the Environment

Alternative 3A.1/Cem meets the remedial action objectives for Subunit A. As with Alternative 3A.1/Vit, Alternative 3A.1/Cem prevents direct access to waste material and mitigates the migration of contaminants to the air, soil, and groundwater. This is accomplished with two components, treatment and off-site disposal.

Treatment of the Subunit A materials through cement stabilization would reduce contaminant mobility. The volume of contaminated material would increase due to additives used in the stabilization process. Treatment through cement stabilization would enable the treated waste form to meet acceptance criteria at NTS. This is due to the fact that the cement stabilized material does not exhibit RCRA hazardous waste characteristics. In addition, the treatment of the material prior to disposal would provide protection in the event the off-site disposal vault were to degrade.

The removal of the contaminants and their disposal off site provides the final element of protection for Alternative 3A.1/Cem and is the same disposal option as Alternative 3A.1/Vit. The off-site disposal vault would provide protection by eliminating access to the waste and preventing migration of contaminants from the waste. As previously discussed in Section 4.2.4.1, the uncertainties associated with institutional controls at this DOE facility are very low. The NTS environmental and demographic characteristics help to ensure long-term protectiveness in the event of institutional control failure. There are no unacceptable short-term risks from Alternative 3A.1/Cem.

4.2.5.2 Compliance with ARARs

Issues related to ARAR compliance for Alternative 3A.1/Cem are similar to Alternative 2A/Cem with the exception of the Subunit A treated material final disposition being at a DOE-owned off-site facility. Alternative 3A.1/Cem meets all ARARs. Because Alternative 3A.1/Cem involves off-site disposal of the treated material, the disposal vault siting criteria and disposal requirements would no longer be applicable nor relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3A.1/Cem focus on waste management and treatment and are similar to the ARARs for Alternative 2A/Cem (see Table F-2 in Appendix F). Consequently, the discussion of compliance for those common ARARs would be identical to that presented in Section 4.2.3.2. Additional documentation of compliance of Alternative 3A.1/Cem with the identified ARARs is presented in Appendix F (Table F-2). The applicable findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 3A.1/Cem would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those requirements associated with the protection of Ohio water quality standards, the control of radon-222 airborne releases, and the control of other radionuclide releases to air and water, and their resulting doses to the public during remedial operations at the FEMP. Appendix D contains the description and results of the analyses supporting exposure assessments for Alternative 3A.1/Cem.

Location-Specific ARAR/TBCs

Alternative 3A.1/Cem would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands, and endangered species during the on-site treatment of the material. As noted above, disposal vault siting criteria and disposal requirements would no longer be applicable nor relevant and appropriate to this alternative because of the proposed use of an off-site disposal vault.

Action-Specific ARAR/TBCs

Alternative 3A.1/Cem would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.3). As was discussed for Alternative 2A/Cem, Alternative 3A.1/Cem would comply with 40 CFR 191 Subpart A (a relevant and appropriate requirement), as well as ARARs associated with the Clean Air Act, Clean Water Act, and RCRA requirements for management and treatment of hazardous waste. Off-site disposition will require shipment of materials. Hazardous waste transport

requirements will be complied with by following the regulations under 40 CFR 262 and the appropriate DOT shipping standards under 49 CFR 172 and 173.

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4.2.5.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 3A.1/Cem would reduce the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6}. Because all of the material is removed from the site, there is no residual risk from Subunit A residues at the FEMP site. Residual risk at NTS is limited by the disposal vault institutional controls, the characteristics of the cement stabilized materials, and the environment.

Adequacy and Reliability of Controls

The reliability of cement stabilization for Alternative 3A.1/Cem is the same as for Alternative 2A/Cem (Section 4.2.3.3). Off-site disposal at NTS has enhanced reliability because the facility is currently used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be reliable at NTS. Additionally, if there is a release at NTS, the climate hydrologic, and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density would also reduce the potential for direct contact with released materials.

Long-Term Environmental Impacts

The long-term environmental impacts to the FEMP site from the removal and treatment actions of Alternative 3A.1/Cem are the same as for Alternative 2A/Vit (Section 4.2.2.3). Impacts to NTS are the same as for Alternative 3A.1/Vit, except that the volume of cement stabilized material would require additional disposal space. The overall impact due to the increased volume is not significant.

4.2.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The reduction in contaminant toxicity, mobility, or volume would be the same for Alternative 3A.1/Cem as for Alternative 2A/Cem (Section 4.2.3.4).

4.2.5.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Protection of the community during removal and treatment operations is estimated to be the same for Alternative 3A.1/Cem as for Alternative 2A/Vit (Section 4.2.2.5). The potential for injury and

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deaths due to the treated material transportation is 0.98 injuries and 0.25 deaths respectively. The estimate of public radiation exposure, expressed in terms of ILCR, along the route to NTS is 4.3×10^{-10}, far below the target risk range of 10^{-4} to 10^{-6}.

Protection of Workers During Remedial Actions

Protection of workers during implementation of Alternative 3A.1/Cem is the same as for Alternative 3A.1/Vit (Section 4.2.4.5). Both alternatives protect workers during remediation by using personal protective equipment, remote operating procedures, and shielding.

Short-Term Environmental Impacts

The short-term impacts of Alternative 3A.1/Cem are the same as the impacts discussed for Alternative 3A.1/Vit (Section 4.2.4.5) with the exception of the number of workers, trucks, and procurement of resources needed to complete the remedial activities. One hundred workers and approximately 10 trucks, making 4 one-way trips per day, are required. For this analysis it is assumed that all resources would be obtained within the area in which cause the collective revenue for the CMSA would increase by 7.4 percent over a period of six years. Minor positive economic impacts to the CMSA would result from the implementation of Alternative 3A.1/Cem.

Duration of Remedial Activities

The removal and treatment components of Alternative 3A.1/Cem would require the same amount of time for implementation as the other action alternatives, 6 years. As with Alternative 3A.1/Vit, there is a chance for the schedule to be delayed as a result of transportation or disposal delays.

4.2.5.6 Implementability

Technical Feasibility

The technical feasibility of implementing the removal and treatment components of Alternative 3A.1/Cem would be the same as described for Alternative 2A/Cem (Section 4.2.3.6). The technical feasibility of implementing the disposal component of Alternative 3A.1/Cem would be the same as described for Alternative 3A.1/Vit (Section 4.2.4.6).

Administrative Feasibility

The administrative feasibility of Alternative 3A.1/Cem is the same as for Alternative 3A.1/Vit.

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Availability of Services and Materials

Cement stabilization includes the use of readily available equipment and materials. This is a demonstrated technology with commercial services available. This alternative would have the same availability of services and materials as those for Alternative 2A/Cem (Section 4.2.3.6).

4.2.5.7 Cost

The total present worth cost of Alternative 3A.1/Cem is $70.1M. A detailed breakdown of the cost is provided in Table 4-5.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and hydraulic removal/transfer system for transfer of the residues, purchase of cement stabilization equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-5. More detailed information is provided in Appendix E.

The alternative includes identical cost components as Alternative 2A/Cem (Section 4.2.3.7), except off-site transportation and disposal replace the on-property vault that was included in Alternative 2A/Cem. As with Alternative 2A/Cem, the largest component of the capital cost is the construction of the hydraulic removal/transfer system, representing approximately 28 percent of the total capital costs.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

The basis of estimate is the same as that discussed for Alternative 2A/Vit (Section 4.2.2.7).

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the radon treatment system. Costs were estimated based on the same assumptions as for Alternative 2A/Vit (Section 4.2.2.7).

TABLE 4–5

COST ESTIMATE FOR ALTERNATIVE 3A.1/CEM

ALTERNATIVE 3A.1: REMOVAL, CEMENT STABILIZATION, DISPOSAL AT NTS			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
SITE PREPARATION	$768,600	$660,000	$1,428,600
WASTE PROCESSING	$1,008,500	$1,065,000	$2,073,500
CEMENT STABILIZATION	$2,590,500	$2,843,300	$5,433,800
HYDRAULIC REMOVAL/TRANSFER SYSTEM	$6,655,400	$7,797,800	$14,453,200
TRANSPORTATION	$5,574,000		$5,574,000
DISPOSAL	$8,104,800		$8,104,800
PACKAGING (15,009 PKGS. @ $955/PKG.)	$3,962,400	$10,371,200	$14,333,600
TOTAL CAPITAL	$28,664,200	$22,737,300	$51,401,500
RISK BUDGET (11.0%)	$3,153,100	$2,501,100	$5,654,200
SUBTOTAL	$31,817,300	$25,238,400	$57,055,700
CONTINGENCY (20.0%)	$6,363,500	$5,047,700	$11,411,200
TOTAL ESTIMATED INSTALLED COST	$38,180,800	$30,286,100	$68,466,900
OPERATION AND MAINTENANCE (O&M) COSTS			
DURING CONSTRUCTION			$11,715,700
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$70,133,000

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on following time periods:
Construction (years): 3
O&M during construction (years): 3
Post–remediation O&M (years): 0

Cement Stabilization

This cost item includes the cost of the cement stabilization equipment and was based on the same assumptions provided for Alternative 2A/Cem (Section 4.2.3.7).

Hydraulic Removal/Transfer System

System components and cost are the same as for Alternative 2A/Cem (Section 4.2.3.7).

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2A/Cem (Subsection 4.2.3.7). The total quantity of containers required for packaging 2A/Cem materials were estimated to be 15,009 containers.

Transportation

This cost item includes transportation of the packaged material, and has the same basis of estimate as Alternative 3A.1/Vit (Section 4.2.4.7). However, the final cost for this alternative was greater than Alternative 3A.1/Vit due to the increased volume of cement-stabilized material.

Disposal

This cost is estimated as described for Alternative 3A.1/Vit (Section 4.2.4.7), but adjusted for the disposal of a greater number of containers for the cement-stabilized material.

O&M Cost

Short-term O&M costs incurred during remediation are the same as for Alternative 2A/Cem ($11.7M, not considering present worth). There are no long-term O&M costs associated with this alternative because no material would remain at the FEMP site.

4.3 SUBUNIT B

4.3.1 Analysis of Alternative 0B - No Action

The No-Action Alternative is retained throughout the FS process as required by the NCP (40 CFR 300.430[e][6]). As with Alternative 0A, Alternative 0B provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action will be taken. In the No-Action Alternative, the materials are considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. The contents of

Silo 3 would remain in place. Alternative 0B does not provide for the monitoring of soil, groundwater, or radon emissions within the scope of Operable Unit 4, and Alternative 0B does not provide for passive or active administrative controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

4.3.1.1 Overall Protection of Human Health and the Environment

The no-action alternative does not meet the remedial action objectives for Subunit B. It is not protective of human health and the environment in the long term based on a comparison to defined EPA criteria. With no maintenance of Silo 3, the silo dome may collapse, releasing contaminants to the groundwater. Use of the groundwater by an off-site resident or by an on-site resident (potential receptor under no action) would result in unacceptable risks (ILCR exceeding $1x10^{-4}$ to $1x10^{-6}$ range). Exposure to the site soils and waste materials following silo collapse would also result in unacceptable risks to humans and biota. Additionally, migration of contaminated groundwater towards and into Paddys Run could result in further human health risk and in adverse environmental impacts to the stream and to aquatic biota.

4.3.1.2 Compliance with ARARs

Potential regulatory requirements that might be applicable or relevant and appropriate to the final remedial alternatives are identified and evaluated in Appendix F. With no further action, certain ARARs would not be met. Eventual failure of the silos would result in release of material from the silo that would violate state water quality standards for receiving surface waters, and exposure limits to the public from radionuclides established under DOE Order 5400.5. Drinking water MCLs and MCLGs would most likely be exceeded if the released material were to migrate into the groundwater of the Great Miami Aquifer.

Other ARARs, such as the location-specific siting of a solid waste landfill, and the action specific closure performance standard under RCRA for a disposal vault, would not be met by this alternative. In addition, design standards for a RCRA solid or hazardous waste disposal vault, or for intruder protection from radiation hazards associated with radioactive waste disposal would not be met. For example, 10 CFR 61.52 requires that the material be disposed so that the top of the material is a minimum 4.5 m (15 ft) below the top surface of the cover. Also, several criteria for the protection of groundwaters would not be met. With unrestricted site access (e.g., no access controls), the standards for general radiation exposure and levels of radium in soil established in DOE Orders and 40 CFR 192 would also not be met.

CERCLA Section 121 cleanup standards, including compliance with ARARs, apply only to remedial actions EPA determines should be taken under CERCLA Sections 104 and 106 authority. A no-action decision can only be made when it is determined that no remedial action is necessary to reduce, control, or mitigate exposure because the site is already protective of human health and the environment. If the alternative passes the protectiveness threshold criterion, then compliance with ARARs is not pertinent to the selection of Alternative 0B.

4.3.1.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Contaminant levels in surrounding media and habitats would increase as a result of transport and deposition of airborne waste material or contaminants leaching from the waste under Alternative 0B. New habitats could become contaminated, especially along Paddys Run. Human health risks that may occur if no action is taken are discussed in Appendix D of this FS. The no-action alternative assumes eventual silo dome failure and the risks from no action are unacceptable. Excess cancer risks could reach unity from ingestion of the perched water beneath the silos (Pb-210 is the primary risk driver), external radiation (Ra-226), food ingestion (arsenic), and inhalation (Th-230). The scenario also has the potential for significant noncarcinogenic affects (HI of 540 for adult and 1900 for child) driven by arsenic through food ingestion. Under the no-action alternative with silo failure, the risk to the off-site farmer is also unacceptable (excess cancer risk of $2x10^{-3}$). Until the silo collapses, there is no projected unacceptable risk to the public from Silo 3 contents.

Because this alternative leaves the silo contents on the property, a review of silo conditions and contaminant release would be conducted at least every 5 years to ensure protectiveness in accordance with CERCLA Section 121 (c).

Adequacy and Reliability of Controls

The no-action alternative only remains protective as long as the silo is intact. Because the silo collapse over the long-term is imminent, the condition has been included in the no-action alternative rendering it unprotective. Under the silo collapse scenario, Silo 3 material cancer risks are estimated to be noticeably higher than Silos 1 and 2 because Silo 3 has no protective bentonite layer.

Long-Term Environmental Impacts

Alternative 0B would not be protective of human health and the environment in the long-term because it does not prevent exposure to waste materials and the possibility of silo collapse. Silo collapse and

subsequent loss of containment could lead to increased contamination levels in the perched ground water zone, surface water and sediment in Paddys Run, and the 0.36 ha (0.76 acre) wetland south of Silos 1 and 2. For the long-term risks associated with Alternative 0B, refer to Section 4.3.1.3, "Magnitude of Residual Risk."

4.3.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

No treatment of the silo contents would be involved in Alternative 0B; therefore, reduction of toxicity, mobility, or volume through treatment will not result.

4.3.1.5 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation of the remedial action. Under the no-action alternative, no remedial action would be taken. There would be no increase in short-term risks and no short-term environmental impacts.

4.3.1.6 Implementability

Technical Feasibility

Under the no-action alternative there would not be any difficulties or uncertainties associated with implementation. The no-action alternative is included in the detailed analysis of alternatives for a baseline comparison.

Administrative Feasibility

No permits or licenses would be required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials

Under the no-action alternative there would be no services or materials required.

4.3.1.7 Cost

There are no costs associated with Alternative 0B-No Action.

4.3.2 Analysis of Alternative 2B/Vitrification

This alternative requires the removal of cold metal oxides from Silo 3, stabilization of the cold metal oxides by vitrification, and on-property disposal of the stabilized cold metal oxides. The cold metal oxides would be removed by a pneumatic removal system introduced through the silo dome. This

equipment would be supported by a work platform that would span the silo. This platform is similar to that used in Alternative 2A. The cold metal oxides would be pneumatically transferred to a processing facility for vitrification and packaging, and then would be disposed of in an on-property above-grade disposal vault. Treated wastes may be staged or placed into interim storage, as required, as a contingency for operational difficulties. The alternative would include the placement of markers to define waste disposal areas, the use of deed restrictions, and the provision of continued federal ownership of the property to preclude drilling or residential development.

Site Preparation/Construction

The site preparation activities will begin with the clearing and grubbing of vegetated areas in the vicinity of the silo. These activities are in preparation for the construction of cold metal oxides processing facility, the transfer trench, and the construction of roads and equipment staging areas. Approximately 2 ha (5 acres) will require clearing and grubbing. The site preparation activities will also consist of the installation of roadways, site fencing, site lighting, process water piping, sewer lines, power poles, and the extension of site power to the areas requiring service.

Other facilities to be constructed include the pneumatic removal work platform with underlying tracks and foundation, a processing facility with equipment for vitrification, and an above-grade disposal vault for the disposal of the stabilized cold metal oxides.

Removal

A pneumatic removal device consisting of a cutterhead and a negative pressure (vacuum) will be used to remove the dry, powdery contents of Silo 3. The dredging pump will be supported by a work platform identical in design, construction, and purpose to that used for the removal alternatives in Subunit A. If removal alternatives are selected for both Subunits A and B, the rail system for the work platform used for Alternative 2A/Vit (Section 4.2.2) will be used for Subunit B. Because all of the cold metal oxides are not accessible to the pneumatic removal system through a single manway, the cutter head will be rotated from manway to manway until all of the cold metal oxides have been removed. During normal operations personnel will be required to work over the dome once every week for approximately 2 hours to reposition the pneumatic removal cutterhead. Other than this weekly activity and required monitoring activities, personnel will not work above the silo dome. Cold metal oxides removal will be conducted 8 hours/day, 7 days/week, and 3 weeks/month. The fourth week of every month will be for equipment maintenance and repairs. It is estimated to take approximately 12 months to remove the Silo 3 contents.

The air entrained in the cold metal oxides, suctioned from the silo, will be separated in a filter/receiver adjacent to the work platform. The cold metal oxides will then be pneumatically "pushed" to the cold metal oxides processing facility for treatment.

The glove box will be used at the interface of the pneumatic removal system and silo dome and will function as secondary containment in conjunction with the silo dome. This setup, along with procedural compliance, is designed to prevent a release to the atmosphere during normal operations in the event of a breach in the primary containment.

Material Processing

Cold metal oxides will be treated through vitrification. This vitrification treatment option is identical to the vitrification option used for Alternative 2A/Vit with the exception that the cold metal oxides will be mixed with silica, alumna, and borate. The molten glass will be poured into DOT specification 7A Type A containers and stored in the facility until the cold metal oxide forms have cooled and been sampled. Due to the very high temperatures required for vitrification (1350°C [2462°F]), superheated steam and volatilized matter will be produced. This off-gas will contain a number of constituents that must be treated before discharge. An off-gas treatment system, similar to that used for Subunit A alternatives, will treat this stream with scrubbers and HEPA filters and then will exhaust to the atmosphere.

The cold metal oxides processing facility will use shielding and radiation control zones to minimize exposure to workers. Highly radioactive components and piping will be shielded or contained in restricted access rooms.

On-Property Disposal

For the on-property disposal alternatives, the containerized metal oxides forms would be transported to an above-grade disposal vault for disposal. Figure 4-6 provides a cross-sectional view of the adopted representative disposal concept. The need for and actual configuration of the components of the disposal vault (i.e., vaults, intruder barriers, etc.) would be established through the remedial design process. As depicted on the figure, the concrete vault would have a service opening to allow access for the placement of DOT specification 7A Type A containers. The floor of the vault would have a minimum slope of 2 percent to facilitate any leachate collection and monitoring. The roof of the vault would also have a minimum slope of 2 percent to allow storm water runoff. As each vault

is filled to capacity, all equipment and temporary utilities would be removed and the vault sealed before the multimedia cap is installed.

The vault would be constructed on a reinforced concrete mat with a minimum thickness of 0.3 m (1 ft). The perimeter of the mat would be bounded by a curb with embedded pipes that are connected to the manholes of the underlying multimedia LC/DS to facilitate the collection of any contaminated leachate after final closure. The LC/DS would be composed of alternating composite soil liners and drainage layers to minimize the potential release of contaminated leachate to the groundwater and the underlying Great Miami Aquifer.

The soil of the composite liners would be constructed of a natural, compacted clay with a maximum permeability of 1×10^{-7} cm/s. The layers would be a minimum of 0.9-m (3-ft) thick. To improve the performance of the clay, a geomembrane of at least 40 mil in thickness would be placed over the surface of the clay, which has been smooth-rolled to ensure good hydraulic contact. To minimize damage to the geomembrane during construction, a sand layer with a minimum thickness of 20 cm (8 in.) would be placed over the geomembranes of the LC/DS.

Between the composite soil liners, drainage layers would be installed to intercept any leachate that may be generated. The drainage layers would be a minimum of 0.6 m (2 ft) each in thickness. The upper 0.3 m (1 ft) of each layer would be a graded natural aggregate and the lower 0.3 m (1 ft) would be a narrow-graded medium aggregate to provide a minimum permeability of 1×10^{-2} cm/s. A geotextile membrane would be placed on the upper surface of each drainage layer to prevent the migration of fines from the overlying material.

During placement of the aggregate, 10-cm (4-in.) diameter pipes would be installed within the aggregate to collect and direct any leachate to a series of manholes lined with HDPE. The leachate would then be removed from the manholes for treatment at the FEMP AWWT facility.

A multimedia cap constructed of five distinct layers of media would provide final closure of the vault. The upper layer of the cap would be a vegetative layer consisting of topsoil with a hardy, shallow root grass cover. This layer would be noncompacted and have a minimum thickness of 0.6 m (2 ft) to support plant growth. The vegetative layer would inhibit erosion and allow runoff during storm events. A drainage layer would be beneath the vegetative layer to intercept infiltrating precipitation. The layer would consist of 0.3 m (1 ft) of pea gravel that would provide a minimum permeability of

1 x 10^{-2} cm/s. A geotextile membrane would be placed between the vegetative layer and the top surface of the drainage layer to prevent the migration of fines from the vegetative layer to the drainage layer.

A layer of cobblestone with a minimum thickness of 0.7 m (2.3 ft) may be installed beneath the drainage layer to serve as an inadvertent intrusion barrier. The need for such a barrier would be established during final remedial design. Beneath the cobblestone would be a composite soil liner to impede downward moisture movement from the drainage layer. The soil of this layer would be natural, compacted clay with a maximum permeability of 1 x 10^{-7} cm/s. The layer would be 0.9 m (3 ft) thick to ensure the isolation of the disposal containers. A geomembrane at least 40 mil in thickness would be placed over the surface of the clay, which is smooth-rolled to ensure good hydraulic contact and thus improving the performance of the clay. To minimize slippage of the overlying layers due to interfacial shearing characteristics, the geomembrane would be textured. A layer of sand, similar to the composite soil liners of the LC/DS, would be placed over the geomembrane to minimize damage during construction.

The foundation of the multimedia cap would be clean, compacted soil. This layer would be a minimum of 15 cm (6 in.) to a maximum of 0.6 m (2 ft) in thickness above the vault. All general and granular material, as well as clay, are regionally available. Upon completion of the multimedia cap, institutional controls including markers, deed restrictions, and continued federal ownership of the FEMP site would be provided to comply with identified ARARs and minimize the potential for future exposures. With buffer zones and fences, 2.4 ha (6 acres) would be required for the disposal vault for Alternative 2B/Vit.

4.3.2.1 Overall Protection of Human Health and the Environment

Alternative 2B/Vit meets the remedial action objectives for Subunit B. Implementation of this alternative would prevent direct access to waste materials and would mitigate the migration of contaminants to the air, soil, and groundwater. Exposure to direct radiation above protective levels also would be prevented. Three primary actions would be used to meet the remedial action objectives, thereby providing adequate protection to human health and the environment. These actions are treatment through vitrification, containment in an on-site engineered disposal vault, and implementation of institutional control measures.

Treatment of Subunit B materials through vitrification would reduce contaminant toxicity, mobility, and volume. The leaching rate of the treated waste form would be reduced, enhancing the protection of the underlying Great Miami Aquifer. Treatment of the material prior to disposal would also provide additional protection in the event that the disposal vault begins to degrade, allowing increased infiltration and subsequent leachate formation. However, beyond the 1,000 year expected design life of the disposal vault, continued protection becomes less certain as a result of possible degradation of the vitrified material itself and subsequent increased leachability. As demonstrated by treatability studies, the leaching rate of the treated material is much slower than the untreated form.

Containment of the treated waste form in an on-site, capped, engineered disposal vault would provide additional control of contaminant migration to human and environmental receptors. The disposal vault would also prevent direct radiation from the treated waste material and radon (minor contribution). The vault design would include sufficient barrier to withstand 1000 years of erosion with minimal or no maintenance and markings to inhibit purposeful or inadvertent human destruction of the facility's engineered protective features. As discussed above, continued long-term effectiveness of the vault cap and leachate collection system is uncertain and eventual degradation could lead to an increased rate of infiltration, leachate formation, and release. Fate and transport modeling using conservative assumptions supports the conclusion that long-term protection of human health and the environment would still be achieved based on the slow rate of degradation of the disposal vault.

Institutional control measures would be employed to supplement the treatment and containment actions in order to provide additional assurance that overall protection would be maintained as engineered components degrade. Institutional controls would include the adoption of long-term federal government ownership of the FEMP site. This ownership of the site would preclude future on-site residential and farming land uses which could result in direct exposure to the waste materials through intrusive actions or facility degradation. The use of institutional controls is also consistent with an ARAR for the on-site engineered disposal vault. To comply with ORC 3734.02, hazardous and solid waste disposal facilities must include a protective covenant to restrict future mining, drilling, and residential uses. In accordance with this requirement, a deed restriction would be placed on the FEMP site property detailing these restrictions. The uncertainty associated with very long institutional control periods includes a possible loss of federal ownership and the loss of or lack of administration of the property records containing the deed restrictions.

Loss of institutional controls in combination with disposal vault failure over the long term (more than 1,000 years) could result in potential contaminant migration or direct exposure to the vitrified material by future human and biota receptors. Exposures to receptors through these pathways (i.e., groundwater, air, etc.) in the event of disposal vault failure would be expected to be minimal due to the positive attributes of the treated wastes. However, direct radiation exposure could be significant in the event of failure due to the presence of significant activity concentrations of long-lived gamma emitting radionuclides. Eventually, the risks from complete failure in the future could approach baseline risk conditions. However, both engineering and institutional controls would have to fail before unacceptable risks to human health would occur.

There are no unacceptable short-term risks from Alternative 2B/Vit. There are worker risks from radiation exposure during removal, treatment, and packaging. However, through the use of remote removal, shielding, and implementation of a worker health and safety plan in compliance with 29 CFR 1910.120(b)(4), these exposures would be kept to ALARA levels and would comply with DOE Orders.

4.3.2.2 Compliance with ARARs

The implementation of Alternative 2B/Vit would comply with all ARARs. With one exception, the identification of ARAR/TBC requirements for 2B/Vit is similar to Alternative 2A/Vit. The one exception involves the omission of disposal requirements established in 40 CFR 191 and a greater emphasis placed on disposal requirements established in 40 CFR 192. The reason for this is that the Subunit B material poses less hazard than the Subunit A material. As a result, the requirements under 40 CFR 192 will offer adequate protection for human health and the environment for the disposal of Subunit B material. With the exception of compliance issues presented for 40 CFR 191 and 192, the discussion of the compliance of this alternative would be identical to that for Alternative 2A/Vit presented in Section 4.2.2.2. The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 2B/Vit would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those requirements associated with meeting drinking water MCLs and MCLGs, the groundwater protection requirements, radon-222 airborne release requirements, other radionuclide release requirements for water and air, and their resulting doses to the public. Appendix D contains the description and results of the analyses supporting the exposure assessments

for Alternative 2B/Vit. Additional documentation of compliance of Alternative 2B/Vit would comply with the identified ARARs is presented in Appendix F (Table F-3).

Location-Specific ARAR/TBCs

Alternative 2B/Vit would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands, endangered species, and the sole source aquifer underlying the FEMP site. As was noted, compliance with the OAC 3745-27-07 prohibition on siting a solid waste disposal vault over a sole source aquifer would be based on justifying and demonstrating attainment of the substantive technical requirements for an exemption to this requirement as discussed in Section 4.2.2.2.

Action-Specific ARARs

Alternative 2B/Vit would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.1). Included would be those standards associated with the design of the multi-barrier engineered above-grade disposal vault system and operational requirements under RCRA and UMTRCA. 40 CFR 192, Subpart A requires that the disposal system be designed to "be effective for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years...". This design criterion is standard for all DOE UMTRCA sites, including sites having an environmental setting similar to the FEMP site. Such UMTRCA disposal cover designs have been modeled with the Corps of Engineers' Hydrologic Evaluation of Landfill Performance (HELP) computer code and shown to maintain their integrity for at least 1000 years. 40 CFR 192, Subpart B requires that average surface concentration of radium-226 not exceed background by more than: "5 pCi/g, averaged over the first 15 cm (6 in) of soil below the surface...". This requirement would be met by covering all the Subunit B waste with a 3 m (10 ft) thick multimedia cover. Compliance with requirements under the Clean Air Act, Clean Water Act, and RCRA would be met by incorporating sound engineering features and best management practices into the remediation and operation of the unit. Additional supporting documentation to justify that Alternative 2B/Vit would comply with the identified ARARs is presented in Appendices D and F (Table F-3).

4.3.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 2B/Vit would reduce the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6}. Figure 4-9 was presented as a conceptual site model for the various action alternatives considered. Residual risk will only be

through completed pathways. The basis of the risk evaluation is presented in Appendix D. Each of these potential concerns would be addressed through the primary remedial action components of Alternative 2B/Vit; treatment, isolation in an above-grade disposal vault, and the application of institutional controls.

Vitrification would significantly reduce the mobility of the COCs and the radon emanation rate, while the direct radiation fields would remain unchanged after vitrification. The disposal vault design, supplemented by institutional controls would preclude contact with or direct radiation exposure from the treated waste by a recreational user. The disposal vault also would contribute to a significant reduction in leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude access to the waste material by an on-site resident.

Because 2B/Vit includes the on-site disposal of treated residues, the 5-year CERCLA review process to ensure continued performance of the disposal system would be part of this alternative.

Adequacy and Reliability of Controls

As previously stated, the projected residual excess cancer risk attributable to Alternative 2B/Vit to viable receptors is less than 10^{-6}. The on-site disposal vault uses proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low level radioactive waste under both DOE and NRC programs, and uranium mill tailings under the DOE Uranium Mill Tailings Radiation Control (UMTRCA) Program and the Formerly Utilized Sites Remedial Action Program (FUSRAP). Fate and transport modeling to assesses the most likely release mechanism, leaching under degradation of the facility, was completed. The results were based on the assumption that components of the system slightly degrade over 1000 years and that infiltration rates (and consequently exfiltration rates) increase to 1.3 cm/yr (based on the HELP model). Also the leachability of the treated material was assumed to be that measured during treatability tests. Under these assumptions, the leaching of contaminants would not pose a risk to off-site receptors. Even if these input parameters were increased to 15 cm/yr (highest possible with no infiltration barrier) and the leachability of the untreated material were used, the overall result would not change. The leaching of the contaminants using these conservative assumptions would result in a risk to off-site receptors of about 10^{-6}.

Vitrification is an innovative technology that has not been previously applied to the stabilization of waste materials at the same scale as contemplated under Alternative 2B/Vit. Over the period of 1989

to 1993, the FEMP site has conducted a series of bench scale treatability tests to examine the performance of vitrification technology on Silo 3 residues. The tests have repeatedly demonstrated consistent reductions in the leachability of both radionuclides and inorganic constituents (see Appendix C). An ongoing glass optimization program underway for the Subunit A residues has identified a relatively wide envelope of operating parameters (temperature, additive rate, and waste composition) under which the vitrification system could perform to produce an acceptable product. These conclusions can be extrapolated to Subunit B material. Additionally, the use of vitrification provides added operational flexibility to recycle glass product not meeting performance based requirements through the glass melter. On this basis, there is a high probability that the vitrification treatment system would retain the required glass product performance requirements for Subunit B residues.

The disposal vault would be designed to preclude the need for long-term management. Operation and maintenance functions would occur until long-term protectiveness was attained at the time when the FEMP site-wide remedial action objectives would be met.

Consistent with DOE Order 5400.5, 40 CFR 264.114 and 40 CFR 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required 5-year CERCLA review.

Long-Term Environmental Impacts

The environmental impacts resulting from the implementation of Alternative 2B/Vit after remedial activities are completed would be essentially the same as for Alternative 2A/Vit. Refer to Alternative 2A/Vit (Section 4.2.2.3) for detailed information, this section only contains a summary. For irreversible and irretrievable commitment of resources, refer to Section 4.7. The following paragraphs summarize the long-term effects of Alternative 2B/Vit on the environment.

Soil and Geology

Construction of the disposal vault would result in the permanent disruption of 2.4 ha (6.0 acres) of land. The disposal configuration would prevent erosion of waste material that could result in surface soil contamination and would prevent leaching that would contaminate subsurface soil. Uncontaminated soil would be used as fill. Borrow pit soil for construction would be obtained from clearing and grubbing.

The regional geology of the FEMP site and surrounding area would not be affected by implementation of Alternative 2B/Vit. Geological conditions are important in terms of site suitability for construction of an on-property disposal vault. Because the material would be vitrified and the appropriate design factors (thickness and performance of cover material and liner) would be incorporated into the facility, the site proposed would be suitable from a geologic standpoint. The facility would also incorporate appropriate protection against seismic damage. A review of local conditions suggests the soil beneath the location of the proposed facility is not susceptible to liquefaction or seismically induced settling.

Water Quality and Hydrology

A system to monitor long-term water quality would be implemented by installing monitoring wells around the perimeter of the disposal vault. No significant long-term hydrological impacts to the surrounding area are expected to result from changes to the site. However, after 1,000 years, some degradation could occur. Run-on and runoff controls would be used at the disposal vault and the remaining areas of the site would be regraded to approximate original contours and would discharge surface runoff to existing on-property drainageways.

Air Quality

Following implementation of Alternative 2B/Vit, the air quality at the FEMP site would be similar to current conditions. There would be no long-term impacts on air quality because the disturbed areas would be revegetated.

Biotic Resources

Long-term impacts may include displacement of potential threatened and endangered species habitat. No critical habitat for threatened and endangered species has been identified in areas to be impacted by Alternative 2B/Vit activities. However, a potential habitat for threatened and endangered species does exist in the disposal area. Implementing Alternative 2B/Vit would result in the loss of 2.4 ha (6.0 acres) of potential habitat for the above species. Following completion of construction and excavation activities, disturbed areas would be backfilled, regraded, and revegetated with native grass species. For detailed information on the biotic impacts refer to Alternative 2A/Vit (Section 4.2.2.3).

Wetlands and Floodplains

A wetlands delineation for the FEMP site was conducted in December 1992 (Ebasco Environmental 1993) and is currently pending COE approval. The delineation identified approximately 12 ha (29

acres) of jurisdictional wetlands in the northern part of the site. Efforts were made to site the disposal vault in areas not containing jurisdictional wetlands. However, the siting of the facility for Alternative 2B/Vit would result in the loss of approximately 5 ha (12.5 acres) of forested wetlands. A wetlands assessment pursuant to the requirements of 10 CFR 1022 has been prepared (Appendix J) for the representative alternative and other alternatives evaluated.

The 100-yr and 500-yr floodplains are located near Silo 3 and the support facilities. However, these areas would not be permanently altered as a result of implementing Alternative 2B/Vit.

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The area of the disposal vault is estimated at less than 0.1 percent of the FEMP site area. However, the presence of the permanent disposal vault would result in future limitations for use of the site. No change would be expected in the local population growth, nearby industrial and commercial operations, or noise level. The net long-term impact of Alternative 2B/Vit on these socioeconomics is expected to be positive because the silo contents and sludge would be isolated and controlled. However, aesthetic perceptions to a visitor or passerby could be altered due to the controls required for the disposal vault. A fenced area topped with barbed wire would be used for material disposal. These controls could result in a noticeable attention drawn to the disposal area.

Cultural Resources

A site-wide archaeological survey would be performed for the areas to be impacted by Alternative 2B/Vit. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, OHPO, AIRFA, and NAGPRA. Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

In Alternative 2B/Vit, vitrification would be used to treat all the Silo 3 contents. This process would reduce contaminant toxicity, mobility, and volume. The vitrified material would undergo a 62 percent decrease in volume as a result of treatment. This result corresponds to a total treated volume of 1471 m^3 (1935 yd^3). The toxicity of radionuclides in the silo contents would not be reduced by the treatment method; however, the operating temperatures considered for the vitrification design (1350°C [2460°F]) would destroy any organic compounds, thus reducing the toxicity of the treated material. Most of the inorganics, including the radionuclides, would be fixed in the final glass-like product.

A remedy-selection treatability study was conducted with Operable Unit 4 materials, including the contents of Silo 3. This treatability study demonstrated the effectiveness of vitrification as a treatment alternative (see Appendix C). Additional remedial design treatability studies would be conducted to further determine the factors that affect the destruction and removal efficiencies for the contaminants during vitrification and the extent of partitioning of undestroyed contaminants between the vitrified material and the off-gas treatment system. The results of these studies would be used to develop appropriate glass formulations, provide data necessary for sizing and design of the full-scale continuous melter system, and to determine the configuration of the final off-gas treatment system for removal of radon.

The chemical and physical properties of Subunit B material were determined and used in developing glass formulas for the bench-scale treatability study tests (Appendix C, Tables C.3-1 to C.3-10). Data from the study revealed that the radon emanation rate from the vitrified Silo 3 material was below detection limits, far less than the EPA limit of 20 $pCi/m^2/s$ for radon emanation from uranium mill tailings. The measured radon emanation rate from the treated material is approximately equal to the emanation rate from natural building materials such as brick and concrete, even though the radium content of the waste glass is $1x10^3$ to $1x10^6$ times greater than that of natural building materials.

Data from the treatability study revealed that significant volume reductions could be achieved through vitrification. As shown in Table C.3-13 for tests CO.1 and CC.1 (applicable to Subunit B materials), the reduction in volume of material was 62 percent. Thus, the final volume was approximately 38 percent of the untreated material volume. This result corresponds to a total estimated treated volume of 1471 m^3 (1935 yd^3).

Vitrified residues from all tests were RCRA nonhazardous as determined by the TCLP test. Thus, TCLP test results (through the leachate concentration) for the treated waste form demonstrated the effectiveness of vitrification as a treatment process for Subunit B wastes. Leachate concentrations were below TCLP regulatory limits for all the glass produced in these tests (Table C.3-14 of Appendix C). Table C.3-18 presents a comparison of the leachate activity from the untreated wastes to the leachate activity from the vitrified wastes.

For Silo 3 material the ratio of activity in the leachate of the untreated waste to that in the vitrified waste was less than that of Silos 1 and 2 material. A wide variation in leaching of the various radionuclides achieved through vitrification was observed. The low ratios of the activity observed in

the leachate from the untreated waste compared to the activity in the leachate from the vitrified waste do not necessarily indicate that radionuclides are immobilized. Instead, the ratios show that some radionuclides are not leached as readily as others from the untreated waste. For example, while nearly 0.87 percent of the Ra-226 in the Silo 3 material is leached from the untreated waste, only 0.0003 percent of the Th-230 is leached. Such differences can arise because of differences in solubility among the various elements at the conditions encountered in the leachate.

The normalized leach rates indicated that all glass formulas exhibited exceptional durability, comparable to glasses developed from vitrified high-level wastes. For discussion purposes only, the normalized leach rates were compared to the Defense Waste Processing Facility Environmental Assessment (a standard representing the maximum acceptable leach rate for high-level waste glasses) (Jantzen et al. 1992) and were found to be an order of magnitude less. Also, the rates are comparable to those measured for simulated high-level waste glasses (Piepel et al. 1989).

Another observation of the treatability tests was that the TCLP appears to leach constituents from the glass more aggressively than the product consistency test (PCT). The difference between the acid conditions of the TCLP and the neutral conditions of the PCT are likely the cause of the great differences in the leaching behavior. Nevertheless, the PCT leach testing demonstrated a high degree of durability for the vitrified Operable Unit 4 wastes.

The viscosity and electrical conductivity of the vitrified waste were measured as a function of temperature. The viscosity data shows the glass from various Silo 3 material tests (Sequence C) had reasonable viscosities for processing within the temperature range reported. The conductivity values for all glasses are close to typical ranges for glass processing. Therefore, the results show that the Silo 3 material can be made into glasses with reasonable conductivity and viscosity for processing in a joule-heated ceramic melter.

In summary, most of the metals would be retained in the final glass-matrix product; and any organic contaminants, if present, would be destroyed by volatilization. Treatability tests demonstrate that the vitrified product effectively immobilizes the RCRA-defined hazardous components and reduces their release to levels less than the regulatory limits. Additional remedial design treatability studies would be conducted to further determine the factors that affect the destruction and removal efficiencies for the contaminants during vitrification and the extent of partitioning of undestroyed contaminants between the vitrified material and the off-gas treatment system. The results of these studies would be

used to develop appropriate glass formulations, provide data necessary for sizing and design of the full-scale continuous melter system, and to determine the configuration of the final off-gas treatment system for removal of radon.

The operating temperatures considered for the vitrification design (1350°C [2460°F]) would destroy any organic compounds present in the residues and fix metals into the nonleachable stabilized melt. Since hazardous inorganic constituents actually become part of the chemical structure of the glass matrix and not merely encapsulated, the process is essentially irreversible.

Literature data on the leachability of the vitrified product from a variety of waste types indicate similar leach resistance; all vitrified material tested to date has passed the RCRA TCLP test. Contaminant release from a vitrified product is controlled by diffusion and is governed by the same factors that affect release from a chemically stabilized/solidified product. The leachability of the vitrified product could be impacted by the development of immiscible phases in the melt because of the variable chemical composition of the waste; however, the short residence time in the melter would minimize the potential for immiscible phase development.

The weathering behavior of volcanic glass (a natural analog to the vitrified product) can provide some measure of the long-term stability and durability of the vitrified product. Only very thin weathering rinds develop on volcanic glass over a period of several million years. The slowness in the overall degradation of a glass grain suggests that the diffusion coefficient or leachability index would remain unchanged over time. Data on the long-term stability of vitrified material are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates. On the basis of the longevity of volcanic glass and diffusion calculations, the vitrified product would be expected to withstand environmental exposure for thousands of years.

Treatment residuals of the vitrification process would be produced from the off-gas treatment system. Off-gases containing particulates and other pollutants would be removed and treated using conventional air pollution control equipment (e.g., scrubbers). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary to adequately reduce the amount of fugitive emissions. Scrubber residuals would be recycled through the vitrification process until all the residual waste is contained in the glass matrix. Furthermore, the effects of vitrification as a treatment are essentially irreversible.

4.3.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Through a combination of engineering controls and access controls, Alternative 2B/Vit would be protective of the community during implementation. Figure 4-10 illustrates that direct emissions from being near the untreated material and gas emissions during treatment are the release mechanisms that could potentially impact the community during remediation activities. Gas collection and treatment systems operated during vitrification of the material would control gaseous contaminant releases. It has been estimated that during implementation of Alternative 2B/Vit, fenceline radon exposure levels for the off-site public would be indistinguishable from background levels, less than 0.5 pCi/L.

Through access to the site during remediation, there is the potential for a trespasser to be exposed to direct radiation from the waste material along with radon, gases, or dust. In addition to the engineering controls that would be implemented to limit the release of contaminants, access controls during remediation would be used. Fences and security forces would limit access of the public to the materials. Access controls are effective, especially in the short term. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 2B/Vit is effective in protecting the community in the short term.

Protection of Workers During Remedial Action

There are no unacceptable risks to workers as a result of implementation of Alternative 2B/Vit. This alternative involves the handling of the waste materials and therefore there are several potential exposure pathways for workers. Both the release of gases and exposure to direct radiation from the waste could cause a risk to workers. It has been estimated that with appropriate protection, the removal and treatment of materials would result in an excess cancer risk level to remediation workers of 4.1×10^{-5} (see Appendix D), well within the occupational standards required by DOE Orders. Most of this risk would occur during handling of the untreated waste. As appropriate, workers would wear protective clothing. Shielding would also be used, along with remote operations where needed.

There are safety issues associated with the removal and vitrification process. The high temperatures and power requirements of vitrification results in potential risk. There are also physical injury risks associated with constructing the on-site disposal vault. There may be accidents bringing the material on site or operating heavy equipment. Without considering the nature of the activity, it has been estimated based solely on labor hours, that the removal, treatment, and on-site disposal actions of Alternative 2B/Vit could result in 4.5 injuries and 0.07 deaths during remediation. All remediation

activities would be conducted in accordance with a health and safety plan developed to meet 29 CFR 1910.120(b)(4). Training and procedures would assure that worker exposure would be ALARA.

Short-Term Environmental Impacts

The short-term impacts resulting from the implementation of Alternative 2B/Vit during remedial activities are basically the same as those identified for Alternative 2A/Vit, Section 4.2.2.5; therefore, the following discussion is a summary.

Soil and Geology

Soil disturbance during implementation of Alternative 2B/Vit would result primarily from preparation of the disposal vault location and construction of access roads, a treatment/packaging area, a staging area, and support facilities. Construction and excavation activities could disturb a total of approximately 3.6 ha (9 acres) of the site. These same activities could also result in the erosion of exposed soil areas. Erosion controls such as straw bales and berm would be used to minimize potential erosion. Measures for reducing fugitive dust generation such as wetting surface or using dust suppressants would be used in exposed soil areas as appropriate. Following completion of all construction and excavation activities, disturbed areas would be filled with clean backfill and topsoil and revegetated with native grasses.

Water Quality and Hydrology

Through erosion control and dust suppression, contaminants disturbed during remediation would not be transported to adjacent surface water bodies. Surface water near the site would be monitored during remediation in accordance with the existing water discharge permit to assess potential impacts to the water from remediation.

Remediation would not increase the release of contaminants to the groundwater since the material would always be contained. However, selected existing groundwater wells on the FEMP site would be monitored during source removal.

Air Quality

Ambient air quality in areas accessible to the public is regulated by both state and federal standards. There are three potential sources of air emissions; 1) dust from construction and earth-moving activities, 2) gas releases during treatment, and 3) heavy equipment exhaust. The exhaust emissions from heavy equipment are not expected to impact air quality.

Dust would be controlled as discussed in the soil section. With the appropriate dust suppression, excavation activities are not expected to negatively impact the air quality. Gas emissions would be controlled through both collection and treatment during waste treatment. Therefore, no significant releases into the environment are expected to occur.

Biotic Resources

The short-term disturbance of on-property vegetation and wildlife habitat under Alternative 2B/Vit would result primarily from activities associated with construction of the on-site disposal vault and other facilities and installation of electric power lines, transformers, process water and sewer lines, and material slurry transfer lines. Local biota (wildlife and wildlife habitat) would be temporarily displaced along with potential threatened and endangered species habitat. However, these impacts would be temporary and permanent habitat losses are expected to be minor.

There also is the potential for impact to biota from contaminant releases such as through erosion, dust emissions, gas releases, and direct radiation. As discussed in previous short-term effectiveness discussions, the releases would be minimized through engineering controls such as erosion control, dust suppression, gas collection and treatment, and shielding of waste materials. There should be no negative exposure impact on biota during implementation of Alternative 2B/Vit.

Wetlands and Floodplains

A site-wide wetlands delineation has identified several areas of wetlands in or adjacent to areas that could be impacted by the implementation of Alternative 2B/Vit. Wetlands north and south of the material treatment facility are not expected to be affected; however, there would be disturbance of wetlands during the construction of the on-site disposal vault. Approximately 2.2 ha (5.5 acres) could be affected. Engineering controls through the site activities such as silt fences, straw bales, would be used to control the migration of eroded soil to wetland areas.

The 100-year and 500-year Paddys Run floodplains are located immediately west of Silos 1 and 2. Alternative 2B/Vit activities are not planned to occur within the floodplains and contaminant migration during remediation would be controlled through engineered erosion controls to minimize impacts on the floodplains.

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For this analysis it is assumed that all of the resources, needed to complete remedial activities, could be obtained within the local area. Consequently, the collective revenue for the CMSA would increase by 3.3% over a period of five years. With the implementation of alternative 2B/Vit, the increase in revenues for the CMSA would have limited impact on surrounding communities.

Cultural Resources

Any areas determined to be of significance resulting from a cultural resource review would be managed consistently with the requirements of the NHPA, OHPO, AIRFA, and the NAGPRA (Luce 1987). A more detailed discussion of management procedure is provided in the short-term effectiveness evaluation for Alternative 2A/Vit.

Duration of Remedial Activities

Remedial action activities under Alternative 2B/Vit are expected to be completed in about 6 years. Construction, testing, and startup of the material processing facility could require at least 3 years, with the possibility of a longer period depending on the difficulties encountered. Material removal activities would require about 3 years, assuming 8 hours/day, 7 days/week, and 3 weeks/month. The treatment facility would operate concurrently with removal for 3 years assuming that operations would be conducted 24 hours/day, 7 days/week, and 3 weeks/month. The time to implement the treatment component of this alternative could be prolonged if pilot-scale testing and full-scale testing of the vitrification facility resulted in scale-up and operational difficulties because of the innovative nature of this treatment technology. Physical, substantial, and continuous on-site activities would be initiated within 15 months after the ROD is approved by the EPA.

4.3.2.6 Implementability

Technical Feasibility

Construction and operation of the removal component of Alternative 2B/Vit would be readily implementable. Pneumatic removal is a standard technology that is normally reliable and readily available. Although pneumatic removal has not been used before on the Silo 3 cold metal oxides, it has been used to remove material of similar consistency. Because the structural integrity of Silo 3 is questionable, extreme caution would need to be exercised during removal of silo contents. In case of silo dome failure and the subsequent implementation of an emergency response plan, all removal operations would cease until an assessment of the failure and its impacts is complete. Upon completion of the assessment, the steps required to complete the remedial action would be determined. Construction and operation of the disposal components of this alternative would be

reliable. Components of the design have been used at numerous other sites. If disposal volumes were greater than anticipated, the disposal vault footprint could be easily increased.

The technical feasibility of the vitrification facility construction is expected to be moderately straightforward, but a full-scale system for similar materials has never been built. The vitrification technology would require engineering scale-up to be implemented full scale at Operable Unit 4. Pilot testing, detailed design, fabrication, installation, and 3 to 6 months of full-scale operation will be needed to optimize the treatment process. The necessary equipment would be modified from available equipment used in the glass-making industry. Construction of the vitrification facility at the FEMP site would include construction of an electric substation.

Operation of the vitrification facility would be somewhat difficult. The vitrification system consists of three basic circuits: a feed preparation circuit, a melter circuit, and an off-gas treatment system. Joule-heated ceramic melters have been used to vitrify liquid high-level radioactive material, radioactively contaminated soil, and waste contaminated with heavy metals in quantities ranging from 4.5 to 410 metric tons (5 to 450 tons). Several vendors have been identified for the electrically based (joule-heated ceramic melters or plasma arc torch) and in situ vitrification technologies.

A trained process engineer would be needed to operate both the physical pretreatment and melting circuits of the electrically based ceramic melter and to act as supervisor of the melter circuit. Operators and maintenance personnel, laborers, laboratory technicians, and administrative personnel would also be needed. Industrial work experience would be required for the system operators and maintenance personnel. The number of operators and maintenance personnel with previous experience in the vitrification of hazardous waste is limited, but these personnel could be drawn from the commercial glass-making industry or the high-level radioactive waste vitrification industry. The melter system could be designed to operate largely by computer, with a combination of human and computerized oversight. Start-up of the vitrification facility would require at least 4 months following construction. Because the melter system has not been previously used at the scale required for the site, operational problems might develop during start-up that could impact the processing schedule and costs.

Potential operational problems in the melter circuit include temperature variation, incomplete melting, immiscible phase development, and thermocouple or heat sensor failure. Refractory failure would not be anticipated to be a problem because the design life of the melter operation is less than the design

life of the refractory at anticipated operating temperatures. Temperature variation and improper control could result in the incomplete melting of feed material. Temperature fluctuations could also cause phase immiscibility. The use of electricity allows for almost immediate control over melt temperatures and thus would aid in controlling variability in melt viscosity and phase immiscibility. Temperatures within the system would be continuously monitored by thermocouples and heat detectors. These thermocouples would probably be prone to failure at the high operating temperatures, necessitating the placement of redundant thermocouples at critical locations in the system and routine replacement and repair as part of maintenance activities. Any product from the vitrification system that was incompletely melted or contained immiscible phases would be returned to the facility until an acceptable product was produced.

The reliability of the melter system for waste treatment is not well established because this system has not yet been implemented at full scale or continuous operation. Similar melting systems used in commercial glass-making report a 90 percent continuous operation efficiency.

Because this system has not been used previously at the scale required for the FEMP site, operational problems might develop during start-up that could affect the processing schedule and costs.

The off-gas treatment system would use standard air pollution treatment and control devices. Although the capability of the individual off-gas treatment devices are known and well demonstrated, the effects are less well known with regard to linking multiple treatment devices together to treat the off-gas expected from vitrification of the Silo 3 contents. The off-gas treatment system would use standard components, but the selected devices and their configuration would have to be explicitly defined, tested, and optimized through bench-scale and pilot-scale testing.

The limited experience in developing the required off-gas treatment system could result in schedule delays or cost increases because more time and personnel might be needed to bring the system on-line. Operators and repair personnel would probably be drawn from the incineration industry because of their experience in operating and maintaining off-gas treatment systems. The likelihood of operational problems would increase as the complexity of the off-gas treatment system increased. It is possible that a complex linkage of treatment devices could lead to operational difficulties with individual devices, and the potential for effects from failure of individual devices could be exacerbated in downstream devices and result in an overall problem with system operations and collection and removal efficiencies. If the off-gas emissions exceeded applicable requirements, delays

would result; failure of monitoring devices or inadequate test results from a full-scale off-gas system could also cause delays until corrections could be implemented. Additional conceptual design and testing would be required to identify and resolve the potential difficulties in designing and operating an off-gas treatment system for a vitrification system.

Operational problems that could develop in the off-gas treatment circuit include production of large amounts of particulates that require secondary handling, added treatment requirements for the scrub solution prior to disposal, monitoring device calibration, maintenance requirements, and exacerbation of operational problems in downstream control devices resulting from failure of an upstream device. The off-gas treatment system would require testing and optimization to resolve these potential problems.

Developing the required off-gas treatment system could result in schedule delays or cost increases because more time and personnel may be needed to bring the system on-line. Operators and repair personnel would probably be selected from the incineration industry because of their experience in operating and maintaining an off-gas treatment system. The likelihood of operational problems increases as the complexity of the off-gas treatment system increases. A complex linkage of treatment devices could lead to operational difficulties with individual devices. The potential for effects from failure of individual devices could also be exacerbated in downstream devices and result in an overall problem with system operations and collection and removal efficiencies.

The effectiveness of the main components of the treatment process for Alternative 2B/Vit would be regularly monitored. The off-gas treatment system effluent would be monitored to determine the off-gas composition and ensure compliance with applicable requirements. The effectiveness of the vitrification process would be monitored by regular testing of the treated product. If a sample fails the leachability criteria, additional samples would be collected, tested, and analyzed to determine the cause of the problem. The failed treated material could be revitrified, if necessary, and a process modification instituted.

About 2.4 ha (6 acres) would be required for the above-grade disposal vault, with a capacity of approximately 3402 m^3 (4450 yd^3).

The effectiveness of the above-grade disposal vault would be monitored through several systems to meet the requirements of the CERCLA five-year review. Groundwater monitoring wells would be located to detect changes in groundwater quality. The monitoring system associated with the disposal vault would provide the information needed to determine if additional corrective action should be taken to prevent the migration of contaminants into the environment.

The implementation of Alternative 2B/Vit would not adversely impact the performance of additional remedial actions at the FEMP site. For example, the presence of the above-grade disposal vault would not affect the ability to remediate groundwater at the site.

Administrative Feasibility

No permits or licenses would be required, but permit information summary packages may be necessary. The substantive technical requirements of air emissions permits would also need to be demonstrated. This may include calculating estimated emissions, providing air emissions controls, developing a sampling and analysis plan to monitor air emissions, and air sampling. Coordination with OEPA would be necessary to ensure that the substantive technical requirements for siting the above-grade disposal vault would be met.

Availability of Services and Materials

Although it is technically feasible to design, construct, and operate a vitrification facility, a full-scale facility for the vitrification of materials similar to those within Operable Unit 4 has never been built.

Remedy-selection treatability studies have been completed and remedial design treatability studies (bench- and pilot-scale) would be performed to address site-specific design requirements. Necessary equipment would be modified from available equipment in the glass-making industry. Additionally, process engineers, operation and maintenance personnel, laborers, laboratory technicians, and administrative personnel would be trained as required. There would be sufficient disposal capacity for the vitrified waste.

The construction activities involved in Alternative 2B/Vit include: construction of the rail system for the work platform, the work platform and hydraulic mining device; clearing and grubbing of areas around the silos and at the location of the material processing facility; construction of access roads, fencing, lighting, water, sewer, and electrical services; construction of an above-grade disposal vault;

construction of a materials processing facility and a vitrification unit; and construction of a multimedia cap.

The construction of the rail system, a work platform, and pneumatic mining device would involve the purchase of materials and services which are standard in the construction industry.

The clearing and grubbing, and construction of roads, fencing, lighting, sewers, and electrical services would involve the use of standard construction equipment and trades, the use of a fence installation contractor, and the purchase of appropriate materials. These would all be readily available.

The construction of an above-grade disposal vault would require the use of standard construction equipment and trades. Materials needed to construct reinforced concrete vault would be purchased. These services and materials would be available locally.

The construction of a materials processing facility would involve the purchase of a pre-engineered building, the process equipment, the process chemicals/materials, electrical transformers and transmission lines, and the instrumentation and controls. It would also involve the use of standard construction equipment and services. Some engineering would be required during construction, start-up, and debugging of the process equipment. Qualified personnel would be needed to operate and maintain the facility. Of these, only the operator may be difficult to retain.

Although it is technically feasible to design, construct and operate a vitrification facility, a full-scale facility for the vitrification of hazardous materials similar to those within Operable Unit 4 has never been built. Remedy-selection treatability studies have been completed and remedial design treatability studies (bench-and pilot-scale) would be performed to address site-specific design requirements. There would be sufficient disposal capacity for the vitrified waste.

The construction of the multimedia cap would require the acquisition of material for a geotextile liner, a clay layer with a permeability of 1×10^{-7}cm/s, a 40 mil textured geomembrane, and clean soil for the foundation. As shown in a materials survey, these materials would be readily available. Standard construction equipment, operators, and trades would be required. The installation of membranes and liners would require specialized equipment and personnel to lay the material and seal seams.

In summary, the resources and materials would be readily available. It would be necessary to ensure that EPA, OEPA, and the local community are fully involved in the development of remedial design/remedial action work plans. Close coordination with the regulatory agencies and the community prior to and during remedial activities is essential to successful implementation.

4.3.2.7 Cost

The total present worth cost of Alternative 2B/Vit is $28M. A detailed breakdown of the cost is provided in Table 4-6.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and pneumatic removal/transfer system for transfer of the residues, purchase of vitrification equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-6. More detailed information is provided in Appendix E.

The largest component of the capital cost is the construction of the pneumatic removal/transfer system. This represents approximately 50 percent of the total capital costs. Most of the expense of this component is due to construction of the steel superstructure that supports the pneumatic system. The second largest element of the capital costs (21 percent) is the purchase of vitrification equipment.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads, and the equipment staging areas. The basis of estimate includes the following assumptions:

- An area of approximately 2.4 ha (6 acres) would be cleared and grubbed.
- Filling would be performed where necessary. The volume of fill was estimated to be 11,500 m^3 (15,000 yd^3). It was assumed that this soil could be obtained from excess on-site soil.

TABLE 4–6

COST ESTIMATE FOR ALTERNATIVE 2B/VIT

ALTERNATIVE 2B: REMOVAL, STABILIZATION W/VITRIFICATION, ON–PROPERTY DISPOSAL			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
SITE PREPARATION	$579,500	$528,700	$1,108,200
WASTE PROCESSING	$915,300	$971,000	$1,886,300
VITRIFICATION	$2,593,400	$1,460,700	$4,054,100
PNEUMATIC REMOVAL/TRANSFER SYSTEM	$4,571,600	$4,744,400	$9,316,000
DISPOSAL VAULT	$498,100	$848,000	$1,346,100
PACKAGING (1,282 PKGS. @ $955/PKG.)	$338,400	$885,900	$1,224,300
TOTAL CAPITAL	$9,496,300	$9,438,700	$18,935,000
RISK BUDGET (11.0%)	$1,044,600	$1,038,300	$2,082,900
SUBTOTAL	$10,540,900	$10,477,000	$21,017,900
CONTINGENCY (20.0%)	$2,108,200	$2,095,400	$4,203,600
TOTAL ESTIMATED INSTALLED COST	$12,649,100	$12,572,400	$25,221,500
OPERATION AND MAINTENANCE (O&M) COSTS			
DURING CONSTRUCTION			$4,923,000
POST–REMEDIATION			$3,162,000
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$27,971,300

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during construction (years): 1
Post–remediation O&M (years): 30

- New fencing would be added across the southern end of the remediation area, around the interim storage area, and between the proposed parking area and the equipment staging area. Fencing would be 2 m (7 ft) high, barbed-wire topped chain link fence. Approximately 550 linear meters (1,800 linear ft) would be required. It is assumed that seven gates would be required, each 4.5 m (15 ft) wide and 2 m (7 ft) high, and topped with barbed wire.

- An equipment staging area would be added to the north end of the remediation site. This area would consist of 15 cm (6 in) of crushed stone [2.5 cm (1 in) maximum diameter) applied over an area 45 m (150 ft) by 60 m (200 ft) (30,000 ft^2).

- Approximately 450 m (1,500 ft) of 6 m (20 ft) wide roads would be constructed in the remediation area. The roads would be constructed of 15 cm (6 in) deep crushed stone [2.5 cm (1 in) maximum diameter].

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and an off-gas treatment system. Costs were estimated based on the following assumptions:

- The waste processing facility would be a modified two-story pre-engineered building built on slab. The first floor would provide approximately 1350 m^2 (14,400 ft^2) and the second floor would have 50 m^2 (500 ft^2). The waste facility would be fully insulated and would have a 10-year design life span.

- The walls of the processing rooms and the storage room will be shielded with 0.6 m (2 ft) thick concrete.

- Approximate dimensions of the various areas of the building were estimated to be as follows: processing area - 820 m^2 (8,800 ft^2), administrative/personnel area - 300 m^2 (3,200 ft^2), miscellaneous equipment area - 450 m^2 (4,800 ft^2), and storage area - 220 m^2 (2,400 ft^2).

- The ventilation system for the general process area would operate continuously, and would either recirculate or exhaust to atmosphere. This system would not be designed to remove radon.

- The general process area ventilation would provide seven air changes per hour. The system would include a 1135 m^3/min (40,000-cfm) blower and HEPA filter, and 91 m (300 ft) of 1.5 m (5 ft) diameter ductwork with dampers and fittings. A second redundant train would be installed.

- A separate ventilation train would be used in the event radon is detected in the process area. The general process area ventilation system would shut down if radon is detected in the general process area.

- The radon treatment system for process air would consist of a 30 m^3/min (1,000 cfm) blower, a calcium sulfate media dehumidification vessel, a carbon adsorption canister, a HEPA filter, and approximately 61 m (200 ft) of 25 cm (10 in) diameter ductwork (with dampers and fittings). This system would be rated for 30 m^3/min (1,000 cfm), and the system would exhaust to atmosphere. A second redundant train would be installed.

Vitrification

This cost item includes the cost of the vitrification equipment and off-gas system, and is estimated based on the following:

- The vitrification equipment would operate 24 hours/day and would be designed to treat 11,800 kg/d (13 tons/day) of material.

- Vitrification equipment includes a horizontal belt filter for sludge dewatering, filtrate recycle tank, surge tank, sodium carbonate and carbon storage/feed facilities, process piping, pumps, mixers, and a joule-heated melter.

- The off-gas treatment system would be rated at 4 m^3/min (150 cfm). It would consist of blowers, scrubbers, carbon adsorbers, and HEPA filters.

Pneumatic Removal/Transfer System

This cost component includes the support superstructure and work platform, rail system, filter/receiver, glove box, and the pneumatic removal equipment. Assumptions used for the cost estimate include:

- The work platform would be a rail-mounted, 54-m (180-ft) structure truss that would span the silos.

- A glove box would be used at the interface of the pneumatic removal system and the silo dome.

- The air suctioned from the silo would be separated in a filter/receiver adjacent to the work platform.

- The pneumatic removal equipment would consist of a cutterhead, vacuum, and pump.

Disposal Vault

The cost of the disposal vault was estimated as follows:

- Cost for the on-property, above-grade disposal vault was estimated at a unit cost of \$939/m^3 (\$718/yd^3).

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- The unit cost estimate is based on a conceptual design for a vault consisting of individual modular cells, each capable of holding 3400 m^3 (120,000 ft^3) of material. As additional disposal volume space is required, additional modular cells were added for cost estimating purposes. Cell numbers were established by rounding up to the nearest whole number.

- The size of the disposal vault was estimated based on the number of packages noted below, assuming each container occupies 2 m^3 (64 ft^3) of space, and was estimated at 2324 m^3 (82,048 ft^3). Assuming a cell size of 3400 m^3 (120,000 ft^3), one cell would be required [697 m^3 (7,500 ft^2) vault footprint area].

- The design of the vault includes a multimedia cap, liner, intruder barrier, and LC/DS.

- The vault would cover approximately 2.4 ha (6 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation. Estimated cost is based on the following:

- Packages would be DOT specification 7A-Type A containers with exterior dimensions of 1.2 m (4 ft) width by 1.2 m (4 ft) length by 1.2 m (4 ft) depth. Interior dimensions would be 1.1 m (3.5 ft) width by 1.1 m (3.5 ft) length by 1.1 m (3.5 ft) depth, providing 1.2 m^3 (43 ft^3) of storage per container.

- Total volume that would be packaged was based on 3895 m^3 (5,093 yd^3) of untreated Silo 3 material. Final packaging volume, assuming a 62 percent volume reduction due to the vitrification process, was 1471 m^3 (1,935 yd^3).

- Packaging and disposal of materials generated during D&D operations are not included in this cost, but are included in the costs for Subunit C.

- Total packaging cost was estimated assuming 2,412 containers.

- A unit cost of $955 per container was determined based on a material cost of $650 per unit and a labor cost of 16 man-hours per unit for handling, filling, and documentation.

O&M Cost

Short-term O&M costs incurred during remediation, and long-term O&M costs are $4.9M and $3.2M, respectively (not considering present worth). Long-term O&M costs include the maintenance and monitoring which would be conducted until FEMP site-wide remedial action objectives are attained, i.e., for a period of approximately 30 years. The monitoring would support the required CERCLA five-year reviews.

4.3.3 Analysis of Alternative 2B/Cementation

This alternative is identical to Alternative 2B/Vit except that cement stabilization is used as the stabilization process option instead of vitrification. Also, as a result of the increased bulking of the stabilized material form (58 percent volume increase for cement stabilization versus 68 percent volume decrease for vitrification), the on-property above-grade disposal vault would require an area of 3 ha (7.5 acres) instead of the 2.4 ha (6 acres) required for the Alternative 2B/Vit. The site preparation/construction, material removal, and features of the above-grade disposal vault will be essentially the same as for Alternative 2B/Vit.

The cement stabilization process is identical to that described for Alternative 2A/Cem (Section 4.2.3) with the exception that cement, flyash, and blast furnace slag are added to the cold metal oxides following removal. Because the cold metals oxides and removal process is dry, water must be added.

4.3.3.1 Overall Protection of Human Health and the Environment

Alternative 2B/Cem meets the remedial action objectives for Subunit B. As with Alternative 2B/Vit 4.3.2.1, Alternative 2B/Cem meets the objectives through treatment, containment in an on-site above-grade disposal vault, and implementation of institutional control measures. The difference between the two alternatives is the treatment method used.

Treatment of Subunit B material through cement stabilization would reduce contaminant mobility but would increase the volume of contaminated material. The leaching rate of the treated waste form would be reduced resulting in protection of the underlying Great Miami Aquifer. As with Alternative 2B/Vit, treatment of the material prior to disposal would provide additional protection in the event that the vault begins to degrade. Similar to Alternative 2B/Vit, there is uncertainty associated with continued long-term protection for Alternative 2B/Cem due to the possible degradation of the stabilized material and subsequent increased leachability.

The containment features of Alternative 2B/Cem include the above-grade vault and provide additional control of contaminant migration along with prevention of direct access to the waste. Uncertainties exist in long-term reliability of the vault although fate and transport modeling results show to be protective.

Both 2B alternatives use institutional controls to provide protection to human health in the event of failure of the engineering controls and to provide an added measure of protection against destruction

of the vault. Additionally, under ORC 3734.02, a restrictive covenant limiting site use is required for any disposal facility. As with the other components of these two alternatives, the long-term reliability of institutional controls is uncertain.

Eventually, complete failure of the engineered controls and the institutional controls could result in human health and environmental risk conditions approaching baseline risk conditions.

Short-term risks for Alternative 2B/Cem would be almost the same as for Alternative 2B/Vit. While the difference in hazards between the two treatment process options is not quantifiable, cement stabilization poses slightly lower risks because it does not employ the high voltages and temperatures that vitrification does.

4.3.3.2 Compliance with ARARs

Alternative 2B/Cem is identical to Alternative 2B/Vit with the exception of the process option used to treat the Subunit B wastes. In this alternative, cement stabilization would be used in place of vitrification. This difference is insignificant for compliance with potential ARAR/TBC requirements (see Table F-3 in Appendix F). Compliance of this alternative would be identical to that of Alternative 2B/Vit presented in Section 4.3.2.2. The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 2B/Cem would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those standards associated with meeting drinking water MCLs and MCLGs requirements, the groundwater protection requirements, radon-222 airborne release requirements, other radionuclide release requirements for water and air, and their resulting doses to the public. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 2B/Cem. Additional documentation of compliance of Alternative 2B/Cem with the identified ARARs is presented in Appendix F (Table F-3).

Location-Specific ARAR/TBCs

Alternative 2B/Cem would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands, endangered species, and the sole source aquifer underlying the FEMP site. Despite the larger footprint of the on-property disposal facility associated with this alternative, the Alternative 2B/Cem

disposal facility would have adequate locational setbacks to comply with these distance requirements. As was noted, compliance with the OAC 3745-27-07 prohibition on siting a solid waste disposal facility over a sole source aquifer would be based on demonstrating the substantive technical requirements for an exemption to this requirement as discussed in Section 4.2.2.2.

Action-Specific ARAR/TBCs

Alternative 2B/Cem would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.3). Included would be those standards associated with the design of the multi-barrier engineered above-grade disposal vault system and operational requirements. As was discussed for Alternative 2B/Vit, Alternative 2B/Cem would comply with the requirements of 40 CFR 192 Subparts A and B. Compliance with requirements under the Clean Air Act, Clean Water Act, and RCRA will be met by incorporating sound engineering features and best management practices into the remediation and operation of the unit. Additional supporting documentation to justify that Alternative 2B/Cem would comply with the identified ARARs is presented in Appendices D and F (Table F-3).

4.3.3.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 2B/Cem reduces the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6}. Since the only difference between Alternatives 2B/Cem and 2B/Vit is the treatment technology applied and since the magnitude of the residual risk under an effective alternative does not depend in this case on the type of treatment technology, the residual risk from both alternatives would be the same.

Adequacy and Reliability of Controls

The projected residual excess cancer risk attributable to Alternative 2B/Cem to viable receptors is less than 10^{-6}. The on-site disposal unit is the same as that for Alternative 2B/Vit and therefore has the same adequacy of controls and the same degree of reliability. Fate and transport modeling of the leaching pathway was completed. The assumptions were the same as for Alternative 2B/Vit except that the leachability of the treated material was assumed to be that of the treatability results for cement stabilization. The results were the same as for Alternative 2B/Vit, leaching of contaminants would not pose an unacceptable risk to off-site receptors.

Cement stabilization is a proven technology that has been previously applied to the stabilization of similar waste materials as those contemplated under Alternative 2B/Cem. Additionally, over the

period of 1989 to 1993, the FEMP site has conducted a series of bench scale treatability tests to examine the performance of the cement stabilization technology on Subunit B materials. The tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics (see Appendix C). On this basis, there is a high probability that the cement stabilization treatment system would obtain the required product performance requirements.

Consistent with DOE Order 5400.5, 40 CFR 264.114 and 40 CFR 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required 5-year CERCLA review.

Long-Term Environmental Impacts

With the exception of the area disturbed, Alternative 2B/Cem has the same long-term environmental impacts as Alternative 2B/Vit (Section 4.3.2.3). Alternative 2B/Cem would permanently disturb 1.8 ha (4.5 acres) of land.

4.3.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2B/Cem uses cement stabilization to treat the contents of Silo 3. Cement stabilization reduces the mobility of contaminants by binding them into a cement mixture. As a result of the additives used in the process, the volume increases. There is no reduction in toxicity. A remedy selection treatability study was conducted with Operable Unit 4 materials to compare vitrification and cement stabilization. The criteria for the comparison included leachability of the treated waste form, the material volume reduction achieved, and the reduction in radon emanation from the material (Appendix C-Section C1.0 and Appendix H).

The chemical and physical properties of Subunit B wastes were determined and used in developing the bench-scale treatability studies. The treated material is effective in reducing radon emanation by an average of 45 percent; however, the lower radon quantities emitted by Subunit B material mean that acceptable levels are emitted after cement stabilization. Data from the study revealed that the radon emanation rates from the treated Silo 3 material were less than the 20 $pCi/m^2/s$ criteria established for DOE in 40 CFR 61. The rates averaged between 13 to 17 $pCi/m^2/s$.

The amount of volume increase caused by the addition of cementatious material varied from 50.3 to 63 percent as a result of the heterogeneity of the Subunit B waste. Consequently, there would be a total treated material volume of 5999 m^3 (7894 yd^3).

The stabilized material from all tests were RCRA nonhazardous, as determined by the TCLP test. Thus, TCLP test results (through leachate concentration) for the treated waste are the demonstration of the effectiveness of cement stabilization as a treatment process for Subunit B waste. A formulation including blast furnace slag, cement, and flyash was the most effective with virtually all chemical and radionuclide constituents having reductions in contaminant concentrations in the leachate. The percent reduction for lead in leachate was typically above 95 percent. The mean reduction of Ra-226 was 83 percent.

Durability was measured by freeze-thaw and wet-dry testing and comparison to ASTM standard (30 percent weight loss) and EPA guidance of 15 percent weight loss. The average weight losses for Subunit B material exceeded 15 percent with one average above 30 percent weight loss. Durability was also measured using the unconfined compressive strength (UCS) test on the durability samples. The comparison of the UCS results are used to indicate how the physical properties of the stabilized material change as a result of the simulated climatic stress. Many of the Subunit B waste samples degraded to the extent that they had no resistance to compressive stress after the wet/dry test, although Subunit B samples responded comparably to Subunit A samples after the freeze-thaw test. Some wet/dry samples crumbled before the test was run. The degradation and leachability results for some contaminants indicate that cement stabilization is not an irreversible treatment process.

Residuals from the stabilization process would be generated from the off-gas treatment system. Off-gases containing particulates and other pollutants would be removed and treated using conventional air pollution control equipment (e.g., scrubbers). Changes in scrubber efficiencies or types of scrubber compounds could significantly affect the predicted amount of scrubber residuals. Remedial design treatability studies testing the off-gas treatment system would be necessary to adequately reduce the amount of fugitive emissions. Scrubber residuals would be recycled through the stabilization process until all of them were contained in a cement form.

4.3.3.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Alternative 2B/Cem provides the same degree of short-term protection of the community as Alternative 2B/Vit (Section 4.3.2.5) using the same engineering and access controls.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers are the same for Alternatives 2B/Vit and 2B/Cem. Although cement stabilization is inherently less dangerous than vitrification, the increase in labor hours results in an estimate of 5.1 injuries and 0.077 deaths during remediation activities.

Short-Term Environmental Impacts

The short-term impacts associated with Alternative 2B/Cem are essentially the same as those for Alternative 2B/Vit, with the exception of workers, trucks and resources needed to implement remedial activities. Approximately 117 trucks making 18 one-way trips per working day would have a minor impact on nearby communities. For this analysis, it is assumed that all expenditures would take place within the CMSA, in which case the implementation of Alternative 2B/Cem would increase revenues by 3.9% over a 5-year period.

Duration of Remedial Activities

The duration of Alternative 2B/Cem is the same as Alternative 2B/Vit.

4.3.3.6 Implementability

Technical Feasibility

The technical implementability, construction, and operation of the removal component of Alternative 2B/Cem would be straightforward and, except for the treatment component, would be the same as Alternative 2B/Vit (Section 4.3.2.6).

The cement stabilization facility would be reliable and straightforward to construct and operate. All of the necessary equipment would be readily available because the process is widely used in the construction and mining industries. It is also used frequently in hazardous material treatment applications. The treatment system would consist of a standard configuration of industrial equipment. The cement stabilization facility would require a supervisor and general laborers with industrial work experience, as well as maintenance personnel. After remedial design testing has further defined and optimized the reagent to cold metal oxide blend, the plant supervisor would be able to respond to operational problems that could arise during processing. Continual testing of treatment batches during operation would determine required modifications to the standard blend to optimize product and immobilization of contaminants.

A significant temperature rise was noted during the treatability testing for the Silo 3 contents. This heat rise needs to be better controlled for Silo 3 stabilization. Optimization of reagent addition over time or use of an inert reagent that could act as a heat sink should be investigated, although this could increase the bulking factor for the treated material.

The benefits of cement stabilization technology are the moderate processing costs, the compatibility with a wide variety of disposal options, and the ability to meet stringent processing and performance requirements. The associated increase in volume caused by adding dry materials could be minimized through encapsulation of the solids and evaporation of the associated water. However, water evaporation increases the complexity and cost of the treatment.

Administrative Feasibility

The administrative feasibility of Alternative 2B/Cem would be the same as 2B/Vit.

Availability of Services and Materials

Alternative 2B/Cem would involve the same activities as Alternative 2B/Vit, with the exception of cement stabilization being utilized in place of vitrification. Because cement stabilization is a commonly used technology, the availability of vendors to provide service and materials would be adequate.

4.3.3.7 Cost

The total present worth cost of Alternative 2B/Cem is $37.4M. A detailed breakdown of the cost is provided in Table 4-7.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and pneumatic removal/transfer system for transfer of the residues, purchase of cement stabilization equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-7. More detailed information is provided in Appendix E.

The largest component of the capital cost is the construction of the pneumatic removal/transfer system which represents approximately 35 percent of the total capital cost. The disposal vault and packaging are the next largest components of the costs, each representing approximately 20 percent of the total

TABLE 4–7

COST ESTIMATE FOR ALTERNATIVE 2B/CEM

ALTERNATIVE 2B: REMOVAL, CEMENT STABILIZATION, ON–PROPERTY DISPOSAL			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
SITE PREPARATION	$579,500	$528,700	$1,108,200
WASTE PROCESSING	$915,300	$971,000	$1,886,300
CEMENT STABILIZATION	$2,253,700	$2,473,400	$4,727,100
PNEUMATIC REMOVAL/TRANSFER SYSTEM	$4,571,600	$4,744,400	$9,316,000
DISPOSAL VAULT	$1,925,800	$3,279,100	$5,204,900
PACKAGING (4,957 PKGS. @ $955/PKG.)	$1,308,600	$3,425,300	$4,733,900
TOTAL CAPITAL	$11,554,500	$15,421,900	$26,976,400
RISK BUDGET (11.0%)	$1,271,000	$1,696,400	$2,967,400
SUBTOTAL	$12,825,500	$17,118,300	$29,943,800
CONTINGENCY (20.0%)	$2,565,100	$3,423,700	$5,988,800
TOTAL ESTIMATED INSTALLED COST	$15,390,600	$20,542,000	$35,932,600
OPERATION AND MAINTENANCE (O&M) COSTS			
DURING CONSTRUCTION			$4,923,000
POST–REMEDIATION			$3,207,000
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$37,358,600

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during construction (years): 1
Post–remediation O&M (years): 30

capital cost.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads and equipment staging areas. The basis of estimate is the same as that discussed for Alternative 2B/Vit.

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the radon treatment system. Costs were estimated based on the same assumptions as for Alternative 2B/Vit.

Cement Stabilization

This cost item includes the cost of the cement stabilization equipment and was based on the following:

- The cement stabilization equipment would operate 24 hours/day and would be designed to treat of 11,800 kg/day (13 tons/day) of material.
- Cement stabilization equipment includes a surge tank, screw feeder, stabilization mixers, flyash, cement, and blast furnace slag storage/feed facilities, process piping, pumps, and mixers.

Pneumatic Removal/Transfer System

System components and cost are the same as for Alternative 2B/Vit.

Disposal Vault

Assumptions used to estimate the disposal vault cost are the same as those described for Alternative 2B/Vit, except for the following:

- The size of the disposal vault was based on the number of packages noted below, assuming each package occupies 2 m^3 (64 ft^3) of space, and was estimated as 8984 m^3 (317,248 ft^3.) Assuming a cell size of 3400 m^3 (120,000 ft^3), three cells would be required [2090 m^2 (22,500 ft^2) vault footprint area].

- The unit cost estimate is based on a conceptual design for a vault consisting of individual modular cells, each capable of holding 3400 m^3 (120,000 ft^3) of material. As additional disposal volume space is required, additional modular cells are added for cost estimating purposes. Cell numbers were estimated by rounding up to the nearest whole number.

- The vault would cover approximately 3 ha (7.5 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation, and was estimated as described for Alternative 2B/Vit, with the following differences:

- Total volume that would be packaged was based on 3895 m^3 (5,093 yd^3) of untreated Silo 3 material. Final packaging volume, assuming a 55 percent volume increase due to the cement stabilization process, was 5999 m^3 (7,894 yd^3).

- Total packaging cost was estimated assuming 4,957 containers.

O&M Cost

Short-term O&M costs incurred during remediation and long-term O&M costs are $4.9M and $3.2M, respectively, not considering present worth. Long-term O&M costs include maintenance and monitoring until all FEMP site-wide remedial action objectives are attained, i.e., in an estimated 30 years the monitoring would support the required CERCLA five-year reviews.

4.3.4 Analysis of Alternative 3B.1/Vitrification

This alternative is identical to Alternative 2B/Vit except that the final disposal location of the stabilized cold metal oxide forms will be at the Low-Level Radioactive Disposal Facility at NTS. The site preparation, construction, cold metal oxide removal, and processing will be the same as for Alternative 2B/Vit.

The off-site disposal option for this alternative involves the packaging, loading, and shipping of the stabilized cold metal oxide forms to the LLRW disposal site at NTS. A possible route for transport of the stabilized forms to NTS will involve rail transportation from the FEMP site through East St. Louis on the CSX rail line. From St. Louis, the stabilized forms will be transported on the UP rail line through North Platte, Nebraska and Salt Lake City, Utah. Currently there is no direct rail line to NTS disposal site. At present, the stabilized forms will be transported by UP to either a point near Las Vegas, Nevada or an area north of Las Vegas. From either location, the containers carrying the

stabilized forms will be transferred to trucks and transported by road to NTS. If a direct rail to NTS becomes available before this alternative is implemented, it should be used in lieu of trucking. Treated waste may be staged or placed into interim storage at the FEMP site as required to accommodate interruptions in the availability of transportation or disposal capacity.

4.3.4.1 Overall Protection of Human Health and the Environment

Alternative 3B.1/Vit meets the remedial action objectives for Subunit B. As with Alternative 2B/Vit, Alternative 3B.1/Vit prevents direct contact with waste material and mitigates the migration of contaminants to the air, soil, and groundwater. This is accomplished with two components, treatment and off-site disposal.

Similar to Alternative 2B/Vit, treatment of the Subunit B materials through vitrification would reduce contaminant toxicity, mobility, and volume. Much like Alternative 2B/Vit, the treatment of the material prior to disposal would provide additional protection in the event the off-site disposal facility were to degrade. The added benefit of treatment for Subunit B is less than for Subunit A because the material has been calcined before and the leachability from the material is less.

The removal of the contaminants and their disposal off site provides the final element of protectiveness for Alternative 3B.1/Vit. The off-site disposal facility will provide protection by eliminating access to the waste and preventing migration of contaminants out of the waste much as the on-site disposal facility would under Alternative 2B/Vit. The NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant release, migration, and direct contact with contaminants. The long-term effectiveness of the necessary institutional controls at the NTS disposal facility is believed to be very reliable.

Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. Further, the climatic (low average annual precipitation) and hydrologic (depths to groundwater ranging from 157 - 600 m [515 - 2000 ft] below ground surface) characteristics would tend to mitigate impacts to human health and the environment in the event that engineering and institutional controls fail.

There are no unacceptable short-term risks from Alternative 3B.1/Vit for which removal and treatment options pose the same risks as Alternative 2B/Vit. Additional risk is associated with

transportation accidents. Radiation exposure to workers and the public as a result of the transportation is expected to be minimal.

4.3.4.2 Compliance with ARARs

Issues related to ARAR compliance for Alternative 3B.1/Vit are similar to Alternative 2B/Vit with the exception of the Subunit B treated wastes, final disposition being at a DOE-owned off-site facility. Alternative 3B.1/Vit meets all ARARs. Because Alternative 3B.1/Vit involves off-site disposal of the treated waste, the disposal facility siting criteria and disposal requirements no longer be applicable nor relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3B.1/Vit focus on waste management and treatment and are similar to the ARARs for Alternative 2B/Vit (see Table F-3 in Appendix F). Consequently, the discussion of the compliance of those common ARARs would be identical to that presented in Section 4.3.2.2. Additional documentation of compliance of Alternative 3B.1/Vit with the identified ARARs is presented in Appendix F (Table F-3). The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 3B.1/Vit would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those requirements associated with the protection of Ohio water quality standards, the control of radon-222 airborne releases, the control of other radionuclide releases to air and water, and their resulting doses to the public.

Location-Specific ARAR/TBCs

Alternative 3B.1/Vit would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands and endangered species during the on-site treatment of the material. As noted above, the State of Ohio disposal facility siting criteria and disposal requirements would no longer be applicable nor relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARAR/TBCs

Alternative 3B.1/Vit would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.3). Included would be those standards associated with on-site requirements under the Clean Air Act, Clean Water Act, and RCRA. These requirements will be met by incorporating sound engineering features and best management practices into the remediation operations of the unit. Off-site disposal will require shipment of materials. Hazardous waste transport requirements will be

complied with by following the regulations under 40 CFR 262 and the appropriate DOT shipping standards under 49 CFR 172 and 173.

4.3.4.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 3B.1/Vit would reduce the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6}. Because all of the material is removed from the site, there is no residual risk at the FEMP site. Residual risk at NTS is limited by the facility institutional controls, the characteristics of the vitrified materials, and the arid climate.

Adequacy and Reliability of Controls

The reliability of vitrification for Alternative 3B.1/Vit is the same as for Alternative 2B/Vit (Section 4.3.2.3). Off-site disposal at NTS has enhanced reliability because the facility is currently utilized by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be reliable at NTS. Additionally, if there is a release at NTS, the climate, hydrologic conditions, and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density would also reduce the potential for direct contact in the advent of disposal facility failure.

Long-Term Environmental Impacts

The long-term environmental impacts of removal and treatment actions of Alternative 3B.1/Vit are the same as for Alternative 2B/Vit (Section 4.3.2.3). Long-term environmental impacts associated with off-site disposal of the treated material at NTS are the same as those presented for Alternative 3A.1/Vit in Section 4.2.4.3.

4.3.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reduction in constituent toxicity, mobility, or volume would be the same for Alternative 3B.1/Vit as for Alternative 2B/Vit based on application of the same treatment technology (Section 4.3.2.4).

4.3.4.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Alternative 3B.1/Vit provides the same level of short-term protection of the community during removal and treatment as does Alternative 2B/Vit (Section 4.3.2.5). There is added risk to the public through transporting the treated material off site. The estimate of public radiation exposure,

expressed in terms of ICLR, along the route to NTS is 1.7×10^{-11}, far below the target risk range of 1×10^{-4} to 1×10^{-6}. It is estimated that 0.08 injuries and 0.02 deaths may occur due to transportation accidents. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 3B.1/Vit is effective in protecting the community in the short term. The basis for these estimates is provided in Appendix D.

The disposal of FEMP materials at NTS would not be expected to exceed protective levels for the community around NTS over the short term. The vitrified materials would meet NTS waste acceptance criteria and, therefore, would be managed within the bounds of the NTS facility's protectiveness criteria.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers during removal and treatment are the same for Alternatives 3B.1/Vit as for 2B/Vit. There are additional radiation exposure risks to the worker resulting from transporting the material to NTS. The excess ICLR is estimated at 1.9×10^{-7}, below EPA's target risk level of 10^{-6}. The estimate of injuries during remediation activities is 1.3 injuries and deaths is 0.019 respectively.

The risk to workers due to radiological exposures during off-loading activities at NTS is conservatively assumed to be similar to the estimated ILCR risk level of 4.1×10^{-5} during treatment/construction activities at the FEMP site. There is uncertainty for some additional risk due to exposure to wastes already present at NTS in the vicinity of off-loading operations for FEMP materials.

Short-Term Environmental Impacts

The short-term environmental impacts at the FEMP site for removal and treatment of materials under Alternative 3B.1/Vit are the same as those for Alternative 2B/Vit (Section 4.3.2.5). The total area disturbed at the FEMP site for Alternative 3B.1/Vit is 1.2 ha (3.0 acres). Alternative 3B.1/Vit involves off-site disposal of the treated waste form at NTS. Short-term environmental impacts for that facility would be the same as for Alternative 3A.1/Vit. Reference is made to Section 4.2.4.5 for a discussion of these impacts.

Duration of Remedial Activities

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The duration of remedial activities is assumed to be the same as for Alternative 2B/Vit. There is more uncertainty in the time estimate since transportation or waste acceptance problems could easily add time to the estimate.

4.3.4.6 Implementability

Technical Feasibility

The technical feasibility of Alternative 3B.1/Vit, with the exception of the disposal activities, is the same as that of Alternative 2B/Vit (Section 4.3.2.6). The technical feasibility of off-site transport and disposal at NTS is straightforward and reliable. Off-site transport of the treated material to NTS would consist of rail transport from the FEMP site to within 483 km (300 mi) of NTS. Currently, NTS is not accessible by rail; therefore, the treated material would be transferred to trucks and transported to NTS. The treated material would be placed in appropriate containers that meet transportation and disposal requirements.

Administrative Feasibility

NTS is a DOE-owned facility; thus, no special permits would be required. However, an addendum to the current FEMP site's waste shipping application would be required for this new waste stream. This alternative would require agency approvals and coordination for the interstate shipment of the material. Many states require advance notification and permitting for shipments of radioactive material entering their state. All material shipments would be required to meet applicable federal and state regulations. The public and regulatory agencies from the states located within the transportation route from FEMP to NTS would likely oppose transport; thus, some coordination would be required to obtain these approvals.

Availability of Services and Materials

With the exception of the disposal components, the availability of services and materials for Alternative 3B.1/Vit are similar to those of Alternative 2B/Vit. NTS currently accepts LLW and it has adequate facilities to accept the Alternative 3B.1/Vit treated material. Transfer areas, storage areas, decontamination facilities, and a laboratory are available on the site. The treated material would be tested to ensure that it complies with NTS waste acceptance criteria.

4.3.4.7 Cost

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The total present worth cost of Alternative 3B.1/Vit is $26.7M. A detailed breakdown of the cost is provided in Table 4-8.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and pneumatic removal/transfer system for transfer of the residues, purchase of vitrification equipment, packaging of material for disposal, transportation, and disposal. Breakdown of the direct and indirect costs for each major component of this alternative are provided in Table 4-8. More detailed information is provided in Appendix E.

This alternative includes identical cost components as Alternative 2B/Vit (Section 4.3.2.7), except off-site transportation and disposal replace the on-property vault component that was included in Alternative 2B/Vit. As with Alternative 2B/Vit, the largest component of the capital cost is the construction of the pneumatic removal/transfer system, representing approximately 50 percent of the total capital costs.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

Site preparation includes clearing and grubbing vegetated areas required for the material processing area, the packaging pad for the removed berm material, the material slurry transfer trench, utilities, and the roads and equipment staging areas. The basis of estimate is the same as that discussed for Alternative 2B/Vit.

Waste Processing

Components of the 3B.1/Vit waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the radon treatment system. Costs were estimated based on the same assumptions as for Alternative 2B/Vit.

Vitrification

This cost item includes the cost of the 3B.1/Vit vitrification equipment, radon treatment system, and off-gas system, and is estimated based on the same assumptions discussed for Alternative 2B/Vit.

TABLE 4–8

COST ESTIMATE FOR ALTERNATIVE 3B.1/VIT

ALTERNATIVE 3B.1: REMOVAL, STABILIZATION W/VITRIFICATION, OFF–SITE DISPOSAL AT NTS			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
SITE PREPARATION	$579,500	$528,700	$1,108,200
WASTE PROCESSING	$915,300	$971,000	$1,886,300
VITRIFICATION	$2,593,400	$1,460,700	$4,054,100
PNEUMATIC REMOVAL/TRANSFER SYSTEM	$4,571,600	$4,744,400	$9,316,000
TRANSPORTATION	$646,900		$646,900
DISPOSAL	$692,300		$692,300
PACKAGING (1,282 PKGS. @ $955/PKG.)	$338,400	$885,900	$1,224,300
TOTAL CAPITAL	$10,337,400	$8,590,700	$18,928,100
RISK BUDGET (11.0%)	$1,137,100	$945,000	$2,082,100
SUBTOTAL	$11,474,500	$9,535,700	$21,010,200
CONTINGENCY (20.0%)	$2,294,900	$1,907,100	$4,202,000
TOTAL ESTIMATED INSTALLED COST	$13,769,400	$11,442,800	$25,212,200
OPERATION AND MAINTENANCE (O&M) COSTS			
DURING CONSTRUCTION			$4,923,000
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$26,655,300

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during construction (years): 1
Post–remediation O&M (years): 0

Pneumatic Removal/Transfer System

The 3B.1/Vit pneumatic removal/transfer system components and cost are the same as for Alternative 2B/Vit.

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2B/Vit. The same number of containers required for Alternative 2B/Vit are required for Alternative 3B.1/Vit.

Transportation

This cost item includes transportation of the packaged material, and is based on the following assumptions:

- Packages would be transported by rail to within 483 km (300 mi) of the disposal facility (NTS) and then transported by truck the remainder of the distance.
- Rail costs were estimated using a unit rate of $2.47 per railcar per km ($3.97 per railcar per mile). Railcars were assumed to weigh 8165 kg (180,000 lbs) each.
- Truck costs were estimated using a unit rate of $0.53/kg ($0.24 per pound) [for the total 483 km (300 mi) trip].

Disposal

- Treated material would be disposed at NTS.
- Unit disposal cost was estimated as $353 m^3 ($10/ft^3).

O&M Cost

Short-term O&M costs incurred during remediation are the same as for Alternative 2B/Vit ($4.9M, not considering present worth). There are no long-term O&M costs associated with this alternative because no material would remain at Subunit B.

4.3.5 Analysis of Alternative 3B.1/Cementation

This alternative is identical to Alternative 2B/Cem except that the final disposal location of the stabilized cold metal oxide material would be the Low-Level Radioactive Disposal Facility at NTS. The site preparation, construction, material removal, and processing would be the same as for Alternative 2B/Cem (Section 4.3.3).

Off-Site Disposal

The route and method of transportation for this alternative will be the same as for Alternative 3B.1/Vit (Section 4.3.4).

4.3.5.1 Overall Protection of Human Health and the Environment

Alternative 3B.1/Cem meets the remedial action objectives for Subunit B. As with Alternative 3B.1/Vit, Alternative 3B.1/Cem prevents direct access to waste material and mitigates the migration of contaminants to the air, soil, and groundwater. This is accomplished with two components, treatment and off-site disposal.

Treatment of the Subunit B materials through cement stabilization would reduce contaminant mobility. Cement stabilization would increase the volume of contaminated material due to additives used in the stabilization process. Treatment of the material prior to disposal would provide additional protection in the event the off-site disposal facility were to degrade.

The removal of the contaminants and their off-site disposal provides the final element of protection for Alternative 3B.1/Cem and is the same disposal option as Alternative 3B.1/Vit. The off-site disposal facility would provide protection by eliminating access to the waste and preventing migration of contaminants from the waste. As previously discussed in Section 4.2.4.1, the uncertainties associated with institutional controls at this DOE facility are very low. The NTS environmental and demographic characteristics help to ensure long-term protectiveness in the event of institutional control failure. There are no unacceptable short-term risks from Alternative 3B.1/Cem.

4.3.5.2 Compliance with ARARs

Issues related to ARAR compliance for Alternative 3B.1/Cem are similar to Alternative 2B/Cem with the exception of the Subunit B treated wastes, final disposition being at a DOE-owned off-site facility. Alternative 3B.1/Cem meets all ARARs. Because Alternative 3B.1/Cem involves off-site disposal of the treated waste, the disposal facility siting criteria and disposal requirements would no longer be applicable nor relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3B.1/Cem focus on waste management and treatment and are similar to the ARARs for Alternative 2B/Cem (see Table F-3 in Appendix F). Consequently, the discussion of compliance for those common ARARs would be identical to that presented in Section 4.3.2.2. The applicable findings of that discussion are summarized below. Additional documentation of compliance of Alternative 3B.1/Cem with the identified ARARs is presented in Appendix F (Table F-3).

Chemical-Specific ARAR/TBCs

Alternative 3B.1/Cem would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those requirements associated with the Ohio water quality standards, the control of radon-222 airborne releases, and the control of other radionuclide releases to air and water, and their resulting doses to the public during remedial operations at the FEMP site. Appendix D contains the description and results of the analyses supporting these assertions for Alternative 3B.1/Cem.

Location-Specific ARAR/TBCs

Alternative 3B.1/Cem would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands, and endangered species during the on-site treatment of the material. As noted above, disposal facility siting criteria and disposal requirements no longer be applicable nor relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARAR/TBCs

Alternative 3B.1/Cem would comply with all pertinent action-specific ARARs identified in Appendix F Table F-1.1). Included would be those standards associated with on-site requirements under the Clean Air Act, Clean Water Act, and RCRA for the management and treatment of hazardous waste. These requirements will be met by incorporating sound engineering features and best management practices into the remediation operations of the unit. Off-site disposal will require shipment of materials. Hazardous waste transport requirements will be complied with by following the regulations under 40 CFR 262 and the appropriate DOT shipping requirements under 49 CFR 172 and 173.

4.3.5.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The implementation of Alternative 3B.1/Cem would reduce the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than $1x10^{-6}$. Because all of the material is removed from the site, there is no residual risk from Subunit B residues at the FEMP site. Residual risk at NTS is limited by the disposal facility institutional controls, the characteristics of the cement stabilized materials, and the arid environment.

Adequacy and Reliability of Controls

The reliability of cement stabilization for Alternative 3B.1/Cem is the same as for Alternative 2B/Cem (Section 4.3.3.3). Off-site disposal at NTS has enhanced reliability because the facility is currently owned and used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be more reliable at NTS. Additionally, if there is a release at NTS, the climate, hydrologic, and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density of the area surrounding NTS would also reduce the potential for direct contact with released materials.

Long-Term Environmental Impacts

The long-term environmental impacts to the FEMP site and surrounding area of removal and treatment actions of Alternative 3B.1/Cem are the same as for Alternative 2B/Cem (Section 4.3.2.3). Impacts to NTS are the same as for Alternative 3B.1/Vit, except that the volume of cement-stabilized material would require additional disposal space. The overall impact of the increased volume is not significant.

4.3.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Reduction in constituent toxicity, mobility, or volume would be the same for Alternative 3B.1/Cem as for Alternative 2B/Cem.

4.3.5.5 Short-Term Effectiveness

Protection of the Community During Remedial Actions

Protection of the community during removal and treatment operations is estimated to be the same for Alternative 3B.1/Cem as for Alternative 2B/Vit (Section 4.3.2.5). The potential injury and deaths due to treated material transportation is 0.33 injuries and 0.08 deaths for this alternative. Estimates of excess cancer risk to the community from transporting the material are 1.9×10^{-11}.

Protection of Workers During Remedial Actions

Protection of workers during implementation of Alternative 3B.1/Cem is the same as Alternative 3B.1/Vit (Section 4.3.4.5). Both alternatives protect workers during remediation by using personal protective equipment, remote operating-procedures, and shielding.

Short-Term Environmental Impacts

The short-term impacts associated with Alternative 3B.1/Cem are essentially the same as those found with Alternative 3B.1/Vit (Section 4.3.4.2). Eighty workers and approximately 20 trucks, making 30 one-way trips per working day, would be required to complete remedial activities. It is assumed for this analysis that all resources needed for Alternative 3B.1/Cem would be purchased within the area in which case the collective revenue for the CMSA would increase by 3.4 percent over a five-year period. Minor impacts are expected as a result of remedial activities associated with Alternative 3B.1/Cem.

Duration of Remedial Activities

The removal and treatment components of Alternative 3B.1/Cem would require the same amount of time for implementation as the other action alternatives, 4 years. As with Alternative 3B.1/Vit, there is a chance for the schedule to be delayed as a result of transportation or disposal delays.

4.3.5.6 Implementability

The implementability for removal and treatment components of Alternative 3B.1/Cem would be the same as that of Alternative 2B/Cem (Section 4.3.3.6). The implementability of disposal for Alternative 3B.1/Cem is the same as that of Alternative 3B.1/Vit (Section 4.3.4.6).

4.3.5.7 Cost

The total present worth cost of Alternative 3B.1/Cem is $34.2M. A detailed breakdown of the cost is provided in Table 4-9.

Capital Cost

The capital cost is associated with site preparation, construction of the waste processing facility and hydraulic removal/transfer system for transfer of the residues, purchase of cement stabilization equipment, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-9. More detailed information is provided in Appendix E.

The alternative includes identical cost components as Alternative 2B/Cem (Section 4.3.3.7), except off-site transportation and disposal replace the on-property vault that was included in Alternative 2B/Cem. As with Alternative 2B/Cem, the largest component of the capital cost is the construction of the pneumatic removal/transfer system, representing approximately 36 percent of the total capital costs.

TABLE 4–9

COST ESTIMATE FOR ALTERNATIVE 3B.1/CEM

ALTERNATIVE 3B.1: REMOVAL, CEMENT STABILIZATION, OFF–SITE DISPOSAL AT NTS			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
SITE PREPARATION	$579,500	$528,700	$1,108,200
WASTE PROCESSING	$915,300	$971,000	$1,886,300
CEMENT STABILIZATION	$2,253,700	$2,473,400	$4,727,100
PNEUMATIC REMOVAL/TRANSFER SYSTEM	$4,571,600	$4,744,400	$9,316,000
TRANSPORTATION	$1,625,600		$1,625,600
DISPOSAL	$2,676,800		$2,676,800
PACKAGING (4,957 PKGS. @ $955/PKG.)	$1,308,600	$3,425,300	$4,733,900
TOTAL CAPITAL	$13,931,100	$12,142,800	$26,073,900
RISK BUDGET (11.0%)	$1,532,400	$1,335,700	$2,868,100
SUBTOTAL	$15,463,500	$13,478,500	$28,942,000
CONTINGENCY (20.0%)	$3,092,700	$2,695,700	$5,788,400
TOTAL ESTIMATED INSTALLED COST	$18,556,200	$16,174,200	$34,730,400
OPERATION AND MAINTENANCE (O&M) COSTS			
DURING CONSTRUCTION			$4,056,000
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$34,169,900

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 3
O&M during construction (years): 1
Post–remediation O&M (years): 0

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Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Site Preparation

The basis of estimate is the same as that discussed for Alternative 2B/Vit (Section 4.3.2.7).

Waste Processing

Components of the waste processing cost include construction of the waste processing facility, the process area general ventilation system, and the radon treatment system. Costs were estimated based on the same assumptions as for Alternative 2B/Vit (Section 4.3.2.7).

Cement Stabilization

This cost item includes the cost of the cement stabilization equipment and was based on the same assumptions provided for Alternative 2B/Cem (Section 4.3.3.7).

Pneumatic Removal/Transfer System

System components and cost are the same as for Alternative 2B/Vit (Section 4.3.2.7).

Packaging

Assumptions used to estimate packaging cost are the same as those described for Alternative 2B/Cem (Section 4.3.3.7).

Transportation

This cost item includes transportation of the packaged material, and has the same basis of estimate as Alternative 3B.1/Vit (Section 4.3.4.7), but was adjusted for the greater quantity of containers of cement-stabilized material.

Disposal

This cost is estimated as described for Alternative 3B.1/Vit (Section 4.3.4.7).

O&M Cost

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Short-term O&M costs incurred during remediation are $4M (not considering present worth). There are no long-term O&M costs associated with this alternative because no material would remain at Subunit B.

4.4 SUBUNIT C

4.4.1 Analysis of Alternative 0C - No Action

The no-action alternative is retained throughout the FS process as required by the NCP (40 CFR 300.430[e][6]). This alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, no remedial action would be taken. In the no-action alternative, the materials are considered to be left "as is", without the implementation of any containment, removal, treatment, or other mitigating actions. All existing equipment, soils, and structures included in Subunit C would remain in place. Alternative 0C does not provide for the monitoring of soil, groundwater, or radon emissions, and Alternative 0C does not provide for active or passive institutional controls to reduce the potential for exposure (e.g., physical barriers, deed restrictions).

4.4.1.1 Overall Protection of Human Health and the Environment

Alternative 0C does not meet the remedial action objectives for Subunit C and therefore is not protective of human health and the environment. The no-action alternative does not contain, remove, or treat the sources of contamination. In the absence of remedial action, risks to on-site workers would exceed the EPA target range of 10^{-4} to 10^{-6}. The Baseline Risk Assessment calculated a value exceeding the 10^{-4} excess cancer risk for a viable receptor (groundskeeper). Under the no-action alternative, Silos 1, 2, and 3 would be expected to deteriorate to the point of collapse, resulting in additional release of constituents of concern to the air, soil, surface water, and groundwater pathways.

In the event institutional controls were lost, an on-site residence could be established. The on-site resident would be exposed to unacceptable levels of contamination through ingestion of food grown in the Operable Unit 4 soil and direct radiation.

Erosion of contaminated soil into Paddys Run or leaching to groundwater with subsequent migration to Paddys Run would threaten environmental receptors such as aquatic biota. In addition to radiological and chemical risks, physical hazards associated with the abandoned silos would remain to threaten the safety of both a resident and a recreational user.

4.4.1.2 Compliance with ARARs

Alternative 0C would not comply with all pertinent chemical-specific ARARs. Contaminated material would be left exposed to the environment, available for immediate transport via the air, groundwater, surface water (due to storm water runoff), and residual soil pathways. Fate and transport modeling indicates that the safe drinking water limits (MCLs in 40 CFR 141) would be exceeded for uranium and gross beta radiation. In addition, localized "hot spots" would exceed residual soil limits (40 CFR 192.12).

Detailed documentation of compliance with ARARs for Alternative 0C is presented in Appendix F.

4.4.1.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Alternative 0C would not be effective because this alternative does not protect against exposure to contaminated soils or the silos. Erosion of the soils would contaminate Paddys Run. Leaching of contaminants from the soil into the groundwater would continue to contaminate the groundwater. This alternative provides no protection against silo failure and the associated physical dangers.

Risks to the general public that may occur if no action is taken is presented in Appendix D of this FS. Risks from exposure to soil only (assumes silo material removed or contained) for a trespassing child and a groundskeeper are fairly low (ICLR of 10^{-5}). However, risks to an on-site farmer from the soils in the event institutional controls are lost are an ILCR of 7×10^{-2} and an HI of 10 (70 for the child). The no-action alternative does not control these risks. The no-action alternative also does not control risk to humans and terrestrial biota from the silo physical dangers.

Because this alternative leaves Subunit C hazardous substances on site, a five year review would have to be conducted to ensure that the no-action remedy provides adequate protection of human health and the environment.

Adequacy and Reliability of Controls

The no-action alternative is not protective under future, unrestricted release conditions. There are no controls over this future risk and as a result, the alternative is not adequate.

Long-Term Environmental Impacts

Alternative 0C would not be protective of human health and the environment in the long-term because it does not protect against the exposure to contaminated surface soil and the runoff to surface waters. Runoff of contaminated soil could lead to increased contamination levels in the perched groundwater zone, surface water and sediment in Paddys Run, and the 0.36 ha (0.76 acre) wetland south of Silos 1 and 2. In addition, the potential for contaminated particulates from the soil to become resuspended in the air exists. For the long-term risks associated with Alternative 0C, refer to Section 4.4.2.3, "Magnitude of Residual Risk."

4.4.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment is not involved in Alternative 0C; therefore, no reduction in toxicity, mobility, or volume would occur.

4.4.1.5 Short-Term Effectiveness

This evaluation criteria addresses the effects of the alternative during the construction and implementation of the remedial action. Under the Alternative 0C, no remedial action will be taken; therefore, there will be no increase in short-term risks.

4.4.1.6 Implementability

Technical Feasibility

Since no remedial action would be taken, there would not be any difficulties or uncertainties associated with construction. The no-action alternative is included in the detailed analysis of alternatives for a baseline comparison.

Administrative Feasibility

No permits or licenses would be required to implement this alternative, so administrative feasibility would not be an issue.

Availability of Services and Materials

For Alternative 0C, there would not be any services or materials required.

4.4.1.7 Cost

There are no costs associated with Alternative 0C-No Action.

4.4.2 Analysis of Alternative 2C

This alternative involves the decontamination, if required, and demolition of Silos 1, 2, 3, and 4. The contaminated material generated in this alternative includes concrete rubble, the existing RTS of Silos 1 and 2, surface and subsurface soils, the decant sump tank, process piping, and the process piping trenches. The concrete slab of the drum Handling Building and concrete foundation of the sump lift station would also be removed. Additionally, contaminated rubble and debris generated consequential to the implementation of remedial actions for Subunits A and B would be dispositioned under this alternative. This rubble and debris includes demolition debris from Subunit A and B treatment process.

It should be recognized that the volume of contaminated soils and rubble being addressed under Subunit C is less than 1 percent of the volumes of similar contaminated materials anticipated to be handled on a sitewide basis under the five FEMP operable units. To ensure the proper integration of sitewide cleanup activities and the expenditure of available resources, interim storage of Operable Unit 4 generated contaminated rubble and debris may be necessary for a period of time. Interim storage would be provided to enable full utilization of projected treatment systems (e.g., Operable Unit 5 soil washing) and to provide for consistency in waste management strategies. Interim storage facilities and practices would be consistent with approved removal action procedures, identified ARARs and other direction provided by EPA.

Removed concrete would be decontaminated to the extent practical for potential free release and disposal in a commercial landfill. Waste materials would be placed in an above-grade disposal vault located on property. Figure 4-12 depicts the proposed Alternative 2C site plan and Figure 4-7 depicts the proposed location for the on-property above-grade disposal vault.

Site Preparation

Site preparation activities would begin by preparing staging areas for the silo demolition equipment, vacuum scabbling machinery, and packaging of contaminated silo rubble, RTS, piping, and foundation. During the D&D of the silos, 4 ha (10 acres) would be cleared and grubbed for the above-grade disposal vault. A haul road approximately 0.5 km (0.8 mi) would be constructed between the Operable Unit 4 and the above-grade disposal vault.

Decontamination and Demolition of Silos 1, 2, 3, and 4

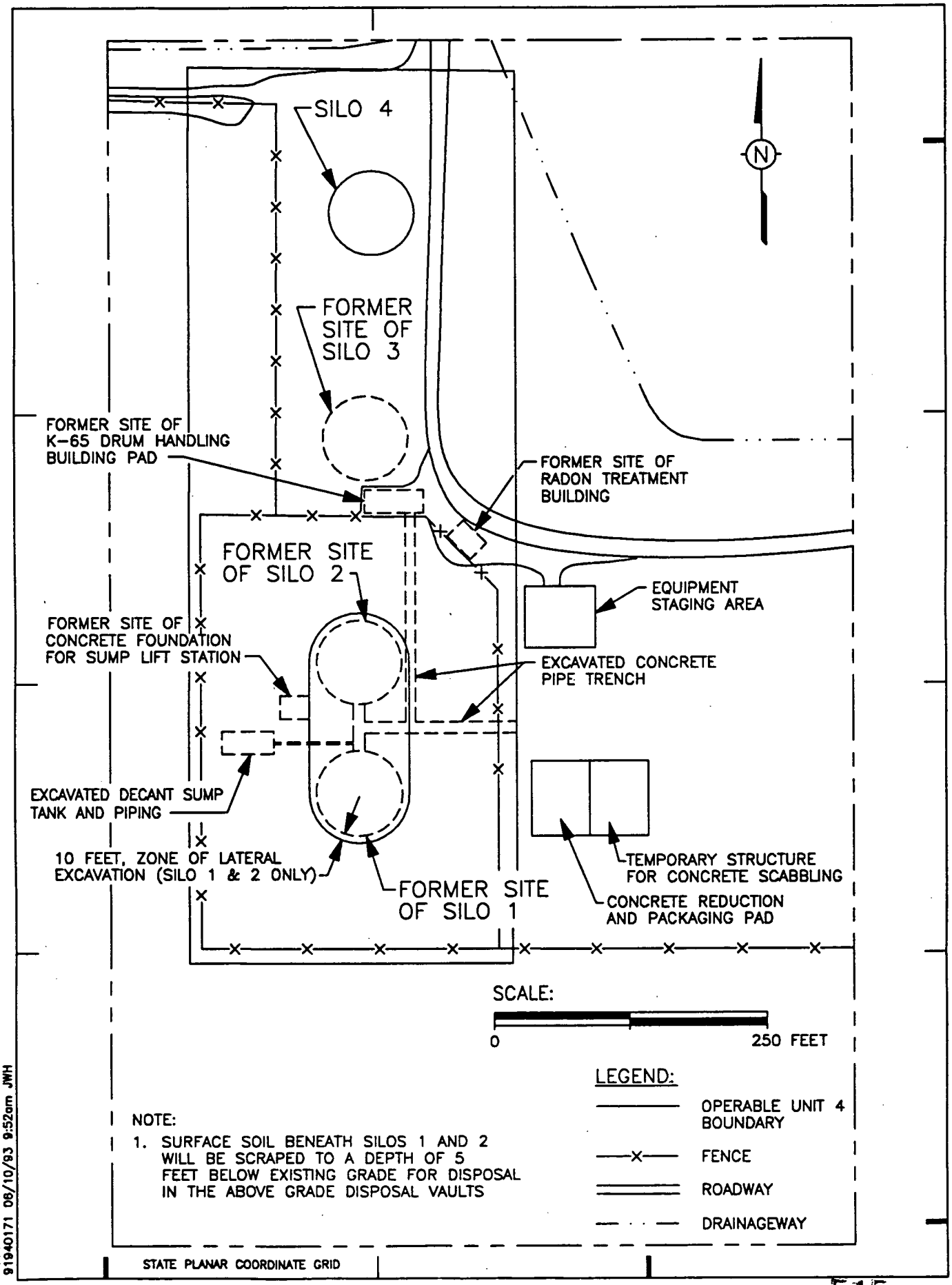

FIGURE 4-12 ALTERNATIVE 2C SITE PLAN

Before Silos 1, 2, and 3 are demolished, loose interior materials and loose concrete would be removed from the silo surfaces. The work platform used for the material removal will be used in this alternative to lower a robotic device, lighting, and video equipment into each silo interior. The robotic device would be equipped with a high-pressure water jet that is capable of moving vertically up the silo walls. A hydraulic pump would be used to remove the water and sediment produced from the pressure washing. The water would be sent to the FEMP AWWT facility for treatment, and the concrete sediment would be packaged with the contaminated concrete from the subsequent concrete scabbling operation. A hydraulic pump would be used to remove the water and sediment produced from the pressure washing. The water would be sent to FEMP AWWT facility for treatment, and the concrete sediment would be packaged with the contaminated concrete from the subsequent concrete scabbling operation. It is estimated to take 2 weeks for this activity.

On the basis of available smear data and process knowledge, Silo 4 is expected to exhibit no elevated concentration of COCs. Silo 4 is expected to be demolished and free released.

Silo demolition would consist of the systematic removal and dismantling of the Silo 1, 2, 3, and 4 domes, walls, floor slabs and footers. The dome removal will involve using a diamond wire rope saw to cut each dome into manageable pieces after appropriate bracing has been installed. Concentric cuts will be made around the circumference of the dome using the four existing manways to cut between. The initial section would be approximately 15 m (50 ft) in diameter. The remaining circular section of each dome would be divided into four equal quadrants.

The demolition would begin with Silo 4 as a testing facility to address any operational difficulties prior to movement to other silos. Following Silo 4, demolition would begin on the Silo 1 dome and then proceed to the Silo 2 dome. A crane would aid in the support of the dome sections during the cutting operation and would transport the sections to a concrete pad for size reduction with a diamond chain saw. While the Silo 2 dome is being dismantled, a second crane would be used to aid in the dismantling and transfer of the Silo 1 wall sections to the pad. A diamond chain saw would be used to cut the walls into sections. At the pad, the wall sections as well as the dome sections would be reduced to manageable sizes with diamond chain saws.

After the Silo 2 dome is removed, one of the two cranes would be transferred to begin the dismantling of the Silo 3 dome. Demolition of the Silos 1 and 2 walls would continue with the remaining crane. Silo 3 would be demolished in a similar fashion to that of Silos 1 and 2. The floor

slabs and footers of the silos would also be removed. This procedure would be performed by scoring the floor in a grid pattern with a masonry saw. A front-end loader would break up and transport the pieces to the concrete pad for further size reduction. The footer would be demolished by a backhoe-mounted pneumatic hammer and transported to the concrete pad by a front-end loader.

The existing RTS, Drum Handling Building pad, sump lift station foundation, concrete trench, decant sump tank, and other facilities would also be removed and decontaminated in a similar fashion.

An estimated 7 months would be required to complete the demolition of Silos 1, 2, 3, and 4 using the described equipment.

Vacuum Scabbling

After the sections of the silos have been cut into manageable sections by a diamond chain saw, the sections would be transferred by a forklift to a temporary structure. The structure would house three vacuum scabbling machines.

For the purposes of this alternative, it is assumed that the depth of interior surface contamination of Silos 1 and 2 is 2.5 cm (1 in) for the floor slab and walls and 0.63 cm (0.25 in) for the domes. For Silo 3, the depth of contamination for all interior surfaces is assumed to be 0.63 cm (0.25 in). The scabbling operation is a mechanical concrete removal process. The upper layers of the concrete could be pulverized by high speed, reciprocating pistons equipped with tungsten carbide cutting tips. The scabbling process is contained inside an evacuated shroud to provide control of airborne particulates and to allow personnel to work without the need for respiratory protection. It is estimated that each machine is capable of scabbling 74.3 to 92.9 m^2 (800 to 1000 ft^2) per 8-hour-day at 0.159 cm (0.06-in) depth. It is estimated that 15 weeks would be required to complete the process.

The scabbling machinery would be equipped with a vacuum system that is capable of packaging the contaminated concrete directly into DOT specification 7A Type A packaging. For the purpose of this alternative, it was estimated that approximately 40 percent of all the silo concrete material [606 m^3 (793 yd^3)] of contaminated concrete would be produced from the scabbling and decontamination operations. Concrete exhibiting highly elevated direct radiation fields would be dispositioned consistent with the selected alternative for Subunit A.

It is estimated that approximately 790 m (2600 ft) of process piping in the process piping trenches would be cut into manageable sections for packaging in DOT specification 7A Type A packaging. The piping would not be decontaminated before packaging. The majority of the piping, according to drawings provided by Catalytic Construction, is 7.6 cm (3 in) diameter carbon steel. A backhoe-mounted pneumatic hammer could be used to fracture the concrete piping trenches. The backhoe then could excavate the trench remnants and transfer them to the concrete pad used for silo demolition. The pieces could be further reduced in size if necessary to allow packaging in DOT specification 7A Type A packaging. It is estimated that 280 m^3 (365 yd^3) of concrete from the trenches, decant sump tank process piping, and existing radon treatment system would be disposed of in the above-grade disposal vault.

Contaminated Surface and Subsurface Soils

Characterization of soils completed as part of the RI Report for Operable Unit 4 identified elevated concentrations of COCs in soils within the berms, surface soils and subsurface soils within the unit. While data are limited, sufficient information is available to derive reasonable estimates of the quantities of contaminated soils requiring remedial action. Available data indicate elevated concentrations of radionuclides in berm soils adjacent to the walls of the silos. Data are not available on the berm soils not immediately adjacent to the silo walls.

Surface soil samples collected from the Operable Unit 4 area indicated elevated concentrations of uranium and other COCs in the upper 15 cm (6 in) of soils along access roads, around Silo 3, and adjacent to the slurry line. Similar concentrations are anticipated across the Operable Unit 4 area including soils at the original grade beneath the berms.

An investigation of the extent of subsurface soil contamination was conducted as part of the RI/FS through completion of slant borings and the collection of samples during well installation. These samples indicated isolated areas of elevated concentrations of uranium and other COCs. Additionally, on the basis of process knowledge and results from the recently completed hydropunching within Operable Unit 4, elevated concentrations of COCs are anticipated in soils directly underlying Silos 1 and 2 and the decant sump tank.

As part of this alternative, proposed soil remediation levels were developed for each of the COCs. The proposed levels were developed employing the information contained in Table 2-5 and the receptor specific Unit Risk and Toxicity Factors presented in Appendix D of the RI Report for

Operable Unit 4. Additionally, soil background values from Table 4-1 of the RI Report for Operable Unit 4 and soil sampling analytical results from Chapter 4.0 of the RI Report for Operable Unit 4 were employed to support the derivation of the proposed action levels. Tables 4-10 and 4-11 present the proposed soil cleanup levels for Operable Unit 4 in context with other pertinent information. It should be noted that the volume of soils potentially requiring removal as part of Subunit C are estimated to represent less than 1 percent of the total volume of soils anticipated to be addressed by remedial actions at the other four operable units. Proposed soil remediation levels will be developed for non-source related areas as part of the FS Report for Operable Unit 5. At the time of writing of this report, investigations were continuing within Operable Unit 5 to support the future derivation of these action levels for the FS Report for Operable Unit 5. These investigations include more detailed examinations of the flow and geochemical properties of the glacial till at the FEMP and the effectiveness of soil washing technologies at removing site contaminants. To ensure the proper integration of waste management strategies and activities across FEMP operable units, re-examination of the Operable Unit 4 remediation levels may be prudent in conjunction with the review and approval process for the FS Report for Operable Unit 5.

A future land use scenario considering continued federal ownership was adopted as the most likely and reasonable land use to support the derivation of proposed Operable Unit 4 soil remediation levels. This future land use assumes that the Federal government would retain perpetual ownership of the FEMP property and continue to exercise its right of ownership to preclude property development and intrusive activities such as drilling. This future land use assumes no continued active access controls or maintenance following the attainment of remedial action objectives on a sitewide basis. Under this scenario, the previously described recreational user was used as the key receptor for development of proposed soil remediation levels.

A rationale, including the following elements, was employed to identify the proposed soil action level. The results of applying this rationale to the Operable Unit 4 soil COCs previously identified in Table 2-5 are summarized in Tables 4-10 and 4-11. To facilitate field implementation of any soil cleanup activities, area based averaging concepts and "hot spot" methodologies employed for the cleanup of similar materials at uranium mill tailing sites under 40 CFR 192 would be adopted.

It is anticipated that to attain the referenced proposed remediation levels, a minimum 15 cm (6 in) of soils will be removed form the entire Operable Unit 4 area. Deeper excavations may also be required to remove identified "hot spots." Following excavation, the excavation areas will be backfilled with

TABLE 4-10

PROPOSED REMEDIATION LEVELS IN SOILS - RADIONUCLIDES

Constituent of Concern	Recreational User 10^{-6} ILCR PRG pCi/g	Background (95th percentile) pCi/g	ARAR Target pCi/g	Max. Detected Soil Concentration, pCi/g		Proposed Remediation Level above Background pCi/g	Risk to Receptors from Proposed Remediation Level	
				Surface	Subsurface		Recreational User	On-Property Farmer
Pb-210 +2 progeny	77	1.33	NA	4.5	101	5	$<1x10^{-6}$	$1x10^{-4}$ (a)
Ra-226 +5 progeny	0.37	1.45	5 (top 6" soil) 15 (max. below 6")	88	206	4	$1.1x10^{-5}$ (b)	$1x10^{-4}$ (c)
Ra-228 +1 progeny	0.77	1.19	NA	0.48	1.24	5	$2.0x10^{-6}$ (b)	$6.0x10^{-4}$ (c)
Sr-90 +1 progeny	1420	ND	NA	1.8	0.8	NA	$<1x10^{-6}$ (d)	$1x10^{-4}$ (d)
Tc-99	38700	ND	NA	3.6	3.6	NA	$<1x10^{-6}$ (b)	$2.0x10^{-4}$ (c)
Th-228	0.4	1.43	NA	2.9	1.3	5	$<1x10^{-6}$ (b)	$3x10^{-4}$ (c)
U-238 +2 progeny	60	1.22	NA	37	53	60	$1x10^{-6}$	$1x10^{-4}$ (c)

Notes:

(a) Includes all crop uptake pathways. The placement of six inches of clean fill precludes direct radiation, incidental ingestion, and dermal contact.

(b) Includes direct radiation pathway only. Other pathways precluded by the six inches of soil fill.

(c) Includes all crop uptake plus direct radiation. Incidental ingestion precluded by six inches of clean fill.

(d) Risks were calculated assuming uniform distribution of Sr-90 at maximum detected concentrations in the subsurface soils. The six inches of clean fill precludes direct radiation and incidental ingestion.

TABLE 4-11

PROPOSED REMEDIATION LEVELS IN SOILS - INORGANICS

Constituent of Concern	Recreational User HI = 0.2 PRG mg/kg	Recreational User 10^{-6} ILCR PRG mg/kg	Background (95th percentile) mg/kg	ARAR Target mg/kg	Max. Detected Soil Concentration, mg/kg		Proposed Remediation Level above Background mg/kg	HI to Receptors from Proposed Remediation Level		Risk to Receptors from Proposed Remediation Level	
					Surface	Sub surface		Recreational User	On-Property Farmer	Recreational User	On-Property Farmer
Antimony	1030		7.7	NA	32	32	7	<0.01	1.0		
Arsenic	770	16	8.45	NA	10	12	16			$1x10^{-6}$	$4x10^{-4}$
Barium	9120		91.3	NA	112	142	128	<0.01	1.0		
Cadmium	2560		0.82	NA	6	7	3.2	<0.01	1.0		
Chromium(III)	NA		15.5	NA	23	25	316	<0.01	1.0		
Molybdenum	>10000		2.6	NA	25	30	27	<0.01	1.0		
Nickel	NA		20.9	NA	39	39	166	<0.01	1.0		
Silver	2560		2.6	NA	10	18	4.8	<0.01	1.0		
Thallium	154		0.58	NA	0.5	0.5	2.0	<0.01	1.0		
Vanadium	>10000		30.4	NA	28	33	109	<0.01	0.2		
Zinc	>10000		62.2	NA	65	67	42	<0.01	1.0		

clean soils and seeded.

Rationale

First, the soil concentration representing the PRG for the 10^{-6} risk level for the recreational user from Table 2-5 was adopted as the proposed preliminary soil remediation level.

Second, pertinent ARARs were identified for the individual COC. If the ARAR concentration level for the COC was less than the value identified above, the ARAR level was adopted.

Third, if the proposed soil remediation level from the first two steps was less than 110 percent of the 95 percentile of the background soil data set, the proposed soil action level was considered indistinguishable from background. That is, any soil concentrations at or below background concentrations would be considered acceptable as a conclusion for remedial actions.

Fourth, the proposed soil remediation level was compared to the 95th percentile of the observed surface and subsurface soil concentrations, which includes the maximum detected values as reported in the RI Report for Operable Unit 4, including non-validated data sets such as CIS on-site gamma spectrometry analysis. The frequency of detection of the COC in the soils was also considered in this evaluation. If the proposed remediation level was greater than the maximum observed concentrations or it was infrequently detected, consideration was given to eliminating the need to propose remediation levels for those COCs.

Fifth, the proposed remediation level was employed to calculate the potential ILCR and HI to the on-property resident farmer. These calculations were completed using the Unit Risk and Toxicity Factors from the RI Report for Operable Unit 4, considering only those pathways of exposure considered viable, following excavation of the top six inches of soil across the Operable Unit 4 area and the placement of six inches of clean backfill. For radionuclides, these pathways included those associated with root uptake by crops and in some cases, depending on the energies associated with the gamma emitting radionuclides, direct radiation was also considered. For the inorganics, only pathways associated with root uptake were considered in the derivation of these risk levels. If the proposed soil remediation level produced an exposure to the on-property resident farmer exceeding 10^{-4} or an HI greater than 1 considering exposures through these pathways, the proposed soil remediation level was adjusted to a concentration equivalent to a 10^{-4} ILCR or a HI of 1 for this on-

property receptor using the identified pathways. This adjustment was made provided the soil concentration was greater than background.

Above-Grade Disposal Vault

The material generated by this alternative would be placed in an on-property above-grade disposal vault. It should be recognized that the chemical and radiological properties of the Subunit C wastes are significantly different than waste being addressed under Subunits A and B. To accommodate these differences, a number of the proposed design features of the representative disposal concept, the above-grade vault, may not be required nor appropriate for the disposal of Subunit C wastes. These features include the requirement for intrusion and radon barriers. The configuration of any on-property disposal facility would be initialized through the remedial design process. For purposes of this FS, the identical representative process options employed for Subunit A and B waste have been used to evaluate the on-property disposal alternatives for Subunit C waste.

The proposed configuration of the above-grade disposal vault was previously identified in Figure 4-8. Each concrete vault will have a service opening to allow access for the placement of DOT specification 7A-Type A packaging. The floor of the vault would have a minimum slope of 2 percent to facilitate any leachate collection and monitoring. The roof of the vault would also have a minimum slope of 2 percent to allow storm water runoff. As each vault is filled to capacity, all equipment and temporary utilities would be removed and the vault sealed before the multimedia cap is installed.

The vaults would be constructed on a reinforced concrete mat with a minimum thickness of 1 ft. The perimeter of the mat would be bounded by a curb with embedded pipes that are connected to the manholes of the underlying multimedia LC/DS to facilitate the collection of any contaminated leachate after final closure. The LC/DS would be composed of alternating composite soil liners and drainage layers to minimize the potential release of contaminated leachate to the groundwater and the Great Miami Aquifer.

The soil of the composite liners would be constructed of a natural, compacted clay with a maximum permeability of 1×10^{-7} cm/s. The layers would be a minimum of 0.9 m (3 ft) thick. To improve the performance of the clay, a geomembrane of at least 40 mil in thickness would be placed over the surface of the clay, which has been smooth-rolled to ensure good hydraulic contact. To minimize damage to the geomembrane during construction, a sand layer with a minimum thickness of 20 cm (8 in) would be placed over the geomembranes of the LC/DS.

Between the composite soil liners, drainage layers would be installed to intercept any leachate that may be generated. The drainage layers would be a minimum of 0.6 m (2 ft) each in thickness. The upper 0.3 m (1 ft) of each layer would be a graded natural aggregate and the lower 0.3 m (1 ft) would be a narrow-graded medium aggregate to provide a minimum permeability of $1x10^{-2}$ cm/s. A geotextile membrane would be placed on the upper surface of each drainage layer to prevent the migration of fines from overlying material.

During placement of the aggregate, 10 cm (4 in) diameter pipes would be installed within the aggregate to collect and direct any leachate to a series of manholes lined with HDPE. The leachate would then be removed from the manholes for treatment at the FEMP AWWT facility.

The multimedia cap may be constructed of five distinct layers of media that would provide final closure of the vault. The upper layer of the multimedia cap would be a vegetative layer consisting of topsoil with a hardy, shallow-root grass cover. This layer would be noncompacted and have a minimum thickness of 0.6 m (2 ft) to support plant growth. The vegetative layer would inhibit erosion and allow runoff during storm events. A drainage layer would be beneath the vegetative layer to intercept infiltrating precipitation. The layer would consist of 0.3 m (1 ft) of pea gravel, that would provide a minimum permeability of $1x10^{-2}$ cm/s. A geotextile membrane would be placed between the vegetative layer and the top surface of the drainage layer to prevent the migration of fines from the vegetative layer to the drainage layer.

A layer of cobblestone with a minimum thickness of 0.7 m (2.3 ft) may be provided beneath the drainage layer to serve as an inadvertent intrusion barrier. Beneath the cobblestone would be a composite soil liner to impede downward moisture movement from the drainage layer. The soil of this layer would be natural, compacted clay with a maximum permeability of $1x10^{-7}$ cm/s. The layer would be 0.9 m (3 ft) thick to ensure the isolation of the disposal containers. A geomembrane of at least 40 mil in thickness would be placed over the surface of the clay, which is smooth-rolled to ensure good hydraulic contact and thus improving the performance of the clay. To minimize slippage of the overlying layers due to interfacial shearing characteristics, the geomembrane would be textured. Similar to the composite soil liners of the LC/DS, a layer of sand would be placed over the geomembrane to minimize damage during construction.

The foundation of the multimedia cap would be clean, compacted soil. This layer would be a minimum of 15 cm (6 in) to a maximum of 0.6 m (2 ft) in thickness above the vaults. All general

and granular material, as well as clay, are regionally available. The spatial requirement for the cap is estimated to be approximately 4.7 ha (11.6 acres). The alternative would include the placement of markers to define waste disposal areas, the use of deed restrictions, and the provision of continued federal ownership of the property to preclude drilling or residential development.

Decant Sump Tank, Process Piping, and Trenches

Upon completion of the Silo 1 and 2 demolition, the decant sump tank would be removed. The sludge in the tank would have been removed in a Subunit A alternative.

After the soil above and surrounding the decant sump tank has been excavated to allow its removal, a crane used for the Silo 1 and 2 demolition would extract the tank. The crane would transfer the decant sump tank to a concrete pad used previously for breaking down the silo structure sections. The decant sump tank would be cut with a gas torch into sections and packaged in DOT specification 7A-Type A packaging.

4.4.2.1 Overall Protection of Human Health and the Environment

Alternative 2C meets the remedial action objectives for Subunit C. The proposed soil remediation levels used to determine which soils to remove for placement in the on-site disposal facility are based on protection of a recreational user. As previously identified, the proposed soil remediation levels were modified, as necessary, to ensure protection of the intruder in the event institutional controls are lost. Implementation of this alternative would prevent direct access to contaminated soil and debris and would mitigate the migration of contaminants to the air, surface soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. To meet these objectives, three response actions would be used, removal, containment in an on-site engineered disposal vault and the placement of clean cover over residual contaminated subsurface soils, and implementation of institutional control measures.

Contaminated soils would be excavated for disposal. These soils include soils in the top six inches that exceed contamination levels protective of a recreational user. Areas of removed soil would be backfilled with clean soil to protect against erosion of remaining lightly contaminated soil causing dust or runoff. After the silos are removed, contaminated soil exceeding proposed soil remediation levels will be excavated. Additional subsurface soil removal provides an extra measure of environmental protection against future migration of contaminants. The excavated silo areas will be backfilled with

clean soil to grade and seeded to protect a recreational user from contact with remaining contaminated soil.

Containment of the removed contaminated soil and contaminated D&D debris in an on-site capped engineered disposal vault would provide control of contaminant migration to the underlying aquifer. The disposal vault would also prevent direct access to the contaminated soil and debris. The facility design would include sufficient barrier to withstand 1000 years of potential erosion with little or no maintenance. Markings would be used to deter purposeful or inadvertent human destruction of the facility's engineered protective features. Long-term effectiveness is uncertain because of eventual degradation of the facility cap and leachate collection system, leading to an increased rate of infiltration, leachate formation, and release. Fate and transport modeling using conservative assumptions supports the conclusion that long-term protection of human health and the environment would still be maintained. Similar disposal facility designs are being employed under federal programs for the long-term containment of similar waste.

Institutional control measures would be used to supplement the removal and containment actions to provide additional assurance that overall protection would be maintained as engineered components degrade. Also, institutional controls will limit access to the remaining contaminated soil that is covered by clean soil. The controls include long-term federal government ownership of the FEMP site. This ownership would preclude future on-site residential and farming uses which could potentially result in exposure to contaminated soil or disposed material. To comply with ORC 37340-02, hazardous and solid waste disposal facilities must include a protective covenant to restrict future mining, drilling, and residential use. A deed restriction would be placed on the FEMP site property detailing these prohibitions. The uncertainty associated with very long-term institutional control periods include a possible loss of federal ownership and the loss of or lack of administration of the property records containing the deed restrictions. Exposure to the inadvertent intruder from the residuals in the soil or the disposed waste would not be expected to be significant due to the low concentrations of COCs in the wastes and soils.

There are no unacceptable short-term risks from Alternative 2C. There are increased worker risks over no action due to radiation and dust exposure during removal and packaging. However, through implementation of a worker health and safety plan in compliance with 29 CFR 1910.120(b)(4), these exposures would be kept to ALARA levels and would comply with DOE Orders.

4.4.2.2 Compliance with ARARs

ARAR compliance for Alternative 2C is similar to that for Alternative 2B/Vit with the exception that Alternative 2C concerns the remediation of demolition debris and soil residuals. The demolition debris and soil residuals associated with Subunit C pose fewer hazards than the material associated with Subunit B. As a result, the proposed on-site disposal facility in this alternative would require less stringent design and engineering features to meet the requirements of 40 CFR 192. This difference was not significant relative to the identification of ARAR/TBC requirements, as is reflected in the common listing requirements for Alternative 2C and Alternative 2B/Vit in Tables F-4 and F-3, respectively of Appendix F. The discussion of the compliance of this alternative would be identical to that presented in Section 4.3.2.2. The findings of that discussion are summarized below.

Chemical-Specific ARAR/TBCs

Alternative 2C would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those standards associated with drinking water MCLs and MCLGs requirements, the groundwater protection requirements, radon-222 airborne release requirements, other radionuclide release requirements for water and air, and their resulting doses to the public. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 2C. Additional documentation of compliance of Alternative 2C would comply with the identified ARARs is presented in Appendix F (Table F-4).

Location-Specific ARAR/TBCs

Alternative 2C would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands, endangered species, and the sole source aquifer underlying the FEMP site. As was noted, compliance with the OAC 3745-27-07 prohibition on siting a solid waste disposal facility over a sole source aquifer would be based on demonstrating attainment of the substantive technical criteria for an exemption to this requirement as discussed in Section 4.2.2.2.

Action-Specific ARARs

Alternative 2C would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.3). Included would be those standards associated with the design of the multi-barrier engineered above-grade disposal vault system and operational requirements that meet the principal requirements contained in 40 CFR 192 Subparts A and B. Because the material associated with Subunit C poses fewer hazards than the material in Subunit B, the disposal facility proposed for

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Subunit C material would require less stringent engineering designs to meet the requirements established in 40 CFR 192. Compliance with requirements under the Clean Air Act, Clean Water Act, and RCRA would be met by incorporating sound engineering features and best management practices into the remediation and operation of the unit. Additional supporting documentation to justify that Alternative 2C would comply with the identified ARARs is presented in Appendices D and F (Table F-4).

4.4.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 2C reduces the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6}. The basis of the risk evaluation is presented in Appendix D. The primary concerns associated with soil in Operable Unit 4 is leachability. An additional concern is exposure to remaining contaminated surface soil through inhalation of particles or incidental ingestion. These concerns are addressed by sufficient removal of soil, covering of excavated areas with clean soil, isolation of the contaminated soil in an engineered disposal vault, and the application of institutional controls. The disposal vault contributes to a significant reduction in leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude the establishment of an on-site residence or farm. Backfilling with clean surface soils would reduce the risk to acceptable levels ($< 10^{-4}$) for both a recreational user and the on-property farmer. In the absence of institutional controls, the vault would continue to provide adequate protection to the on-property farmer and recreational user. Risk assessment results for the RME on-property farmer are in the range of $1x10^{-4}$ to $1x10^{-5}$ indicating that residual risks would be acceptable with a loss of institutional controls.

Because Alternative 2C includes the on-site disposal of debris and soil and because some residual contamination in the soil would remain, the 5-year CERCLA review process to ensure continued performance of the disposal system would be part of this alternative.

Adequacy and Reliability of Controls

As previously identified, the projected residual excess cancer risk attributable to Alternative 2C to viable receptors is less than 10^{-6}. The on-site disposal vault uses proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes and low level radioactive waste under both DOE and NRC programs. Fate and transport modeling to assess the most likely release mechanism under degradation of the facility,

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leaching, was completed. The results were based on the assumption that components of the system slightly degrade over 1000 years and that infiltration rates (and consequently exfiltration rates) increase to 1.3 cm/yr (based on the HELP model). Also, the leachability of the soil contaminants was based on geochemical information. Under these assumptions, the leaching of contaminants would not pose a risk to off-site receptors. Even if these input parameters were increased to 15 cm/yr (highest possible with no infiltration barrier) the result would not change. Comparable modeling of leaching from the residual soils (assuming an infiltration rate of 15 cm/yr) also illustrated that there would be no risk to the off-site resident from the soil left behind.

Dismantling and decontamination are proven technologies that have been reliably applied at almost all DOE facilities. Decontamination activities would be conducted to separate the contaminated material from clean material which might be released, thereby minimizing the amount of waste to be disposed.

The combination of institutional controls, soil removal to PRGs protective of a recreational user, and covering excavated areas with clean soil would provide protection to the recreational user and would keep an on-site residence from being established. Therefore surface exposure pathways are adequately and reliably controlled. In the event institutional controls were lost, the residual risk to the on-property resident farmer would be expected to be less than 1×10^{-4} and a HI of 1.

Consistent with DOE Order 5400.5, 40 CFR 264.114 and 40 CFR 191.14, active monitoring would assess the performance of the disposal system. This monitoring supports the required 5-year CERCLA review. As a result of the findings of the review, there is a potential that the disposal system may require maintenance, modification, or replacement. The risks associated with this replacement would be generally limited to direct radiation to on-site workers. Consistent with DOE Order 5480.11, these potential exposures would be maintained as low as reasonably achievable and within regulatory limits.

Long-Term Environmental Impacts

The nature of the long-term impacts after remediation activities associated with the implementation of Alternative 2C are the same as those associated with Alternative 2A/Vit (see Section 4.2.2.3). The following impact analysis for Alternative 2C is a summary.

Soil and Geology

Construction of the disposal vault would result in the permanent disruption of 4.7 ha (11.6 acres) of land. The disposal configuration would prevent erosion of waste material that could result in surface soil contamination and would prevent leaching that would contaminate subsurface soil. Uncontaminated soil would be used as fill. Borrow pit soil for construction would be obtained from clearing and grubbing and clean berm soil.

The regional geology of the FEMP site and surrounding area would not be affected by implementation of Alternative 2C. Geological conditions are important in terms of site suitability for construction of an on-property disposal vault. The site proposed would be suitable from a geologic standpoint. The facility would also incorporate appropriate protection against seismic damage. A review of local conditions suggests the soil beneath the location of the proposed facility is not susceptible to liquefaction or seismically induced settling.

Water Quality and Hydrology

A system to monitor long-term water quality would be implemented by installing monitoring wells around the perimeter of the disposal vault. No significant long-term hydrological impacts to the surrounding area are expected to result from changes to the site. However, after 1,000 years, some degradation could occur. Run-on and runoff controls would be used at the disposal vault and the remaining areas of the site would be regraded to approximate original contours and would discharge surface runoff to existing on-property drainageways.

Air Quality

Following implementation of Alternative 2C, the air quality at the FEMP site would be similar to current conditions. There would be no long-term impacts on air because disturbed areas would be revegetated limiting dust production.

Biotic Resources

Long-term impacts may include displacement of potential threatened and endangered species habitat. No critical habitat for threatened and endangered species has been identified in areas to be impacted by Alternative 2C activities. However, a potential habitat for threatened and endangered species does exist in the disposal area. State threatened and endangered species observed are identified in Alternative 2A/Vit.

The long-term residual risks to ecological receptors associated with Operable Unit 4 would be minimized by the implementation of this alternative. The primary pathways of concern associated with ecological receptors coming in contact with Operable Unit 4 include surface soil (e.g., ingestion, plant uptake) and runoff of surface soil to surface water bodies (e.g., exposures to aquatic habitat and ingestion of surface water). This alternative involves the removal of the top six inches from the entire operable unit and replacement with clean fill. Therefore, ecological receptors will have very minimal contact with residual contaminants. The residual contaminants of concern remaining in soil after the remedial action would be uranium in the subsurface soil at levels of approximately 60 pCi/g. Therefore, residual contaminants (i.e., uranium) would not pose a risk to ecological receptors within Operable Unit 4 due to its limited ability to enter the surface soil and surface water pathway.

Wetlands and Floodplains

A wetlands delineation for the FEMP site was conducted in December 1992 (Ebasco Environmental 1993) and is currently pending COE approval. The delineation identified approximately 12 ha (29 acres) of jurisdictional wetlands in the northern part of the site. Efforts were made to site the disposal vault in areas not containing jurisdictional wetlands. However, the citing of the facility would result in the loss of approximately 0.2 ha (0.5 acres) of forested wetlands.

The 100-yr and 500-yr Paddys Run floodplains would not be permanently altered as a result of implementing Alternative 2C.

Socioeconomics and Land Use

The area of the disposal vault is estimated at less than 0.7 percent of the site. However, the presence of the permanent disposal vault would result in future limitations for use of the site. No change would be expected in the local population growth, nearby industrial and commercial operations, or noise level. The net long-term impact of Alternative 2C on these socioeconomics is expected to be positive because the soil and debris would be isolated and controlled. However, aesthetic impacts would occur as a consequence of on-property material disposal.

Cultural Resources

A site-wide archaeological survey would be performed for the areas to be impacted by Alternative 2C. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, OHPO, AIRFA, and NAGPRA. Because any

cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative does not include treatment of the contaminated silo structures, berm material, or soils; therefore, no reduction in toxicity, mobility, or volume would be achieved through treatment. However, as a part of remedial action work plan preparation, an approach would be developed to reduce the volume of material requiring management as low-level waste. Following decontamination, it is conceivable that concrete and other structural materials might be suitable for free-release off site.

4.4.2.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Through a combination of engineering controls and access controls, Alternative 2C would be protective of the community during implementation.

Through access to the site during remediation, there is the potential for a trespasser to be exposed to direct radiation from the debris and soil or dust. In addition to the engineering controls (such as dust suppression) that would be implemented to limit the release of contaminants, access controls during remediation would be used. Through the use of fences and guards, access to the materials by the public would be limited. Access controls are effective, especially in the short term. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 2C is effective in protecting the community in the short term.

Protection of Workers During Remedial Action

There are no unacceptable risks to workers as a result of implementation of Alternative 2C. This alternative involves the handling of contaminated debris and soils; therefore, there are several potential exposure pathways for workers. Both the release of dust particles and exposure to direct radiation from the soil and materials could cause a risk to workers. It has been estimated that appropriate protection to a remediation worker can be taken so there is no risk increase. However, for the nonremediation worker, the potential for any alternative involving soil removal to be associated with an excess cancer risk level of 7.6×10^{-7} (Appendix D).

There are safety issues associated with the removal and demolition process as there may be accidents. Without considering the nature of the activity, it has been estimated, based solely on labor hours, that Alternative 2C could have 4.5 injuries and 0.066 deaths during remediation activities. All remediation activities would be conducted in accordance with a health and safety plan developed to meet 29 CFR 1910.120(b)(4). Training and procedures would assure that worker exposure would be ALARA.

Short-Term Environmental Impacts

Short-term impacts for Alternative 2C would be basically the same as those associated with Alternative 2A/Vit. Therefore, the following discussion is provided at a summary level.

Soil and Geology

Soil disturbance during implementation of Alternative 2C would result primarily from preparation of the on-site disposal vault; construction of access roads, decontamination/packaging area, equipment staging area, and support areas; excavation of contaminated areas and borrow pit areas; demolition of the silos, and demolition of the processing facility. Construction and excavation activities could disturb approximately 5.7 ha (14.1 acres) of the site.

Construction and excavation activities at the site could result in the erosion of exposed soil areas. Engineered controls such as straw bales and berms could be used to minimize potential erosion. Following completion of construction and excavation activities, disturbed areas would be filled with clean backfill and revegetated with native grasses.

Water Quality and Hydrology

Through erosion control and dust suppression, contaminants disturbed during remediation would not be transported to adjacent surface water bodies. Surface water near the site would be monitored during remediation in accordance with the existing water discharge permit to assess potential impacts to the water from remediation.

Remediation would not increase the release of contaminants to the groundwater since the most contaminated material would be removed. However, the existing monitoring network on the FEMP site would be sampled for short-term monitoring of groundwater elevations and concentrations during source removal.

Air Quality

Ambient air quality in areas accessible to the public is regulated by both state and federal standards. There are two potential sources of air emissions; dust from construction and earth-moving activities heavy equipment exhaust. The exhaust emissions from heavy equipment are not expected to impact air quality.

Dust would be controlled as discussed in the soil section. With the appropriate dust suppression, excavation activities are not expected to negatively impact the air quality.

Biotic Resources

The short-term disturbance of on-property vegetation and wildlife habitat under Alternative 2C would result primarily from activities associated with 1) construction of the on-site disposal vault and other facilities, 2) excavation of berm soils, and 3) installation of electric power lines, transformers, process water and sewer lines, and material slurry transfer lines. Local biota (wildlife and wildlife habitat) would be temporarily displaced along with potential threatened and endangered species habitat. However, these impacts would be temporary and permanent habitat losses are expected to be minor.

There also is the potential for impact to biota from contaminant releases such as through erosion and dust emissions. As discussed in previous short-term effectiveness discussions, the releases would be minimized through engineering controls such as erosion control and dust suppression. There should be no negative exposure impact on biota during implementation of Alternative 2C.

Wetlands and Floodplains

A site-wide wetlands delineation has identified several areas of wetlands in or adjacent to areas that could be impacted by the implementation of Alternative 2C. Wetlands north and south of the material treatment facility are not expected to be affected; however, there would be disturbance of wetlands during the construction of the on-site disposal vault. Approximately 0.2 ha (0.5 acres) of the drainage ditch wetlands would be affected. Engineering controls through the site activities, such as silt fences and straw bales, would be used to control the migration of eroded soil to wetland areas.

The 100-year and 500-year Paddys Run floodplains are located immediately west of Silos 1 and 2. Alternative 2C activities are not planned to occur within the floodplains and contaminant migration during remediation would be controlled through engineered erosion controls to minimize impacts on the floodplains.

Socioeconomics and Land Use

Short-term impacts to socioeconomics and land use would be minor. Employment needed to implement Alternative 2C would require 48 workers and approximately 6 trucks making 84 one-way trips per working day. It is assumed for this analysis that many of the workers needed for the remedial activities already work at the site; consequently, the relocation of additional workers to the area would not have a significant impact on public facilities within the CMSA.

The collective revenue for the CMSA would increase by approximately 4 percent. The additional expenditures would be spent over 2 years of implementation. Therefore, only minor economic impacts are expected for the CMSA as a result of implementing Alternative 2C.

Cultural Resources

Any areas determined to be of significance resulting from a cultural resources review would be managed consistently with the requirements of the NHPA, OHPO, AIRFA, and the NAGPRA.

Duration of Remedial Activities

Approximately 3 months would be required for site preparation; 15 months to demolish, decontaminate, and containerize the silo structures, treatment facility, surface soil, subsurface soil, process piping, and decant sump tank. Demobilization activities would extend the duration of the alternative to 2 years. During this time frame, the disposal vault would be constructed and capped. Physical, substantial, and continuous on-site activities would be initiated within 15 months after the ROD is approved by EPA.

4.4.2.6 Implementability

Technical Feasibility

Silo decontamination with a remotely controlled device is not standard; however, such devices are commonly used and should not be difficult to implement. Silo demolition process facility deconstruction and the construction of the above-grade disposal vault are standard civil engineering technologies commonly used throughout industry.

The technologies in Alternative 2C have been widely demonstrated and provided significant and reliable isolation of the material from the environment. Some of the uncertainties related to the alternative would include the availability of on-site borrow material and the amount of time needed to

acquire necessary permits. The technologies would involve the use of several contractors. All the technologies would have more than one contractor available for competitive bidding.

The construction of the cap would require delivery of various types of soil including clay. Future remediation requirements could involve above-grade disposal vault repair or replacement or retrieval of the contents of the above-grade disposal vault. Repair or replacement of the cap or LC/DS would involve technologies similar to the original construction and would not be difficult. The contents could be accessed by simply digging out the multimedia cap and retrieving the DOT specification 7A Type A packaging.

The effectiveness of the alternative would be monitored to meet the needs of CERCLA five-year review. Visual inspection and groundwater sampling would measure the effectiveness of the alterative in meeting the required conditions. Detection of contaminants in the groundwater or visual abnormalities in the multimedia cap would initiate actions to mitigate the problem.

Administrative Feasibility

No permits or licenses would be required, but permit information summary packages may be required. Coordination with OEPA would be necessary to demonstrate compliance with substantive technical requirements to construct the disposal vault.

Availability of Services and Materials

Components involved in this alternative include: site preparation; silo decontamination and demolition; vacuum scabbling; tank piping; trench removal; contaminated soil excavation; process facility demolition; construction of an above-grade disposal vault; installation of an LC/DS; and construction of the multimedia cap.

Each of these operations requires standard and widely-available construction equipment, materials, and services. No specialty equipment or services would be required and no specialty labor skills would be necessary for the majority of activities. Specialized equipment and trained personnel would be required to install the vault membranes and liners.

4.4.2.7 Cost

The total present worth cost of Alternative 2C is $58M. A detailed breakdown of the cost is provided in Table 4-12.

TABLE 4–12

COST ESTIMATE FOR ALTERNATIVE 2C

ALTERNATIVE 2C: DEMOLITION, REMOVAL, ON–PROPERTY DISPOSAL			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
DEMOLITION & REMOVAL	$3,980,300	$5,977,100	$9,957,400
PACKAGING (20,625 PKGS. @ $955/PKG.)	$5,445,000	$14,251,900	$19,696,900
DISPOSAL VAULT	$6,410,200	$10,914,800	$17,325,000
TOTAL CAPITAL	$15,835,500	$31,143,800	$46,979,300
RISK BUDGET (11.0%)	$1,741,900	$3,425,800	$5,167,700
SUBTOTAL	$17,577,400	$34,569,600	$52,147,000
CONTINGENCY (20.0%)	$3,515,500	$6,913,900	$10,429,400
TOTAL ESTIMATED INSTALLED COST	$21,092,900	$41,483,500	$62,576,400
OPERATION AND MAINTENANCE (O&M) COSTS			
POST–REMEDIATION			$3,567,000
TOTAL PRESENT WORTH COST (CAPITAL AND O&M @ 7%)			$58,044,500

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 2
O&M during construction (years): 0
Post–remediation O&M (years): 30

Capital Cost

The capital cost is associated with silo demolition and removal, Subunit A and B processing facilities and equipment D&D, construction of the above-grade disposal vault, and packaging of material for disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-12. More detailed information is provided in Appendix E.

The largest component of the capital cost is packaging. This represents approximately 45 percent of the total capital costs. The second largest element of the capital costs (40 percent) is the disposal vault.

Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Demolition and Removal

This cost component involves the decontamination and demolition of Silos 1, 2, 3, 4, and the waste processing facility. Costs were estimated based on the following:

- Site preparation would include clearing and grubbing of approximately 4.7 ha (11.6 acres) for the above-grade disposal vault. A haul road approximately 0.32 km (0.8 mile) would be constructed.

- The material would include contaminated silo rubble, the existing RTS of Silos 1 and 2, surface and subsurface soils, drum handling pad, the decant sump tank, process piping and trenches, and the waste processing facilities, including the equipment superstructure.

- Forty percent of Silos 1, 2, and 3 concrete [606 m^3 (793 yd^3)] would be contaminated and require disposal. The remainder of the concrete, approximately 925 m^3 (1207 yd^3) of less contaminated concrete could be free released or transferred to Operable Unit 3 for disposal.

- Approximately 790 m (2,600 ft) of process piping in the process trenches would be cut into manageable sections but not decontaminated prior to packaging.

- A backhoe-mounted pneumatic hammer would be used to fracture the concrete piping trenches. Estimated volume of concrete from trenches would be 240m^3 (315 yd^3).

- Silo 4 would be demolished but no prior decontamination would be necessary. All of Silo 4 material would be free released.

- Subsoil beneath Silos 1 and 2 would be excavated to a depth of approximately 1.5 m (5 ft) and laterally to the toe of the berm. Contaminated pockets of subsoil would also be excavated. Soil quantities were estimated to be 11,198 m^3 (14,646 yd^3).

Disposal Vault

The cost of the disposal vault was estimated as follows:

- Cost for the on-property, above-grade disposal vault was estimated at a unit cost of \$751 m^3 (\$574/yd^3).

- The unit cost estimate is based on a conceptual design for a vault consisting of individual modular cells, each capable of holding 3400 m^3 (120,000 ft^3) of material. As additional disposal volume space is required, additional modular cells are added for cost estimating purposes. Cell numbers were estimated by rounding up to the nearest whole number.

- The size of the disposal vault was based on the number of packages noted below, assuming each package occupies 2 m^3 (64 ft^3) of space, and was estimated as 37,395 m^3 (1,320,000 ft^3). Assuming a cell size of 3400 m^3 (120,000 ft^3), 11 cells would be required [7664 m^2 (82,500 ft^2) vault footprint area].

- The design of the vault includes a multimedia cap, liner, and LC/DS. No intrusion barrier would be included in the design.

- The vault would cover approximately 4.7 ha (11.6 acres) of property.

Packaging

Packaging cost includes the cost of purchasing the containers and the labor associated with handling, filling, and documentation. Estimated cost is based on the following:

- Packages would be DOT specification 7A Type A containers with exterior dimensions of 1.2 m (4 ft) width by 1.2 m (4 ft) length by 1.2 m (4 ft) depth. Interior dimensions would be 1.1 m (3.5 ft) width by 1.1 m (3.5 ft) length by 1.1 m (3.5 ft) depth, providing 2 m^3 (43 ft^3) of storage per package.

- Final packaging volume was estimated to be 24,634 m^3 (32,214 yd^3 or 869,778 ft^3).

- Packaging and disposal of materials generated during D&D operations for Subunits A and B are included in this cost.

- Total packaging cost was estimated assuming 20,625 containers.

- A unit cost of \$955 per container was determined based on a material cost of \$650 per unit and a labor cost of 16 man-hours per unit for handling, filling, and documentation.

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O&M Cost

Long-term O&M costs are $3.6M (not considering present worth). Long-term O&M includes maintenance and monitoring which would be performed until the FEMP site-wide remedial action objectives are met, i.e., approximately 30 years. Monitoring would support the required CERCLA five-year review.

4.4.3 Analysis of Alternative 3C.1

This removal alternative is identical to Alternative 2C (Section 4.4.3) except the on-property disposal, monitoring, and institutional control will be replaced by transportation and off-site disposal of the material.

Off-Site Disposal

The off-site disposal option for Alternative 3C.1 involves the packaging, loading, and shipping of the contaminated material generated by this alternative to NTS. The material to be disposed of would consist of silo rubble, building debris, and process equipment from the RTS for Silos 1 and 2, surface and subsoil soils, the decant sump tank, process piping, and process piping trenches.

The material would be packaged in DOT specification 7A Type A packaging at the FEMP site and transported by an existing road from Operable Unit 4 to a transfer facility. Shipping of the treated material to NTS would involve rail transportation from the FEMP site through East St. Louis on the CSX rail lines. From St. Louis, the treated material would be transported on the Union Pacific (UP) rail lines through North Platte, Nebraska, and Salt Lake City, Utah. Currently there are no direct rail lines to NTS. Presently, the treated material would be transported to either a point near Las Vegas, Nevada or one of the areas north of Las Vegas. From either location, the containers carrying the treated material would be transferred to trucks for transportation over roads to NTS. If a direct rail line to NTS becomes available before this alternative is implemented, it may be used in lieu of shipping the treated material by truck on the last leg of its trip. Wastewaters may be staged or placed into interim storage at the FEMP site as required to accommodate interruptions in the availability of disposal capacity.

4.4.3.1 Overall Protection of Human Health and the Environment

Alternative 3C.1 meets the remedial action objectives for Subunit C. The proposed soil remediation goals used to determine which soils to remove and dispose off site are based on protection of a recreational user. The proposed soil cleanup levels also adequately protect the on-property farmer in

the event that institutional controls fail. Implementation of this alternative would prevent direct access to contaminated soil and debris and would mitigate the migration of contaminants to the air, surface soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. To meet these objectives, three response actions are used, removal and placement of clean cover, off-site disposal, and implementation of institutional control measures.

Contaminated soils would be excavated for disposal to the same levels as in Alternative 2C (Section 4.4.2.1). These soils include soils in the top six inches that exceed contamination levels protective of a recreational user. Areas of removed soil would be backfilled with clean soil to protect against erosion of remaining lightly contaminated soil causing dust or runoff. After the silos are removed, contaminated soil with high radiological contaminant concentrations will also be removed as discussed in Alternative 2C. The excavated silo areas will be backfilled with clean soil to grade to protect receptors from contact with remaining contaminated soil.

Institutional control measures would be used to preclude site development so as to limit access to the remaining contaminated soil that is covered by clean soil. As in Alternative 2C, the controls include continued federal ownership of the FEMP site. This ownership would preclude future on-site residential and farming land uses which could potentially result in exposure to contaminated soil or material disposed of in the vault. The uncertainty associated with long-term institutional control periods include a possible loss of federal ownership. In the event institutional controls were lost, exposures to the on-property resident farmer would not be expected to be significant due to the six inch soil cover and the level of residual contamination.

The off-site disposal provides a final element of protection under Alternative 3C.1. The off-site disposal facility at NTS would provide protection by eliminating access to the soil or debris and from migration of contaminants out of the material much as the on-site disposal facility would under Alternative 2C. The NTS facility is located in a sparsely populated, arid environment with a reduced potential for contaminant release, migration, and direct contact with contaminants. The long-term effectiveness of the necessary institutional controls at the disposal facility is estimated to be more reliable than those that would be implemented at the FEMP site. Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. Further, the climatic (low average annual precipitation) and hydrogeologic (depths to groundwater ranging from 157 to 600 m [515 to 2000 ft] below ground

surface) characteristics would tend to mitigate impacts to human health and the environment in the event that engineering and institutional controls fail.

There are no unacceptable short-term risks from Alternative 3C.1. There are worker risks due to radiation and dust exposure material during removal and packaging. Through the use of shielding and implementation of a worker health and safety plan in compliance with 29 CFR 1910.120(b)(4), these exposures would be kept to ALARA levels and would comply with DOE Orders. There are also increased risks to workers and the community from moving the waste off site. Both rail and trucks would be used but most of the potential risk is from truck movement.

4.4.3.2 Compliance with ARARs

ARAR compliance for Alternative 3C.1 is similar to ARAR compliance for Alternative 2C with the exception that Alternative 3C.1 calls for disposal of demolition debris and soil residuals at a DOE-owned off-site facility. Because Alternative 3C.1 involves off-site disposal of debris and soil residuals, the disposal facility siting criteria and disposal requirements would no longer be applicable nor relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3C.1 are similar to those for Alternative 2C (see Table F-4 in Appendix F). Consequently, the discussion of the compliance of this alternative would be identical to that presented in Section 4.4.2.2. The findings of that discussion are summarized below. Additional documentation of compliance of Alternative 3C.1 would comply with the identified ARARs is presented in Appendix F (Table F-4).

Chemical-Specific ARAR/TBCs

Alternative 3C.1 would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those requirements associated with compliance of Ohio water quality standards, the control of Radon-222 airborne releases, and the control of other radionuclide releases to air and water, and their resulting doses to the public. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 3C.1.

Location-Specific ARAR/TBCs

Alternative 3C.1 would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those associated with the protection of wetlands and endangered species during the on-site remediation. As noted above, disposal facility siting criteria and management requirements would no longer be applicable nor relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARARs

Alternative 3C.1 would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.3) including those standards in 40 CFR 192.12 for cleanup of lands contaminated with residual radioactive material. Compliance with requirements under the Clean Air Act, Clean Water Act, and RCRA would be met by incorporating sound engineering features and best management practices into the remedial operations under this alternative. Off-site disposal would require shipment of waste materials. Hazardous waste transport requirements would be complied with by following the regulations under 40 CFR 262, and the appropriate DOT shipping requirements under 49 CFR 172 and 173.

4.4.3.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 3C.1 would reduce the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6} similar to Alternative 2C. As with Alternative 2C, residual contamination would remain at the site in the soil. The level of risk from the residual soil is controlled by excavating soil that exceeds proposed remediation levels. These levels provide adequate protection to the recreational user and the on-property resident farmer. The excavated contaminated soil and debris would be disposed at NTS.

Adequacy and Reliability of Controls

The reliability of the D&D activities and soil removal actions of Alternative 3C.1 would be the same as for Alternative 2C (Section 4.4.2.3). Off-site disposal at NTS has enhanced reliability because the facility is currently used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be more reliable at NTS. Additionally, if there is a release at NTS, the climate, hydrologic conditions, and geologic characteristics would considerably reduce the potential for contaminant migration. The low population density would also reduce the potential for direct contact in the event of disposal facility failure. In the event institutional controls were lost at the FEMP site, exposure would be expected to be acceptable to the on-property resident farmer due to the nature and level of residual contamination.

Long-Term Environmental Impacts

The long-term environmental impacts of removal and treatment actions of Alternative 3C.1 are the same as for Alternative 2C. The difference between the two alternatives is the disposal option. The

impacts for NTS would be the same as those associated with Alternative 3B.1/Vit (Section 4.3.3.3). Reference is made to these discussions and it will not be repeated here.

4.4.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative does not include treatment of the contaminated silo structures, processing facility debris, berm material, or soil; therefore, no reduction in toxicity, mobility, or volume would be achieved. However, as a part of remedial action work plan preparation, an approach would be developed to reduce the volume of material requiring management as low-level waste. Following decontamination, it is conceivable that concrete and other structural material might be suitable for free-release off site.

4.4.3.5 Short-Term Effectiveness

Protection of the Community During Remedial Action

Alternative 3C.1 provides the same level of short-term protection of the community during removal and D&D as does Alternative 2C (Section 4.4.2.5). There would be added risk to the public through transporting the soil and debris off site. Because of the overall low radiological activity of the soil and debris, there would be no estimated increase in radiation exposure to the public during transportation. It is estimated that 1.3 injuries and 0.33 deaths would occur due to transportation accidents. All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that Alternative 3C.1 is effective in protecting the community in the short term. The basis for these estimates is provided in Appendix D.

The disposal of Operable Unit 4 materials at NTS would not be expected to exceed protective levels for the community around NTS over the short term. The contaminated soil and debris would meet NTS waste acceptance criteria and therefore would be managed within the bounds of the NTS facility's protectiveness criteria.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers during removal and D&D are the same for Alternatives 3C.1 as for 2C. There are no additional radiation exposure risks to the worker resulting from transporting the material to NTS. The estimated occurrences of injuries during remediation activities is 1.4 and death is 0.021. There are additional radiation exposure risks to workers from transporting the material to NTS. The excess ILCR is estimated at 3.0×10^{-8}, below the EPA's target risk level of 10^{-6}. The accident risks to workers during off-loading 544

activities at NTS are conservatively assumed to be similar to those for remediation activities at the FEMP site.

Short-Term Environmental Impacts

The short-term environmental impacts at the FEMP site for removal, D&D, packaging, and loading of materials under Alternative 3C.1 are the same as those for Alternative 2C (Section 4.4.2.5).

The total area disturbed at the FEMP site as part of this alternative would be 1 ha (2 acres). The short-term impacts for Alternative 3C.1 disposal operations at NTS would be similar to those under Alternative 3B.1/Vit (Section 4.2.4.5). Reference is made to that discussion and it will not be repeated here.

Duration of Remedial Activities

Remedial actions for Alternative 3C.1 are expected to require 2 years to complete. This time frame includes transporting the containers of soil and debris to NTS. Physical, substantial, and continuous on-site activities would be initiated within 15 months after the ROD is approved by EPA.

4.4.3.6 Implementability

Technical Feasibility

The technical feasibility of Alternative 3C.1, with the exception of the disposal activities, is the same as that of Alternative 2C (Section 4.4.2.6). The technical feasibility of off-site transport and disposal at NTS is straightforward and reliable. Off-site transport to NTS would consist of rail transport from Fernald to within 483 km (300 mi) of NTS. Currently, NTS is not accessible by rail; therefore, the material would be transferred to trucks and transported to NTS. The soil and debris would be placed in appropriate containers that meet transportation and disposal requirements.

Administrative Feasibility

The wastes generated in this alternative would be similar to FEMP waste streams currently approved for disposal at NTS; therefore, an addendum to the FEMP NTS Waste Shipping Application would not likely be required. All material shipments would be required to meet applicable federal and state regulations.

Availability of Services and Materials

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Alternative 3C.1 would include the activities of Alternative 2C with the exception of the disposal facility component. The shipping of the material to NTS would require the services of transporters (both rail and truck), standard construction equipment and trades for loading the transport vehicles, and the services of NTS for disposal. NTS currently accepts LLW from FEMP and has adequate facilities to accept Subunit C waste. Transfer areas, storage areas, decontamination facilities, and a laboratory are available on the site.

4.4.3.7 Cost

The total present worth cost of Alternative 3C.1 is $59.5M. A detailed breakdown of the cost is provided in Table 4-13.

Capital Cost

The capital cost is associated with silo demolition and removal, packaging, transportation, and disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-13. More detailed information is provided in Appendix E.

This alternative includes cost components identical to Alternative 2C (Section 4.4.2.7). The largest component of the capital cost is packaging. This represents approximately 40 percent of the total capital costs. The second largest element of the capital costs (22 percent) is the disposal. Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Demolition and Removal

This component is the same as described for Alternative 2C.

Packaging

This cost item has the same basis of estimate as Alternative 2C.

Transportation

This cost item includes transportation of the containerized material, and is based on the following assumptions:

- Packages would be transported by rail to within 483 km (300 mi) of the disposal facility (NTS) and then transported by truck the remainder of the distance.

TABLE 4–13

COST ESTIMATE FOR ALTERNATIVE 3C.1

ALTERNATIVE 3C.1: SILO DEMOLITION, REMOVAL, OFF–SITE DISPOSAL AT NTS			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
DEMOLITION & REMOVAL	$3,980,300	$5,977,100	$9,957,400
TRANSPORTATION	$8,642,600		$8,642,600
DISPOSAL	$4,120,900	$7,016,600	$11,137,500
PACKAGING (20,625 PKGS. @ $955/PKG.)	$5,445,000	$14,251,900	$19,696,900
TOTAL CAPITAL	$22,188,800	$27,245,600	$49,434,400
RISK BUDGET (11.0%)	$2,440,800	$2,997,000	$5,437,800
SUBTOTAL	$24,629,600	$30,242,600	$54,872,200
CONTINGENCY (20.0%)	$4,925,900	$6,048,500	$10,974,400
TOTAL ESTIMATED INSTALLED COST	$29,555,500	$36,291,100	$65,846,600
TOTAL PRESENT WORTH COST (CAPITAL @ 7%)			$59,525,300

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 2
O&M during construction (years): 0
Post–remediation O&M (years): 0

- Rail costs were estimated using a unit rate of $2.47 per railcar per km ($3.97 per railcar per mile). Railcars were assumed to weigh 8165 kg (180,000 lbs) each.

- Truck costs were estimated using a unit rate of $0.24 per pound [for the total 483 km (300 mi) trip].

Disposal

- Packaged material would be disposed at NTS.
- Unit disposal cost was estimated as $353 m^3 ($10/ft^3).

O&M Cost

There are no short-term or long-term O&M costs associated with this alternative.

4.4.4 Analysis of Alternative 3C.2

This removal alternative is identical to Alternative 2C (Section 4.4.3) except the on-property disposal, monitoring, and institutional actions process options will be replaced by transportation and off-site disposal of the material at a hypothetical permitted commercial disposal site.

Off-Site Disposal

The off-site disposal option for Alternative 3C.2 involves the packaging, loading, and shipping of the contaminated material generated by this alternative to a permitted commercial disposal site. The material to be disposed of will consist of silo rubble, building debris, and process equipment from the RTS for Silos 1 and 2, surface and subsoil soils, the decant sump tank, process piping, and process piping trenches. The material will be packaged in DOT 7A Type A containers at the FEMP site and transported from the FEMP site to the representative commercial disposal facility by rail. The length of the route is estimated to be 3057 km (1900 mi).

For the purposes of this feasibility study, it was assumed that the representative commercial disposal facility would be located east of Clive, Utah. The location has an annual precipitation rate of approximately 12 cm (5 in) and an evaporation rate greater than 152 cm (60 in). The soil of the site is a naturally low permeability clay. Consistent with 3C.1, staging or interim storage of the wastes at the FEMP site may be required to accommodate interruptions in the availability of disposal capacity.

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4.4.4.1 Overall Protection of Human Health and the Environment

Alternative 3C.2 meets the remedial action objectives for Subunit C in the same manner as Alternative 3C.1 (Section 4.4.3.1). The proposed soil remediation levels used to determine which soils to remove and dispose off site are based on protection of a recreational user. Implementation of this alternative would prevent direct access to contaminated soil and debris and would mitigate the migration of contaminants to the air, surface soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. To meet these objectives, three response actions are used, removal and placement of clean cover, off-site disposal, and implementation of institutional control measures.

Contaminated soils would be excavated for disposal to the same levels as in Alternative 2C (Section 4.4.2.4). The excavated areas will be backfilled with clean soil to grade to protect receptors from contact with remaining contaminated soil.

As in Alternative 2C and 3C.1, Alternative 3C.2 includes institutional controls through continued federal government ownership of the FEMP site. This ownership would preclude future on-site residential and farming uses which could potentially result in exposure to contaminated soil.

The off-site disposal provides an element of protection for Alternative 3C.2. A commercial facility located in an arid environment would be protective against direct contact with the soil or debris as well as migration of contaminants and material to the same extent as NTS (Alternative 3C.1). Disposal of the soil and debris at an off-site commercial facility is subject to some uncertainties associated with long-term protectiveness. As long as the facility owner maintains operations in compliance with applicable permits protectiveness is ensured.

There are no unacceptable short-term risks from Alternative 3C.2. The risks are slightly less than disposal at NTS because the waste can be sent by rail instead of a rail/truck combination. Through the use of shielding and implementation of a worker health and safety plan in compliance with 29 CFR 1910.120(b)(4), exposures would be kept to ALARA levels and would comply with DOE Orders.

4.4.4.2 Compliance with ARARs

ARAR compliance for Alternative 3C.2 is similar to ARAR compliance for Alternative 2C with the exception that Alternative 3C.2 calls for disposal of demolition debris and soil residuals at an off-site

commercial facility. Because Alternative 3C.2 calls for off-site disposal of debris and soil residuals, the disposal facility siting criteria and disposal requirements would not be applicable nor relevant and appropriate. The remaining ARAR/TBC requirements for Alternative 3C.2 are similar to those for Alternative 2C (see Table F-4 in Appendix F). Consequently, the discussion of the compliance of this alternative would be identical to that presented in Section 4.4.2.2. The findings of that discussion are summarized below. Additional documentation of compliance of Alternative 3C.2 with the identified ARARs is presented in Appendix F (Table F-4).

Chemical-Specific ARAR/TBCs

Alternative 3C.2 would comply with all pertinent chemical-specific ARARs identified in Appendix F (Table F-1.1). Included would be those requirements associated with the Ohio water quality standards, the control of Radon-222 airborne releases, the control of other radionuclide releases to air and water, and their resulting doses to the public. Appendix D contains the description and results of the analyses supporting the exposure assessments for Alternative 3C.2.

Location-Specific ARAR/TBCs

Alternative 3C.2 would comply with all pertinent location-specific ARARs identified in Appendix F (Table F-1.2). Included would be those requirements associated with the protection of wetlands and endangered species during the on-site remediation. As noted above, disposal facility siting criteria and management requirements would not be applicable nor relevant and appropriate to this alternative because of the proposed use of an off-site disposal facility.

Action-Specific ARARs

Alternative 3C.2 would comply with all pertinent action-specific ARARs identified in Appendix F (Table F-1.3). Included would be those requirements associated with standards in 40 CFR 192.12 for cleanup of lands contaminated with residual radioactive material. Compliance with requirements under the Clean Air Act, Clean Water Act, and RCRA would be met by incorporating sound engineering features and best management practices into the remedial operations under the alternative. Off-site disposal would require the shipment of Operable Unit 4 waste materials. Hazardous waste transport requirements will be complied with by following the regulations under 40 CFR 262 and the appropriate DOT shipping requirements under 49 CFR 172 and 173.

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4.4.4.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

The application of Alternative 3C.2 would reduce the residual risk to viable receptors to a Hazard Index of less than 0.2 and an ILCR of less than 10^{-6} similar to Alternative 2C.1 (Section 4.4.2.3).

Adequacy and Reliability of Controls

The reliability of the D&D activities and soil removal actions of Alternative 3C.2 are the same as for Alternative 2C. The reliability of a commercial facility in an arid environment is essentially the same as the NTS facility (Alternative 3C.1) since both are in an arid environment with favorable hydrogeologic characteristics and currently manage low-level disposal of radioactive waste. If there is a release at the commercial facility, corrective action measures would be implemented. Continued monitoring is typically a requirement of the facility's permit.

Long-Term Environmental Impacts

The long-term environmental impacts of removal and treatment actions of Alternative 3C.2 are the same as for Alternative 2C and 3C.1 The discussion presented below focuses on the impacts to a commercial facility located in Utah.

Soil and Geology

Soil at the commercial facility would be permanently disturbed for the disposal of the Subunit C materials. Borrow material may be required for the construction of additional disposal cells at the facility. The commercial facility in Utah would be situated in an hydrogeologic, demographic, ecologic, and climatic setting favorable to radioactive and hazardous waste disposal.

Water Quality and Hydrology

The disposal of contaminated soil and debris at a commercial facility in an arid location under this alternative is not expected to have significant impacts on water quality or hydrology. Typically there are no continuously flowing streams in arid regions. Stream beds carry water only during unusually intense or persistent rains. Rainfall (which averages 1 cm [0.4 in] per year) infiltrates quickly into moisture deficient soil. These parameters, coupled with very suitable geology, would help minimize long-term impacts to water quality. Engineered controls (capping) and ongoing monitoring activities would also be used to control and minimize water quality impacts.

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Air Quality

Following implementation of Alternative 3C.2, the air quality at the commercial disposal site would be similar to current conditions. There would be no long-term impacts on air because of the depth of the cap on the disposal facility and because disturbed areas would be revegetated.

Biotic Resources

The disposal activities at the commercial disposal facility related to Alternative 3C.2 are not expected to impact the habitat of endangered species or displace any other species since approval for locating the commercial facility would mean that stringent environmental siting requirements would already have been met.

Wetlands and Floodplains

Alternative 3C.2 material would not be disposed of within a wetland or floodplain. As with FEMP on-property disposal considerations, the commercial disposal facility would be bound by the same requirements to not dispose of the Operable Unit 4 material in a wetland or floodplain.

Socioeconomics and Land Use

Selection of a commercial facility in an arid region means low population density and limited land use potential. The off-site areas adjacent to the facility would be predominantly rural and aesthetic impacts would not be expected to change. Material disposal activities (associated with this alternative) would not impact socioeconomics or land use.

Cultural Resources

An archaeological survey would be performed for the areas to be impacted by Alternative 3C.2. Any areas determined to be of significance from a cultural resources standpoint would be managed consistently with the requirements of NHPA, OHPO, AIRFA, and NAGPRA. Because any cultural resources identified would either be avoided or managed appropriately, there would be no impacts to cultural resources at the FEMP site or the commercial facility.

4.4.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative would not include treatment of the contaminated silo structures, processing facility debris, berm material, or soil; therefore, no reduction in toxicity, mobility, or volume would be achieved. However, as a part of remedial action work plan preparation, an approach would be developed to reduce the volume of material requiring management as low-level waste. Following

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decontamination, it is conceivable that concrete and other structural martials might be suitable for free-release off site.

4.4.4.5 Short-Term Effectiveness

Protection of the Community during Remedial Action

Alternative 3C.2 would provide the same level of short-term protection of the community as Alternative 3C.1 All potential short-term risks to the public are so small that even a significant deviation in the assumptions would not change the conclusion that both Alternatives 3C.1 and 3C.2 are effective in protecting the community in the short-term.

Protection of Workers During Remedial Action

Estimates of potential radiation exposure to remediation and nonremediation workers during removal, D&D, and off-site disposal are the same for Alternatives 3C.2 as for 3C.1 (Section 4.4.2.5).

Short-Term Environmental Impacts

The short-term environmental impacts at the FEMP site for removal, D&D, containers, and loading of materials under Alternative 3C.2 are the same as those for Alternative 2C (Section 4.4.2.5).

Duration of Remedial Activities

Remedial actions for Alternative 3C.2 are expected to require 2 years to complete. Physical, substantial, and continuous on-site activities could be initiated within 15 months after the ROD is approved by EPA.

4.4.4.6 Implementability

Technical Feasibility

All activities that would be conducted for Alternative 3C.2 are standard construction techniques that are technically feasible and reliable and are the same (except for disposal location) as Alternative 3C.1 (Section 4.4.3.6).

Administrative Feasibility

The administrative feasibility of Alternative 3C.2 would involve a variance to DOE policy for disposal at a commercial facility. The public and regulatory agencies from the states located within

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the transportation route from the FEMP site to the commercial disposal facility might op[redacted] transport; thus, some coordination would be required to solicit concurrence.

Availability of Services and Materials

The availability of services and materials would be the same as that described in Alternative 3C.1 except for the availability of the disposal facility.

4.4.4.7 Cost

The total present worth cost of Alternative 3C.2 is $82.4M. A detailed breakdown of the cost is provided in Table 4-14.

Capital Cost

The capital cost is associated with silo demolition and removal, packaging, transportation, and disposal. Breakdown of direct and indirect costs for each major component of this alternative are provided in Table 4-14. More detailed information is provided in Appendix E.

This alternative includes cost components identical to Alternative 2C (Section 4.4.2.7). The largest component of the capital cost is disposal. This represents approximately 47 percent of the total capital costs. The second largest element of the capital costs (29 percent) is the packaging. Assumptions used to estimate the capital cost of each of the major components of this alternative are provided below.

Demolition and Removal

This component is the same as described for Alternative 2C.

Packaging

This cost item has the same basis of estimate as Alternative 2C.

Transportation

This cost item includes transportation of the packaged material, and is based on the following assumptions:

- Packages would be transported by rail to the disposal facility.
- Rail costs were estimated using a unit rate of $2.47 per rail car per km ($3.97 per railcar per mi). Railcars were assumed to weigh 8165 kg (180,000 lbs) each.

TABLE 4–14

COST ESTIMATE FOR ALTERNATIVE 3C.2

ALTERNATIVE 3C.2: SILO DEMOLITION, REMOVAL, OFF–SITE DISPOSAL AT PERMITTED COMMERCIAL DISPOSAL FACILITY			
DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
CAPITAL COSTS			
DEMOLITION & REMOVAL	$3,980,300	$5,977,100	$9,957,400
TRANSPORTATION	$6,316,200		$6,316,200
DISPOSAL	$14,011,000	$18,463,400	$32,474,400
PACKAGING (20,625 PKGS. @ $955/PKG.)	$5,445,000	$14,251,900	$19,696,900
TOTAL CAPITAL	$29,752,500	$38,692,400	$68,444,900
RISK BUDGET (11.0%)	$3,272,800	$4,256,200	$7,529,000
SUBTOTAL	$33,025,300	$42,948,600	$75,973,900
CONTINGENCY (20.0%)	$6,605,100	$8,589,700	$15,194,800
TOTAL ESTIMATED INSTALLED COST	$39,630,400	$51,538,300	$91,168,700
TOTAL PRESENT WORTH COST (CAPITAL @ 7%)			$82,416,500

NOTES:

Costs are order of magnitude costs (–30% to +50% accuracy).
Present worth cost calculated based on the following time periods:
Construction (years): 2
O&M during construction (years): 0
Post–remediation O&M (years): 0

Disposal

- Packaged material would be disposed at a permitted commercial facility.
- Unit disposal cost was estimated as $1200/m^3$ ($34/ft^3$).

O&M cost

There are no short-term or long-term O&M costs associated with this alternative.

4.5 MONITORING AND MITIGATIVE MEASURES

Monitoring and mitigation measures would be used at the FEMP site during implementation of any of the action alternatives. These measures would provide a high degree of effectiveness in minimizing potential adverse impacts associated with the implementation of the alternatives. Depending on the alternative selected, DOE would prepare a Mitigation Action Plan (MAP) to track mitigation commitments made in the ROD for this Remedial Action, in accordance with DOE procedures for implementing NEPA (10 CFR 1021). For activities related to off-site disposal it is expected that similar measures would be implemented at the off-site facilities.

Alternatives 2A, 2B and 2C would involve the disposal of treated Operable Unit 4 waste material on-property. In all cases the appropriate design features would be engineered into the on-property disposal facilities. These features include a LC/DS, low permeability caps, and monitoring systems. Monitoring systems for groundwater would detect releases from the on-property disposal facilities and the data would support any decisions, if required, regarding the appropriate response action to be implemented. In addition, some loss of terrestrial habitat and wetlands would result from the construction activities and commitment of land to on-property disposal. Areas of terrestrial habitat disturbed during construction activities and not committed to on-property disposal would be revegetated. Mitigation measures would be taken to off-set losses to wetland areas incurred during construction of on-property disposal facilities.

Alternatives 3A, 3B, 3C.1 and 3C.2 would require the disposal of Operable Unit 4 waste material off site. Monitoring systems would be in place at NTS and the selected commercial facility to detect any releases from waste material. In addition, disposal facilities would be designed with the appropriate leachate collection/detection systems. The implementation of specific mitigation measures to off-set losses to biotic resources, wetlands, etc. would be the responsibility of the individual disposal sites.

With respect to general environmental monitoring at the FEMP site, air, surface water and groundwater would be monitored before, during, and after remedial activities. If adverse effects are detected in any of these media, work would be stopped until the effects are controlled and/or appropriate response actions are implemented.

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4.6 UNAVOIDABLE ADVERSE IMPACTS

A number of unavoidable adverse impacts (Table 4-15) would occur when any of the action alternatives are implemented. As stated in the alternatives and in Table 4-15, many of these impacts would only be temporary.

4.7 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Implementing remedial action Alternatives 2A, 2B and 2C (i.e., on-property disposal) would result in permanent commitment of on-property land for material disposal at the FEMP site. Land at NTS and the permitted commercial disposal site would be permanently committed for disposal for Alternatives 3A, 3B, 3C.1, and 3C.2.

Soil at the FEMP site and NTS would be disrupted by construction and excavation activities. Many impacts would be temporary, pending completion of remedial activities and restoration programs. The implementation of Alternatives 3A, 3B, 3C.1, and 3C.2 would temporarily disturb between 1.0 ha and 1.5 ha (2.5 and 3.5 acres) at the FEMP site (e.g., excavation and construction) and permanently disrupt approximately 10 ha (25 acres) at the NTS for a disposal facility. Alternatives 2A, 2B and 2C would disturb between 2.4 ha to 4.7 ha (6 acres to 11.6 acres) and 4.7 ha (11.6 acres) for waste disposal. All areas disturbed at the FEMP site would be regraded and revegetated.

Alternatives 2A, 2B, and 2C would disturb between 3.9 ha to 5.8 ha (9 to 14.3 acres) of terrestrial habitat at the FEMP site during excavation and construction activities. In addition, 2.4 to 4.7 ha (6 to 11.6 acres) would be permanently committed to disposal. The long-term impacts from the on-property disposal alternatives would be minimal (e.g., potential for temporary displacement of threatened and endangered species, and terrestrial biota). Terrestrial habitat at the off-site disposal areas (Alternatives 3A, 3B, 3C.1 and 3C.2) is limited and little displacement of species would be expected to occur.

Between 0.2 to 5.0 ha (0.5 to 12.35 acres) of forested wetlands would be affected by Alternatives 2A, 2B and 2C utilized for on-property disposal. If either alternative is selected, appropriate notification

TABLE 4-15

UNAVOIDABLE ADVERSE IMPACTS ON RESOURCES

Affected Resource	Impact Type
Soil and Geology	Soil at the FEMP site, NTS and a commercial disposal facility would be disrupted by construction and excavation activities. Many impacts would be temporary, pending completion of remedial activities and restoration programs. The implementation of Alternatives 3A and 3B would temporarily disturb between 1 to 1.5 ha (2 to 3.5 acres) at the FEMP (e.g., excavation and construction) and permanently disrupt approximately 5 ha (10 acres) at NTS or a disposal facility. Alternative 3C.2 would permanently commit approximately 5 ha (10 acres) land for disposal at a commercial facility. Alternatives 2A and 2B would commit 2.4 to 4.3 ha (1 to 2 acres) and 5.3 ha (13 acres). Alternative 2C would commit 4.7 ha (11.5 acres) of land at the FEMP site. All areas disturbed at the FEMP site would be regraded and revegetated. The regional geology of the FEMP site and surrounding area would not be affected by any of the alternatives. Implementation of Alternatives 3A, 3B, 3C.1 and 3C.2 would not affect the regional geology of NTS or the commercial disposal facility and surrounding areas.
Water Quality and Hydrology	Short-term impacts (e.g., release of sediment and fugitive dust) on water quality and hydrology would be minimal for all alternatives. Several alternatives would use regrading and revegetation around the silos to minimize potential water quality impacts. Institutional actions implemented around disposal facilities at the FEMP site (Alternatives 2A, 2B and 2C) would eliminate impacts to water quality and hydrology. Assuming monitoring and maintenance activities continue at NTS and the commercial disposal facility, no long-term impacts would be expected from waste disposal at NTS (Alternatives 3A, 3B, and 3C.1) or the commercial disposal facility (Alternative 3C.2).
Air Quality	Some temporary impacts to air quality at the FEMP site would result from fugitive dust emissions associated with construction and excavation activities (e.g., grading, compacting, loading). Lesser impacts would also be incurred from vehicle and equipment exhausts. These impacts are not expected to affect human health or the environment. No long-term impacts on air quality would be expected from activities associated with any alternatives. Disturbed areas would be restored (e.g., regraded and revegetated) after completion of the remedial activities, thus minimizing the potential for the fugitive dust release. Waste disposal facilities at all sites would be designed to prohibit emission from stored waste. Only in the case of an accident during remedial actions would appreciable air quality impacts occur.

TABLE 4-15
(Continued)

Affected Resource	Impact Type
Biotic/Ecological Resources	Short-term disturbance of on-site vegetation and riparian and aquatic habitat would be expected. Approximately 5.8 ha (14.3 acres) would be disturbed under Alternatives 2A and 2B. Alternative 2C would disturb between 4 to 5.3 ha (10 to 13 acres) of habitat at the FEMP site during excavation and construction activities. Alternative 2C would displace 4.2 ha (1.7 acres) of habitat. In addition, 2.4 to 3.2 ha (6 to 8 acres) would be permanently committed to disposal. The long-term impacts from the on-site disposal alternatives would be minimal (e.g., potential for temporary displacement of threatened and endangered species, terrestrial biota). Habitat at NTS and the commercial disposal facility (Alternatives 3A, 3B, 3C.1 and 3C.2) is limited and it is believed little displacement of species would occur.
Wetlands and Floodplains	Approximately 5 ha (12.35 acres) of wetlands at the FEMP site would be impacted by Alternatives 2A and 2B. Alternative 2C would impact approximately 0.2 ha (0.5 acre) utilized for on-property disposal. If either alternative is selected, appropriate notification and mitigation activities would be initiated. No wetlands or floodplains are present at NTS (Alternatives 3A, 3B, and 3C.1) or the commercial disposal facility (Alternative 3C.2).
Socioeconomics and Land Use	Most alternatives would result in minimal short-term impacts (e.g., increased traffic noise) to the socioeconomics and land use. The long-term socioeconomic and land use impacts for the FEMP site would be positive because the waste would be isolated and controlled, thus no changes from current land use would be expected. Several alternatives entail removing waste from the site, thus helping to eliminate impacts on future populations and economic growth at the FEMP site. Disposal of this waste at the NTS or a commercial disposal facility would not be expected to impact socioeconomics or land use. Total costs of each alternative considered ranged from approximately $0 to $60M. For this analysis it is assumed that all resources required for remedial activities, can be found within the thirteen county Consolidate Metropolitan Statistical Area (CMSA). The cumulative operating budget for the CMSA was approximately $805,000,000.00. Depending on the subunit alternatives chosen, the collectible revenue for the CMSA could increase up to approximately 8% over a 5 to 7-year period.

TABLE 4-15
(Continued)

Affected Resource	Impact Type
Visual Resources	Construction and excavation activities would result in some minor incremental increases over the current visual and aesthetic impacts of the former FEMP Production Area. Following completion of remedial action activities, some visual and aesthetic impact would remain (e.g., well-lighted, fenced disposal area), but there would be lower magnitude than current impacts at the FEMP site. Visual impacts would be reduced through the maintenance of a vegetative cover. The long-term impacts would be incremental for off-site disposal locations for Alternatives 3A, 3B, 3C.1, and 3C.2. Short-term impacts would be incurred at off-site locations for all of the action alternative during construction, excavation, and transportation activities. These impacts would be temporary and would cease following completion of remedial action activities and site restoration.
Noise	Ambient noise levels would temporarily increase as a result of construction, excavation, and transportation activities. All noise impacts would be temporary and would cease following completion of remedial activities.

and mitigation activities would be initiated. No wetlands or floodplains are present at the off-site facilities (Alternatives 3A, 3B, 3C.1 and 3C.2).

Consumptive use of geological resources (e.g., quarried rock, sand, and gravel) and petroleum products (e.g., diesel fuel and gasoline) would be required for removal, construction, and disposal activities of all the action alternatives. Supplies of these materials would be provided by the construction contractor. Additional fuel use would result from off-site transport of the materials. However, adequate supplies are available without affecting local requirements for these products.

The treatment processes for the action alternatives would require the consumptive use of materials and energy. The cement stabilization process would require additives such as cement and flyash. The vitrification process would be energy-intensive and require commitment of a considerable supply of electricity. Cement and flyash are readily available locally in the quantities required, and electricity can be obtained from the local utility.

The committed land would be actively monitored and maintained. Periodic monitoring of nearby surface water and groundwater from monitoring wells around the perimeter of the facility would be performed, and periodic site inspections would identify any damage to the above-grade disposal vault. Maintenance activities would be performed as necessary. Hence, no impacts to groundwater are expected to occur from Operable Unit 4 remedial activities.

4.8 IMPACTS OF POTENTIAL LOSS OF INSTITUTIONAL ACTIONS

To assess whether each of the alternatives achieve and maintain protection of human health (and the associated criteria of compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness), an FS risk assessment was performed employing the methodologies identified in the Risk Assessment Work Plan. The FS risk assessment is included as Appendix D of this report. To assess protectiveness, two viable land use scenarios were evaluated along with representative receptors in order to provide a boundary of risk information to decision makers. The land use scenarios examined included a Future Land Use without Continued Federal Ownership scenario and a Future Land Use with Continued Federal Ownership scenario. The assumptions for these scenarios are summarized below.

Future Land Use without Continued Federal Ownership Scenario

This scenario was examined to provide risk for the least restrictive future land use assumption. Under this scenario, the facility is assumed to revert to the primary land use of the land surrounding the FEMP site, a family farm. For this scenario, an on and off-property farmer is examined. For the on-property farmer, two receptors are examined, a Reasonable Maximum Exposure (RME) and a Central Tendency (CT) resident farmer. The RME resident farmer uses risk parameters to provide an upper bound estimate of the risk an on-property farmer could reasonably be expected to receive. Under the CT resident farmer receptor, risk parameters are adjusted as identified in Appendix D to provide an estimate of the risk the on-property farmer could reasonably be expected to receive under typical living conditions. For this land use scenario, active operations and maintenance are assumed to continue until site-wide remedial action objectives are attained. After this time, active maintenance is assumed to be discontinued. Five-year CERCLA statutory reviews are assumed to continue. The residue containment system is assumed to remain relatively unchanged with no direct intrusion into the waste materials occurring. Exfiltration from the capped residues is estimated to increase to 1.3 cm/yr to the underlying Great Miami Aquifer. The on-property farmer is assumed to withdraw his drinking, crop irrigation and livestock water from the Great Miami Aquifer from a point adjacent to the disposal vault or within the Operable Unit 4 boundary.

Future Land Use with Continued Federal Ownership Scenario

This scenario was examined to provide risk information for a viable future site land use which incorporates passive institutional controls. Under this scenario the FEMP site is assumed to remain under the ownership of the federal government. The government is assumed to continue to exercise its rights as owners of the property to preclude further development of the site. Continued federal ownership would preclude certain activities on the property including homesteading, farming, and the installation of domestic wells. Active access controls are assumed to be discontinued following the attainment of site remedial action objectives. To provide an upper bound estimate of the risk contribution reasonably expected to be received under this land use, a recreational user is examined in addition to the off-property farmer. The recreational user is assumed to be an individual who plays on the property as a child and uses the property less frequently for recreational purposes as an adult. Assumptions for operations and maintenance and exfiltration rates from the capped residues are consistent with the other land use scenario described above.

To evaluate the alternatives for attainment of overall protection of the environment, the remaining pathways to environmental receptors were examined to determine the degree to which the alternatives mitigate environmental degradation. Section 2.0 summarizes benchmark values which are considered

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to be protective of ecological receptors. These can be compared to contaminant concentrations determined by the fate and transport modeling conducted for assessing alternative performance. The prevention of degradation of the Great Miami Aquifer due to migration of contaminants from residual wastes and soils is a remedial action objective which is protective of both human health and the environment. Attainment of this objective can be measured by compliance with maximum contaminant levels (MCLs), proposed MCLs, and maximum contaminant level goals (MCLGs) established under the Safe Drinking Water Act (SDWA). Each alternative is also assessed for its short-term and long-term effects on soil and geology, water quality and hydrology, air quality, biotic resources, and wetlands and floodplains.

If any deterioration of containment system is detected, DOE would take any necessary actions to ensure the safety of the nearby environment. In the unlikely event that institutional controls are lost at some time in the distant future, deterioration of the containment system without corrective measures could result in the eventual release of contaminants and potential future impacts on human health and the environment under any of the alternatives.

For disposal on the FEMP site, the likelihood of protracted exposure at the above-grade disposal vault is low because the local community is expected to retain awareness of the site and permanent markers would be in place. To comply with ORC 3742.02, solid waste disposal facilities, such as the one proposed for on-site construction for Alternatives 2A, 2B, and 2C, would require in any conveyance deeds, a protective covenant to restrict future mining, drilling, and residential development.

At the FEMP site, deterioration of the multimedia caps over waste material could result in the release of radon gas and contaminated particulates to the air, and water infiltration into the cell could result in leaching of contaminated material to surface water and groundwater if the cap of foundation material is breached. Nearby individuals could be exposed to radiation if releases occurred. The impacts to human health at the FEMP disposal areas could be measurable because there are residents within 2 to 3 km (1 to 2 mi). Any material transported from the disposal area could be in a range where it could be in contact with humans. There could also be adverse human impacts due to intrusion into the facility if institutional controls are lost. In addition, contaminants released to off-site areas via surface water or groundwater transport could impact biota and habitats off site. The magnitude of the future impacts would depend on the extent of the release and on local land use conditions at the time it occurred.

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The overall potential environmental impacts of losing institutional controls after disposal at the ~~off-~~site location (NTS) would affect air quality, surface water, and groundwater quality. Air quality could be impacted by deterioration of the containment cap by exposing material to the air. Because the conditions at the off-site disposal areas are located in an arid climate with high wind velocities and little vegetation, a portion of any material exposed to the air could be suspended in air and transported for some distance, because there is little vegetation or terrain to act as a barrier. Dispersion of material, however, could be great because of high wind velocities. Impact to surface and groundwater would be minimal because of the lack of rainwater that could transport any material. Even though there is low annual rainfall, periodic and heavy rains could transport material to within a short distance from the disposal area. Groundwater would be impacted little because of the depth to groundwater and dry climate. Ecological impact would not occur to threatened and endangered species or other biotic resources unless they maintained a habitat within a short distance of the off-site disposal areas.

The impacts to human health at the off-site disposal areas would be small because the nearest resident to NTS is 30 to 40 km (19 to 25 mi) away. Any material transported from the disposal area would be at a more limited distance. There could be adverse human health impacts due to intrusion into the facility if institutional controls are lost. Because of the low population density of the area where the off-site disposal facilities are located, there should be no significant impact.

4.9 SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Implementation of any of the final action alternatives would require the short-term use of the FEMP site to support cleanup activities and the short-term commitment of depletable resources such as construction materials, petroleum-based products, and natural gas. All final action alternatives would involve the long-term commitment of land for material disposal at the FEMP site, NTS, or the permitted commercial disposal site. This commitment of land at any one of the three sites would be consistent with current land uses. The short-term commitments would be more than offset by the long-term gain that would result from this action, i.e., cleanup of the FEMP site to levels that are protective of human health and the environment. Following remediation, portions or all of the current site could be released for future uses, as appropriate, to enhance long-term productivity. However, a likely scenario is that portions of the site would be committed to disposal and would, therefore, be controlled and monitored. Thus, other portions of the site could be released for limited use.

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5.0 COMPARATIVE ANALYSIS

5.1 INTRODUCTION

Section 5 presents a comparative analysis of the final remedial action alternatives for Operable Unit 4 with respect to the CERCLA evaluation criteria described in Section 4.0. This analysis is the second stage of the detailed evaluation process and provides information which forms the basis for selecting a preferred remedial alternative for Operable Unit 4. The Proposed Plan, which is issued concurrently with this FS-EIS will identify DOE's preference for an Operable Unit 4 remedial action alternative and will solicit public comments as part of the modifying criteria evaluation used to document the selection of the final remedial alternative in the ROD. For this analysis, the evaluation criteria include two categories, threshold and primary balancing. More information concerning the evaluation criteria can be found in Section 4.1.2, Overview of the Detailed Analysis. The modifying criteria of state and community acceptance will be addressed in the ROD once formal comments on the FS-EIS and Proposed Plan have been received and a final remedy selection decision is being made. These two criteria are not addressed in this comparative analysis.

The threshold category contains the two criteria that must be satisfied by the selected alternative:

- Overall protection of human health and the environment
- Compliance with ARARs

These criteria are of greatest importance in the comparative analysis because they reflect the key statutory mandates of CERCLA, as amended. If an alternative does not satisfy both of these criteria, it cannot be carried forward to the primary balancing category and is not eligible to be selected as the final remedy.

The primary balancing category contains the five criteria under which the relative advantages and disadvantages of the alternatives are compared to determine the most appropriate remedy:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

The first and second criteria address the statutory preference for treatment as a principal element of the remedy and the bias against off-site land disposal of untreated material. Together with the third

and fourth criteria, they form the basis for determining the general feasibility of each potential remedy and determining whether costs are proportional to the overall effectiveness, considering both the cleanup period and the time following cleanup. By this means, it can be determined whether a potential remedy is cost-effective.

Consistent with the format of the detailed analysis of alternatives in Section 4.0, a comparative analysis under the threshold and primary balancing criteria for Subunits A, B, and C is presented in Sections 5.2, 5.3, and 5.4, respectively. Tables 5-1 through 5-3 summarize the comparative analysis for each subunit. Table 5-4 presents a comparison of the environmental impacts associated with each alternative. Table 5-5 summarizes the long-term and short-term radiological incremental lifetime cancer risks estimated for each alternative. Short-term risks are provided to assess the potential impacts to the public and remedial action workers during implementation of the alternative. The basis for determining the risks are detailed in Appendix D. The results of the comparative analysis are summarized in Appendix G.

The preferred alternative for Operable Unit 4 to be described in the Proposed Plan is assembled by combining the preferred alternatives selected from each of Subunits A, B, and C. This comparative analysis provides the basis for the selection.

5.2 SUBUNIT A

Subunit A alternatives compared include:

- Alternative 0A - No Action
- Alternative 2A - Removal, Stabilization (Cem/Vit), On-Property Disposal
- Alternative 3A.1 - Removal, Stabilization (Cem/Vit), Off-Site Disposal at NTS

A summary of the Subunit A comparative analysis results is presented in Table 5-1.

5.2.1 Threshold Criteria

5.2.1.1 Overall Protection of Human Health and the Environment

Assessment of protectiveness for Operable Unit 4 alternatives assumes a reasonable future land use scenario which incorporates passive institutional controls. Under this scenario, the FEMP site is assumed to remain under the ownership of the federal government, precluding such activities as

TABLE 5-1

SUBUNIT A - COMPARATIVE ANALYSIS

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility or Volume Through Treatment	Short-Term Effectiveness	Implementability	Present Worth Cost
0A - No Action	Not protective	Does not meet all ARARs	Not effective or permanent	No treatment	High	Reliable Technology Easy	-0-
2A/Vit - Removal, Vitrification, On-Property Disposal	Protective[1]	Complies with all ARARs[2]	Effective and reliable	Reduces toxicity, organics, mobility, and volume	Medium	Innovative Technology Moderately Difficult	$43.6M
2A/Cem - Removal, Cement Stabilization, On-Property Disposal	Protective[1]	Complies with all ARARs[2]	Effective and reliable	Reduction of mobility	Medium	Reliable Technology Easy	$74.0M
3A.1/Vit - Removal, Vitrification, Off-Site Disposal - Nevada Test Site	Protective	Complies with all ARARs	Effective and most reliable	Reduces toxicity, mobility, and volume	Medium	Innovative Technology Moderately Difficult	$42.2M
3A.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - Nevada Test Site	Protective	Complies with all ARARs	Effective and most reliable	Reduces mobility	Medium	Reliable Technology Difficult	$70.1M

[1]Assessment of protectiveness adopts the use of continued federal government ownership and evaluates risk to the off-property farmer.
[2]Assumes substantive technical requirements for Ohio disposal facility siting are met.

NA - Not Applicable

TABLE 5-2

SUBUNIT B - COMPARATIVE ANALYSIS

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility or Volume Through Treatment	Short-Term Effectiveness	Implementability	Present Worth Cost
0B - No-Action	Not protective	Does not meet all ARARs	Not effective or permanent	No treatment	High	Reliable Technology Easy	-0-
2B/Vit - Removal, Vitrification, On-Property Disposal	Protective[1]	Complies with all ARARs[2]	Effective and reliable	Reduces toxicity (organics), mobility, and volume	Medium	Innovative Technology Moderately Difficult	$28.0M
2B/Cem - Removal, Cement Stabilization, On-Property Disposal	Protective[1]	Complies with all ARARs[2]	Effective and reliable	Reduces mobility	Medium	Reliable Technology Easy	$37.4M
3B.1/Vit - Removal, Vitrification, Off-Site Disposal - NTS	Protective	Complies with all ARARs	Effective and most reliable	Reduces toxicity (organics), mobility, and volume	Medium	Innovative Technology Moderately Difficult	$26.7M
3B.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - NTS	Protective	Complies with all ARARs	Effective and most reliable	Reduces mobility	Medium	Reliable Technology Difficult	$34.2M

[1]Assessment of protectiveness adopts the use of continued federal government ownership and evaluates risk to recreational users and the off-property farmer.
[2]Assumes substantive technical requirements for Ohio disposal facility siting are met.

NA - Not Applicable

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TABLE 5-3

SUBUNIT C - COMPARATIVE ANALYSIS

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence Through Treatment	Reduction of Toxicity, Mobility or Volume	Short-Term Effectiveness	Implementability	Present Worth Cost
0C - No-Action	Not protective	Does not meet all ARARs	Not effective or permanent	No treatment	High	Reliable Technology Easy	-0-
2C - Demolition, Removal, On-Property Disposal	Protective[1]	Complies with all ARARs[2]	Effective and most reliable	No treatment	High	Reliable Technology Easy	$58.0M
3C.1 - Demolition, Removal, Off-Site Disposal - NTS	Protective	Complies with all ARARs	Effective and most reliable	No treatment	Medium	Reliable Technology Moderately Difficult	$59.5M
3C.2 - Demolition, Removal, Off-Site Disposal - Permitted Commercial Disposal Site	Protective	Complies with all ARARs	Effective and most reliable	No treatment	Medium	Reliable Technology Moderately Difficult	$82.4M

[1]Assessment of protectiveness adopts the use of continued federal government ownership and evaluates the risk to the off-property farmer.
[2]Assumes substantive technical requirements for Ohio disposal facility siting are met.

NA - Not Applicable

TABLE 5-4

SUMMARY OF ENVIRONMENTAL IMPACTS FOR REMEDIAL ALTERNATIVES

ALTERNATIVE	SOIL AND GEOLOGY[1]	WATER QUALITY AND HYDROLOGY	AIR QUALITY	BIOTIC RESOURCES	WETLANDS AND FLOODPLAINS	SOCIOECONOMICS AND LAND USE	CULTURAL RESOURCES	TRANSPORT IMPACTS
SUBUNIT A								
0A	No Impacts	Potential release to surface and groundwater	Potential release to ambient air	Potential exposure to ecological receptors	Potential release to 0.32 ha of wetlands	Restriction of site's future use	No impacts	No impacts
2A Vit/Cem	4.3/5.8 ha temporarily disturbed 2.8/4.3 ha committed to disposal	minor impacts assuming monitoring and controls	Fugitive dust emissions Minor impacts assuming controls	5.8 ha disturbed 2.6 ha terrestrial habitat lost	5.0 ha forested wetland lost	Up to 5.0% increase in CMSA revenue Restricted site use	No impact due to identification of management	Fugitive dust due to on-property movement
3A Vit/Cem	1.5 ha temporarily disturbed Approximately 5.0 ha committed at NTS	Minor impacts due to geology at NTS	Fugitive dust emissions Minor impacts assuming controls	3.2 ha disturbed Minor impacts at NTS	No impacts	Up to 5.0% increase in CMSA revenue	No impact due to identification and management	ILCR of 2.2×10^{-10} along route to NTS

TABLE 5-4
(Continued)

ALTERNATIVE	SOIL AND GEOLOGY[1]	WATER QUALITY AND HYDROLOGY	AIR QUALITY	BIOTIC RESOURCES	WETLANDS AND FLOODPLAINS	SOCIOECONOMICS AND LAND USE	CULTURAL RESOURCES	TRANSPORT IMPACTS
SUBUNIT B								
0B	No impacts	Potential release to surface and groundwater	Potential release to ambient air	Potential exposure to ecological receptors	Potential release to 0.32 ha of wetlands	Restriction of site's future use	No impacts	No impacts
2B Vit/Cem	3.9/4.5 ha temporarily disturbed 2.4/3.0 ha committed to disposal	Minor impacts assuming monitoring and controls	Fugitive dust Minor impacts assuming controls	5.8 ha disturbed 2.6 ha terrestrial habitat lost	5.0 ha forested wetlands lost	Up to 4.0% increase in CMSA revenue Restricted site use	No impact due to identification and management	Fugitive dust due to on-property movement
3B Vit/Cem	1.5 ha temporarily disturbed Approximately 5.0 ha committed at NTS	Minor impacts due to geology at NTS	Fugitive dust Minor impacts assuming controls	3.2 ha habitat disturbed Minor impacts at NTS	No impacts	Up to 4.0% increase in CMSA revenue	No impact due to identification and proper management if required	ILCR of 9×10^{12} along route to NTS

TABLE 5-4
(Continued)

ALTERNATIVE	SOIL AND GEOLOGY[1]	WATER QUALITY AND HYDROLOGY	AIR QUALITY	BIOTIC RESOURCES	WETLANDS AND FLOODPLAINS	SOCIOECONOMICS AND LAND USE	CULTURAL RESOURCES	TRANSPORT IMPACTS
SUBUNIT C								
0C	No impacts	Potential runoff to surface water	Potential for airborne contamination	Potential exposure to ecological resources	Potential runoff to 0.32 ha of wetlands	Restriction of site's future use Restricted site use	No impacts	No impacts
2C	4.7 ha temporarily disturbed 5.7 ha committed to disposal at FEMP	Minor impacts assuming monitoring and controls	Fugitive dust Minor impacts assuming controls	4.2 ha terrestrial habitat lost	0.20 ha drainage ditch wetlands lost	Up to 4.0% increase in CMSA revenue	No impact due to identification and proper management if required	Fugitive dust due to on-property movement
3C.1	1.0 ha temporarily disturbed Approximately 5.0 ha committed at NTS	Minor impacts due to geology at NTS	Fugitive dust Minor impacts assuming controls	Minor impacts at NTS	No impacts	Up to 4.0% increase in CMS revenue	No impact due to identification and proper management if required	ILCR of 4.8×10^{12} along route to NTS
3C.2	1.0 ha temporarily disturbed Approximately 5.0 ha committed at off-site permitted commercial disposal site	Minor impacts due to geology at off-site permitted commercial disposal site	Minor impacts at off-site permitted commercial disposal site	Minor impacts at off-site permitted commercial disposal site	No impacts	Up to 4.0% increase in CMSA revenue	No impact due to identification and proper management if required	ILCR of 2.4×10^{12} along route to off-site permitted commercial disposal site

[1]Commitment of acres is at FEMP unless indicated otherwise.

TABLE 5-5

SUMMARY OF LONG-TERM AND SHORT-TERM RADIOLOGICAL INCREMENTAL LIFETIME CANCER RISKS

Alternative	Future Land use w/continued Federal Ownership	Future Land Use w/o Cont. Fed. Ownership	Short-term Risks	
	Off-Property Farmer	On-Property Farmer	Public	Worker[a]
SUBUNIT A - SILOS 1 AND 2 CONTENTS				
0A - No Action	1.0×10^{-4}	≈ 1[c]	N/A	N/A
2A/Vit - Removal, Vitrification, On-Property Disposal	B.S.L.[e]	B.S.L.	<.5 pCi/l[j]	4.0×10^{-4}
2A/Cem - Removal, Cement Stabilization, On-Property Disposal	B.S.L.	B.S.L.	<0.5 pCi/l	4.0×10^{-4}
3A.1/Vit - Removal, Vitrification, Off-Site Disposal at Nevada Test Site	N/A[f]	N/A[f]	8.3×10^{-10}	4.0×10^{-4}
3A.1/Cem - Removal, Cement Stabilization, Off-Site Disposal -Nevada Test Site	N/A[f]	N/A[f]	4.3×10^{-10}	4.0×10^{-4}
SUBUNIT B - SILO 3 CONTENTS				
0B - No-Action	1.0×10^{-4}	≈ 1[c]	N/A	N/A
2B/Vit - Removal, Vitrification, On-Property Disposal	B.S.L.	B.S.L.	<0.5 pCi/l	4.1×10^{-5}
2B/Cem - Removal, Cement Stabilization, On-Property Disposal	B.S.L.	B.S.L.	<0.5 pCi/l	4.1×10^{-5}
3B.1/Vit - Removal, Vitrification, Off-Site Disposal at Nevada Test Site	N/A[f]	N/A[f]	1.7×10^{-11}	4.1×10^{-5}
3B.1/Cem - Removal, Cement Stabilization, Off-Site Disposal at Nevada Test Site	N/A[f]	N/A[f]	1.9×10^{-11}	4.1×10^{-5}

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TABLE 5-5
(Continued)

Alternative	Future Land use w/continued Federal Ownership	Future Land Use w/o Cont. Fed. Ownership	Short-term Risks	
	Off-Property Farmer	On-Property Farmer	Public	Worker[a]
SUBUNIT C - SILOS 1, 2, AND 3 STRUCTURES, SOILS AND DEBRIS				
0C - No-Action	4.0×10^{-5}	5×10^{-4}	N/A	N/A
2C - Demolition, Removal, On-Property Disposal	B.S.L.	B.S.L.	<0.5 pCi/l	7.6×10^{-7}
3C.1 - Demolition, Removal, Off-Site Disposal at NTS	N/A[f]	N/A[f]	4.8×10^{-12}	7.6×10^{-7}
3C.2 - Demolition, Removal, Off-Site Disposal at a permitted commercial disposal site	N/A[f]	N/A[f]	2.4×10^{12}	7.9×10^{-7}

[a]Worker receiving highest risk (worker near the soil/berm excavation activities or remediation worker)
[b]Total radiological ILCR from air and groundwater pathways, assuming the future source-term scenario. ILCR includes contributions from Subunits A and B combined.
[c]Total radiological ILCR from groundwater, air, silo contents, and soil exposure pathways, assuming the future source term scenario. ILCR includes contributions from Subunits A and B combined.
[e]Below screening level. (10^{-6} excess cancer risk and HICI)
[f]Long-term risk pathways are eliminated because the material is disposed of off property.
[g]Total radiological ILCR from air exposure pathways impacted by Subunit C source term, assuming the current source term scenario.
[h]Subunit D is not quantitatively evaluated because of the absence of a source term.
[i]Long-term risk pathway eliminated by cap depth and institutional actions
[j]Exposure to public from radon.

homesteading, farming, and the installation of domestic wells. Two potential receptors examined under this scenario are an off-property farmer and a recreational user.

To assess each alternative's long-term effectiveness for maintaining protective levels, a less restrictive future land use scenario was assumed. Under this scenario, the federal government loses control of the FEMP site and the facility is assumed to revert to the primary use of the surrounding land, the family farm. For this scenario, an on- and off-property farmer receptor are examined. Appendix D provides detail on the assumptions used to develop the scenarios and examine risks to the receptors.

Table 5-5 summarizes both the long-term and short-term radiological incremental lifetime cancer risks for each subunit alternative. Short-term risks are provided to assess the potential impacts to the public and remedial action workers during implementation of each alternative.

All of the Subunit A alternatives, except 0A - No Action, would provide overall protection of human health and the environment. All of the action alternatives (2A/Vit, 2A/Cem, 3A.1/Vit, and 3A.1/Cem) would limit exposures to contaminants by removing the sources of contamination, treating the source materials, and placing the treated materials either in an on-property above-grade disposal vault or an off-site facility (NTS) owned by DOE. The basic differences among the action alternatives are the treatment options (vitrification or cement stabilization) and the disposal options (on property or off site).

Both treatment options provide a stabilized material which reduces the potential for contaminant migration. Treatability study results demonstrate that the vitrified waste form would be expected to have greater durability over time, thereby reducing the potential for contaminant migration to human and ecological receptors. Short-term risks to the public and workers associated with the implementation of both treatment options are similar. Vitrification is considered to pose a higher risk to workers because of high operating temperatures and limited field experience.

The off-site disposal location would be the NTS facility which has been used selectively by DOE for disposal of low-level radioactive waste. The NTS incorporates engineering and institutional controls to ensure protectiveness and is located in a climatic, demographic, and hydrogeologic setting which favors minimization of contaminant migration to both human and environmental receptors. In the long-term event of degradation of engineered features or loss of institutional controls, these site characteristics coupled with the treated waste material would ensure continued protectiveness.

The on-property disposal option would employ an above-grade disposal vault designed for a life of 1,000 years with no active maintenance. The vault would prevent exposure to direct radiation and would minimize infiltration of water and subsequent leaching of contaminants from the treated material into the Great Miami Aquifer. The vault design would incorporate an intruder barrier to inhibit purposeful or inadvertent human destruction of its protective features. The FEMP site demographic characteristics, as compared to NTS, provide a higher probability of purposeful or inadvertent intrusion into the vault. Potential direct radiation doses to the intruder could be significant.

As the result of additives which increase the volume of untreated waste by up to 216 percent, Alternative 2A/Cem would provide more protection from direct radiation than Alternative 2A/Vit in the event of a breach of the intruder barrier. The tradeoff is that the increased waste volume requires a much larger, more costly disposal vault.

Short-term risks to the public and workers are slightly greater for the off-site disposal option due to the increased risks of transportation accidents resulting in injuries or radiation exposure. The greatest short-term risk of this type is associated with Alternative 3A.1/Cem because of the increased volume of treated material requiring transportation off site.

The nature and extent of impacts to biota from implementing Alternatives 2A/Vit and 2A/Cem would be similar. Both alternatives involve site preparation and construction for a processing facility and disposal vault, construction of a hydraulic mining device work platform, removal of the Silos 1 and 2 contents, and stabilization of the contents. Potential environmental impacts associated with implementing Alternatives 2A/Vit and 2A/Cem include the permanent loss of some on-site habitats. Short-term impacts include the temporary loss of habitats at the FEMP site and possible impacts of accidental spills of construction and operational materials. Mitigative measures would be employed to minimize these short-term risks.

Environmental impacts associated with implementing alternatives 3A.1/Vit and 3A.1/Cem include those identified with alternatives 2A/Vit and 2A/Cem, in addition to potential impacts from transportation to and disposal activities at NTS.

Alternative 0A would not provide adequate overall protection of human health and the environment. Alternative 0A would not eliminate, reduce, or control the migration of contaminants to human and

environmental receptors. Based on the results of the BRA presented in the RI Report for Operable Unit 4 (DOE 1993a), the no-action alternative would not be adequately protective. Over the long term, risks to human health and the environment would increase with loss of current site access controls.

5.2.1.2 Compliance with ARARs

Except for Alternative 0A - No Action, the attainment of pertinent ARARs under each of the Subunit A alternatives would be comparable. A comprehensive list of potential ARARs is presented in Appendix F. Key requirements are discussed in Section 4.0 within the evaluation of each alternative against this criterion. The following summarizes those evaluations.

Chemical-Specific ARARs

All of the action alternatives (2A/Vit, 2A/Cem, 3A.1/Vit, and 3A.1/Cem) for Subunit A meet the chemical-specific ARARs associated with potential releases to groundwater, air, and surface water. As demonstrated by fate and transport modeling, the Subunit A action alternatives would attain the concentration-based limits for specific chemicals under 40 CFR 141.11, .61, 191.16, and 40 CFR 264.94. Additionally, dose-based requirements for the protection of potential public receptors using affected groundwaters are defined in DOE Order 5400.5 and 40 CFR 191.16. DOE Order 5400.5 limits the allowable annual effective dose equivalent, from all pathways including groundwater, to any member of the public from exceeding 100 mrem. As specified in 40 CFR 191.16, the annual dose equivalent to the whole body or critical organ is limited to 4 mrem, assuming the consumption of 2 liters per day of potable groundwater.

Guidance is provided in 40 CFR 257.3-4 and 40 CFR 264.94 as to the point of compliance for demonstrating whether the groundwater protection requirements for inorganic and organic contaminants would be attained. The most restrictive requirements for these constituents appears in 40 CFR 264.94 which requires the disposal vault to meet the concentration-based limits in the uppermost aquifer underlying the waste management area beyond the point of compliance. The uppermost aquifer and point of compliance is the Great Miami Aquifer. One thousand year fate and transport modeling of uranium, the principal groundwater constituent of concern, indicates the uranium concentration would not exceed the proposed 20 μg/L MCL, defined in 40 CFR 141, at the point of compliance.

The most critical chemical-specific ARAR relative to airborne releases for Subunit A materials relates to radon. The maximum permissible surface release rate of radon-222, as specified in NESHAP, 40 CFR 61 Subpart Q, is 20 pCi/m^2/s, surface averaged. This requirement is supplemented by 40 CFR 192.02(b) Subpart A which requires that the concentration of radon-222 in air at or above any location outside the disposal site not increase the annual average by more than 0.5 pCi/L. Requirements for other radionuclides are established in 40 CFR 61 Subpart H and DOE Order 5400.5, Chapter III. Compared to the untreated Subunit A materials, the vitrified waste form is more effective in reducing radon emanation than the cement stabilized form. Engineered barriers and packaging associated with the disposal of treated materials, in either form, would effectively control the radon flux. A radon treatment system would be employed during treatment operations for both Alternative 2A/Vit and 2A/Cem to control radon release over the short term.

Alternative 0A - No Action would not meet 40 CFR 161 radon flux requirements based on the current configuration of Silos 1 and 2. Also, several criteria for the protection of groundwater would not be met. In the event existing access controls were discontinued and a family farm was established on the FEMP site, exposure limits embodied within DOE Order 5400.5 for members of the general public could be exceeded.

Location-Specific ARARs

Alternatives 3A.1/Vit and 3A.1/Cem would comply with all pertinent location-specific ARARs. Included would be those associated with the protection of wetlands (40 CFR 258.12, 40 CFR 6.302), floodplains (40 CFR 257.3-1, 40 CFR 264.18, 40 CFR 6.302, 10 CFR 1022), and endangered species (50 CFR 200 and 204) during the on-property treatment of materials. Disposal facility siting criteria would not be applicable nor relevant and appropriate to Alternatives 3A.1/Vit and 3A.1/Cem as they propose off-site disposal.

Alternatives 2A/Vit and 2A/Cem would meet all of the ARARs cited above; in addition, they would meet the ARARs associated with construction of an on-site disposal vault. In particular, the State of Ohio maintains a number of solid waste disposal design considerations within OAC 3745-27-07. Through the definition of an Area of Contamination for Operable Unit 4, which includes the area encompassing the operable unit boundary and any proposed on-property treatment and disposal areas, these requirements would be considered relevant and appropriate to the implementation of Alternatives 2A/Vit and 2A/Cem. The OAC requirements contain setback requirements pertaining to the distance of the disposal vault from the property line, as well as the distance from the nearest

domicile or water supply well. An additional requirement specifies a distance of 4.5 m (15 ft) from the bottom of the liner system and the top of the uppermost aquifer.

OAC 3745-27-07 (B)(5) prohibits solid waste disposal facilities from being constructed over sole source aquifers. Exemptions to this requirement have been granted on the basis of technical considerations including: presence of a significant thickness of low permeablilty material between the disposal vault liner and the aquifer; no significant interconnection between the aquifer and any significant zones of saturation that exist above the aquifer; and, no adverse impact to human health or safety or the environment. The disposal facility proposed for Alternatives 2A/Vit and 2A/Cem would meet those technical considerations. A discussion of the data to support this position is in Section 3.2.2.1 and Appendix D.

Alternative 0A - No Action would not meet all location-specific ARARs. In particular, Subunit A materials are currently at a location on the FEMP site where the glacial overburden is thin compared to the proposed location for the disposal vault. Accordingly, the technical exemption requirements for locating a disposal facility over a sole-source aquifer would not be met.

Action-Specific ARARs

All Subunit A action alternatives would comply with all pertinent action-specific ARARs. For Alternatives 2A/Vit and 2A/Cem, the above-grade disposal vault would incorporate the design requirements for the disposal of uranium mill tailings (40 CFR 192), and hazardous waste under RCRA, (i.e., the TSDF requirements under 40 CFR 264). As a result of elevated direct penetrating radiation associated with the treated Subunit A residues, the prescriptive intruder protection requirements defined in 10 CFR 61.7 have been adopted for on-property disposal.

The design of the on-property disposal vault would also include appropriate engineered features that satisfy the requirements of the Clean Water Act (40 CFR 125.100 and 104), the Ohio Water Quality Standards, and RCRA Subtitle C - Hazardous Waste (40 CFR 262.11, 261.7, 262.20, and the 264 Subparts identified in Appendix F).

An action-specific ARAR/TBC requirement particular to on-property disposal of Subunit A material at the FEMP site is 40 CFR 191 (Standards for the Management, Storage and disposal of Spent Nuclear, High Level and Transuranic Wastes). In October 1990, EPA directed DOE to consider 40 CFR 191 Subpart A (dealing with the storage and management of waste) as an ARAR to the on-property

portions of remedial activities involving the K-65 residues, and to consider Subpart B (pertaining to waste disposal) as a TBC requirement for on-property Subunit A disposal alternatives.

40 CFR 191 Subpart A specifies a public dose limit to be complied with during waste storage and remediation operations. Estimates of the dose to the public calculated for the short-term risk assessment indicate that exposures would be a small fraction of the one mrem/yr limit (Appendix D).

40 CFR 191.13 (in Subpart B) set forth containment requirements that the disposal system must be designed to provide a reasonable expectation that specified cumulative radionuclide-specific release limits would not be exceeded for 10,000 years. In order to demonstrate compliance with such a requirement, a probabilistic assessment of all events that could result in a release of waste material from the disposal vault would need to be undertaken, along with an assessment of the impact each identified release would have on the accessible environment. On this basis, the likely compliance or noncompliance of Alternatives 2A/Vit and 2A/Cem could not be assessed. All other provisions of 40 CFR 191 would be attained by these alternatives.

Alternatives 3A.1/Vit and 3A.1/Cem would comply with all pertinent action-specific ARARs identified in Appendix F, including 40 CFR 191 Subpart A. Hazardous waste transport requirements would be complied with by following the regulations under 40 CFR 262 and the appropriate DOT shipping standards under 49 CFR 172 and 173.

5.2.2 Primary Balancing Criteria

Those alternatives that satisfy the threshold criteria comparative analysis are carried forward for further comparative analysis under the primary balancing criteria. The no-action alternative, Alternative 0A, will be carried forward as the baseline alternative for comparison purposes in accordance with the NCP. Alternatives that will be carried forward will include:

- Alternative 0A - No Action
- Alternative 2A/Vit -Removal, Vitrification, On-Property Disposal
- Alternative 2A/Cem - Removal, Cement Stabilization, On-Property Disposal
- Alternative 3A.1/Vit - Removal, Vitrification, and Off-Site Disposal at NTS
- Alternative 3A.1/Cem - Removal, Cement Stabilization, and Off-Site Disposal at NTS

5.2.2.1 Long-Term Effectiveness and Permanence

All Subunit A alternatives, with the exception of Alternative 0A - No Action, would ensure long-term protectiveness to human health and the environment. For all alternatives, projected FEMP site residual risk to viable receptors (off-property farmer and recreational user) would be less than 10^{-6} ILCR, and no non-carcinogenic effects (HI less than 0.2) would be indicated for either receptor.

Alternatives 3A.1/Vit and 3A.1/Cem include removal and treatment of the source materials, followed by transportation and off-site disposal at NTS. Removal and treatment of the Subunit A materials eliminates the potential for exposure to direct radiation, and mitigates the migration of constituents to the air, soil, and water. Treatability studies demonstrated that both the vitrified and the cement-stabilized material exhibits reduced leachability of constituents compared to the untreated materials. Both treated materials have TCLP results below RCRA limits. Vitrification of the untreated materials reduced radon emanation significantly and reduced the residue volume by approximately 50 percent.

Vitrification is an innovative technology which has not been previously applied to the stabilization of waste materials at the same scale as contemplated under Alternative 2A/Vit. The results of treatability tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics. Cement stabilization is a proven technology that has been previously applied to the stabilization of similar waste materials as those contemplated under Alternative 2A/Cem. The performance characteristics of the cement-stabilized material in reducing leachability are generally comparable to those of the vitrified material; however, degradation and leachability results for some constituents indicate that cement stabilization is not an irreversible treatment process.

Off-site disposal at NTS would provide protection by eliminating access to the treated materials and preventing migration of constituents from the materials. The NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant migration, and direct contact with contaminants. Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. As the result of a low average annual precipitation and depths to groundwater ranging from 157 - 600 m (515 - 2000 ft) below ground surface, impacts to human health and the environment would be mitigated in the event that engineering and institutional controls fail.

Long-term environmental impacts under Alternatives 3A.1/Vit and 3A.1/Cem would include those associated with the removal and treatment activities performed at the FEMP and disposal activities at the NTS. There are no long-term environmental impacts at the FEMP site pertaining to the removal and treatment processes. Long-term environmental impacts at NTS would include some permanent disturbance of soils (i.e., acquisition of borrow material) associated with disposal activities. No significant long-term impacts would be expected for water quality and hydrology, air quality, biotic resources, socioeconomics and land use, or cultural resources. No wetland or floodplain areas have been delineated at the NTS.

Alternatives 2A/Vit and 2A/Cem include the removal and treatment of source materials followed by on-property disposal in an above-grade disposal vault. The long-term effectiveness afforded by the removal and treatment processes would be identical for both Alternatives 2A/Vit and 2A/Cem. The design features of the disposal vault would provide effective long-term containment of the treated material. The vault would use proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low-level radioactive waste under both DOE and NRC programs, and uranium mill tailings under the DOE UMTRCA and FUSRAP. Fate and transport modeling was performed to assess leaching of constituents under degradation of the facility (slight degradation of components over 1000 years). The results of this modeling, based on conservative assumptions for infiltration rates, show that the leaching of constituents would not pose a risk to off-site receptors. Loss of institutional controls in combination with disposal vault failure over the long term (more than 1,000 years) could result in potential contaminant migration or direct exposure to the treated material by future human and ecological receptors. Exposures to receptors through these pathways would be expected to initially be minimal due to the positive attributes of the treated materials. Direct radiation exposure could be significant in the event that the disposal vault is breached.

Long-term environmental impacts associated with construction of the on-property disposal vault for Alternatives 2A/Vit and 2A/Cem include permanent disruption of up to 5.8 ha (14.3 acres) of land. No significant long-term impacts are expected for water quality and hydrology, air quality, socioeconomics, or cultural resources. A potential habitat for threatened and endangered species has been identified in the area proposed for the disposal vault. This same area has been identified as forested wetlands. No floodplains would be permanently altered as the result of implementing either of these two alternatives.

Alternative 0A - No Action would not be protective of human health and the environment in the long term because it would not prevent exposure to the Silos 1 and 2 residues. Silo collapse and subsequent loss of containment would lead to increased contamination levels in air, soils, groundwater, surface water, and sediments. Based on the results of the BRA, Alternative 0A would not be adequately protective under all evaluated land use scenarios, except current land use conditions with continuation of access controls. For these land use scenarios, at least one receptor receives risks which are calculated to exceed 10^{-4}.

5.2.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 2A/Vit, 2A/Cem, 3A.1/Vit, and 3A.1/Cem would employ one of two treatment processes for the Subunit A residues. Alternatives 2A/Vit and 3A.1/Vit would use vitrification to physically bind the constituents in a glass-like matrix which would significantly reduce contaminant mobility. Vitrification also would reduce radon emanation significantly. Treatability tests of the vitrification process have demonstrated that an overall material volume reduction of about 59 percent could be expected. The high operating temperatures of the vitrification process have also been shown to effectively destroy any organic compounds present in the residue matrix. The effects of vitrification as a treatment are essentially irreversible.

TCLP tests were conducted on both the untreated and vitrified form of the residues. The results showed that the leachate concentrations of hazardous metals were below regulatory limits for all glasses made during the bench-scale tests. Product Consistency Tests (PCT) were also performed on the vitrified materials. PCT leach testing demonstrated a high degree of durability for the vitrified materials. Literature data on the leachability of the vitrified product from a variety of material types indicate similar leach resistance. Data on the long-term stability of vitrified material are not available, and the life expectancy of the vitrified product is difficult to estimate from short-term leach rates; however, on the basis of the longevity of volcanic glass (a natural analog to the vitrified product), the vitrified product would be expected to withstand environmental exposure for thousands of years.

Alternatives 2A/Cem and 3A.1/Cem would use the cement stabilization process to treat the Subunit A residues. Cement stabilization would reduce the mobility of constituents by binding them into a cement mixture. Radon emanation would be reduced somewhat, but not as much as through the vitrification process. Various reagents would be added to the mixture to improve the characteristics of the final treated material, e.g., improved metals adsorption, increased leachability resistance,

decreased effects of process inhibitors. The addition of reagents to the untreated residues causes an overall increase in volume ranging from 136 to 216 percent.

TCLP tests were conducted on both the untreated and cement stabilized form of the residues. The results showed that the leachate concentrations of RCRA metals were below regulatory limits for all cement stabilized forms produced during the bench-scale tests.

Treatability tests have been performed to determine the best formulations resulting in a product having the most favorable leach resistance and durability characteristics. Static leach tests were generally the same order of magnitude as for the TCLP leachate results. Degradation and durability testing indicate that cement stabilization is not an irreversible process.

Alternative 0A - No Action does not include treatment.

5.2.2.3 Short-Term Effectiveness

For the Subunit A action alternatives, the various removal, treatment, and disposal activities would result in increased short-term exposures compared with Alternative 0A. The short-term effectiveness of removal is expected to be the same among the alternatives for Subunit A that include removal. The risks from transportation accidents would be incrementally higher for the cement stabilization alternatives than for the vitrification alternatives because of the larger volume of material.

Short-term impacts associated with the action alternatives would include temporary disruption of approximately 3.2 ha (7.8 acres) of land at the FEMP site. Increased fugitive dust during excavation activities and the potential for minor impacts to biota and wetlands [0.36 ha (0.9 acres)] does exist. However, the appropriate engineering controls would minimize these potential short-term impacts. All transportation to NTS would be in compliance with DOT and DOE guidelines.

The time required to implement any of the removal and treatment alternatives is estimated to be approximately six to seven years.

The short-term effectiveness for Alternative 0A would remain unchanged from current conditions so that no significant changes in potential exposure are expected. The estimated risks are summarized in Appendix G.

5.2.2.4 Implementability

The removal and treatment activities in Alternatives 2A/Cem and 3A.1/Cem could be implemented using standard equipment, procedures, and readily available resources. Hydraulic removal is a standard mining technology that is normally reliable and uses readily available equipment. The cement stabilization technology has been applied successfully at a number of remedial sites. EPA considers cement stabilization a demonstrated treatment technology and has approved its use in the final remedy for many NPL sites. This technology has also been applied at other sites that are radioactively contaminated. The cement stabilization process would require large quantities of cement, flyash, and blast furnace slag, which are available.

Alternatives 2A/Vit and 2A/Cem would require on-property disposal vaults. Alternatives 3A.1/Vit and 3A.1/Cem would not require an on-property disposal vaults. Off-site transportation would be technically straightforward, and the necessary resources are available. For disposal, NTS has the resources and capacity to accept the treated Subunit A material. However, off-site transport and disposal would be subject to various state and federal requirements; therefore, administrative feasibility may require increased coordination efforts with jurisdictional agencies for off-site disposal. A Waste Certification Acceptance Program for the Subunit A materials would be required to be prepared and approved for shipment to NTS. Public acceptance and approval of treated material shipment by the State of Nevada must be obtained for these alternatives. Opposition by the State of Nevada may require extensive negotiations with the Nevada Division of Environmental Protection to facilitate the disposal at NTS.

Although removal and disposal are the same for Alternative 2A/Vit as for Alternative 2A/Cem and for Alternative 3A.1/Vit as for Alternative 3A.1/Cem, the vitrification process is more difficult to implement than the cement stabilization process. The vitrification process would require fewer chemical reagents than for the cement stabilization process but larger amounts of energy (electricity). In addition, the vitrification process equipment would be more complex to construct and operate than that of the cement stabilization process. There is limited experience available for the types and quantities of the material from the silos and decant sump tank on which to base an assessment of the likely performance of the vitrification technology. The vitrification technology is not as widely available as the cement stabilization technology. Off-gas treatment is also an additional complexity with vitrification where delays could occur. The combination of these complexities makes implementation of Alternatives 2A/Vit and 3A.1/Vit more difficult than Alternatives 2A/Cem and

3A.1/Cem. However, operational experience is being gained as part of the structured treatability 738 studies and vitrification pilot facility planning currently in progress.

Because there are no actions required, Alternative 0A would be easy to implement.

5.2.2.5 Cost

Cost estimates are used in the feasibility study process under the CERCLA to eliminate those remediation alternatives which are significantly more expensive than competing alternatives but do not offer commensurate performance or overall protection of human health and the environment. The cost estimates developed are order-of-magnitude estimates with an intended accuracy range of -30 to +50 percent. Estimates are considered to be order-of-magnitude because of the uncertainties in the information used to develop the estimates. Final costs would depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final scope, final schedule, final engineering design, and other variables.

The categories of costs developed were capital, short-term O&M (during remediation), and long-term O&M (post-remediation). Total present worth costs were developed for each alternative, assuming a discount rate of seven percent, so that all alternatives with costs incurred over differing time periods could be compared on an equivalent basis. Capital and O&M costs for each Subunit A alternative evaluated in the detailed analysis (Section 4.0) are presented in Table 5-6.

There are no capital or O&M costs associated with Alternative 0A-No Action. Alternative 3A.1/Vit is the least expensive action alternative. The present worth cost of Alternative 2A/Vit is approximately $1.4M higher than that of Alternative 3A.1/Vit. This is due to the higher cost of constructing an on-property above-grade disposal vault as compared to off-site transportation and disposal at NTS. Alternatives 3A.1/Cem and 2A/Cem are approximately 66 percent and 75 percent more expensive, respectively, than Alternative 3A.1/Vit. The alternatives that include cement stabilization are more expensive than the vitrification alternatives primarily due to the additional packaging, transportation (for Alternative 3A.1/Vit), and disposal of the larger volume of cement-stabilized material. Use of the cement stabilization treatment process results in over six times the volume that the vitrification process generates.

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TABLE 5–6

SUBUNIT A ALTERNATIVE COSTS

Alternative	COST[a]			
	Capital	O&M During Remediation	Post–Remediation O&M	Total Present Worth
0A	0	0	0	0
2A/Vit	36,537,400	11,692,500	3,425,400	43,601,900
2A/Cem	71,238,200	11,715,700	3,582,000	74,038,600
3A.1/Vit	36,588,000	11,692,500	0	42,229,300
3A.1/Cem	68,466,900	11,715,700	0	70,133,000

[a]Values are given in dollars ($).

Sensitivity Analysis of Present Worth Costs

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Some factors that can greatly impact present worth costs are the extent of remediation required, i.e., scope of project, duration of construction, remediation, or O&M, and discount rate. The quantity of material included in Subunit A (Silos 1 and 2 material) is fairly well defined. A detailed construction schedule was developed for the duration of construction and remediation, so these factors are not likely to change significantly. Since the relative cost of post-remediation O&M is relatively low in comparison to the capital and short-term O&M costs, a change in the post-remediation time period is not likely to have a major impact on present worth cost. Therefore, discount rate is one factor that can be varied at this time to provide a sensitivity analysis on present worth costs.

A range of three to ten percent for the discount rate was analyzed and the results are provided in Table 5-7. The sensitivity analysis indicates that the relative cost comparison presented for a discount rate of seven percent does not significantly change for the other discount rates evaluated in the sensitivity analysis.

5.3 SUBUNIT B

Subunit B alternatives compared include:

- Alternative 0B - No Action
- Alternative 2B - Removal, Stabilization (Cem/Vit), and On Property Disposal
- Alternative 3B.1 - Removal, Stabilization (Cem/Vit), and Off Site Disposal at NTS.

A summary of the Subunit B comparative analysis is presented in Table 5-2.

5.3.1 Threshold Criteria

5.3.1.1 Overall Protection of Human Health and the Environment

All of the Subunit B alternatives, except 0B-No Action, provide for the protection of human health and the environment. Table 5-5 summarizes both the long-term and short-term incremental lifetime cancer risks for each alternative. Long-term risks represent the residual risks to the hypothetical reasonably maximally exposed receptor potentially remaining at the site following implementation of the alternative. Short-term risks are provided to assess the potential impacts to the public and remedial action workers during implementation of the alternative. All of the action alternatives would limit exposures to contaminants by removing the residues from the deteriorated silo structure, treating the materials to reduce the mobility of the radiological and inorganic chemical constituents, and

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TABLE 5-7

SENSITIVITY ANALYSIS
SUBUNIT A PRESENT WORTH COSTS

Discount Rate (%)	PRESENT WORTH COST[a]			
	Alternative 2A/Vit	Alternative 2A/Cem	Alternative 3A.1/Vit	Alternative 3A.1/Cem
3	47,718,700	80,565,800	45,528,500	75,612,200
4	46,587,100	78,797,000	44,659,500	74,168,900
5	45,531,800	77,129,900	43,822,600	72,779,100
6	44,544,500	75,555,500	43,017,900	71,442,700
7	43,601,900	74,038,600	42,229,300	70,133,000
8	42,714,900	72,601,600	41,472,900	68,876,900
9	41,863,000	71,212,200	40,732,600	67,647,400
10	41,059,000	69,894,400	40,024,500	66,471,400

[a]Values are given in dollars ($).

placing the treated materials in an on-property, above-grade disposal vault or off-site facility (NTS) owned by DOE.

Both the vitrification and cement stabilization treatment processes provide a waste form which significantly reduces the potential for contaminant migration and radon emanation. The results of treatability studies completed on the two treatment processes for Silo 3 residues demonstrate that the vitrified waste form would be expected to be more durable over the long term, with both a reduced volume and radon emanation rate. These factors would contribute to the conclusion that the vitrified material better supports the overall goal of providing for the long-term protection of human health and the environment than does the cement stabilized waste form. Short-term risks to the public, workers, and the environment associated with the implementation of the treatment process would be expected to be similar.

As a result of the necessary additives to facilitate cementation, the volume of waste requiring disposal for alternatives including this treatment technology would be expected to increase by over 62 percent. The vitrification process would reduce the volume of contaminated material requiring disposal by 55 percent.

The off-site disposal location would be the NTS facility which has been used for FEMP low level waste disposal since August 1985. NTS disposal methods include engineering and institutional control measures to preclude contact with the waste and minimize the potential for migration of contaminants from the disposed wastes. These controls, when coupled with the climatic, demographic, and hydrogeologic setting of the NTS site, provide assurance of the long-term protection of human health and the environment.

The on-site disposal option would employ an above-grade disposal vault designed for a life of 1000 years with the requirement for no active maintenance. The disposal vault would prevent exposure to direct radiation and minimize infiltration of water and subsequent leaching of contaminants to the underlying clays and ultimately to the Great Miami River. Disposal vault design features would inhibit purposeful or inadvertent intrusion into the disposed wastes. In the event intrusion did occur, the exposures and resultant risks to these intruders would not be expected to be significant due to the characteristics of the treated wastes. The FEMP site demographic features, as compared to NTS, provide a higher probability of intrusion into the disposed wastes.

Short-term risks to the public and workers are slightly greater for the off-site disposal option due to the increased risks of transportation accidents resulting in injuries or radiation exposure. The greatest short-term risk of this type is associated with Alternative 3B.1/Cem because of the increased volume of treated material requiring transportation off site.

Table 5-4 provides a summary of the environmental impacts associated with the implementation of each of the remedial alternatives. The potential short-term environmental impacts associated with each of the alternatives are comparable. Short-term impacts include the temporary loss of habitats at the FEMP site and possible impacts of accidental spills of construction and operation materials. Mitigative measures would be employed to minimize these impacts.

Long-term environmental impacts associated with each of the alternatives are comparable and would not be expected to be significant. Impacts from implementing Alternatives 2B/Vit and 2B/Cem would include the permanent loss of some on-site habitats.

Alternative 0B would not provide adequate overall protection of human health or the environment. Alternative 0B would not adequately eliminate, reduce, or control the migration of contaminants to human and environmental receptors. Based on the results of the BRA presented in the RI Report for Operable Unit 4 (DOE 1993a), the no-action alternatives would not be adequately protective. Risks to human health would increase in the event current access controls were lost.

5.3.1.2 Compliance with ARARs

Except for Alternative 0B - No Action, all Subunit B alternatives would attain all pertinent chemical, location and action-specific ARARs and TBCs. A comprehensive list of potential ARARs is presented in Appendix F. Key requirements are discussed in Section 4.0 within the evaluation of each alternative against this criterion. The following summarizes those evaluations.

Chemical-Specific ARARs

All of the action alternatives (2B/Vit, 2B/Cem, 3B.1/Vit, and 3B.1/Cem) for Subunit B meet the chemical-specific ARARs associated with potential releases to groundwater, air, and surface water. As demonstrated by fate and transport modeling, the Subunit B action alternatives, including on-property disposal, would attain the concentration-based limits for specific chemicals under 40 CFR 141.11, 141.61, 191.16, and 40 CFR 264.94 and dose-based requirements for the protection of potential public receptors defined in DOE Order 5400.5 and 40 CFR 191.16.

Guidance is provided in 40 CFR 257.3-4 and 40 CFR 264.94 as to the point of compliance ~~for~~ demonstrating whether the groundwater protection requirements for inorganic and organic contaminants would be attained. The most restrictive requirements for these constituents appears in 40 CFR 264.94, which requires the disposal vault to meet the concentration-based limits in the uppermost aquifer underlying the waste management area beyond the point of compliance. The uppermost aquifer and point of compliance is the Great Miami Aquifer. Fate and transport modeling of potential releases of uranium, the principal groundwater constituent of concern, from the on-property disposal vault indicates the uranium concentration would not exceed the proposed 20 μg/L MCL at the point of compliance during the 1000 year modeling horizon.

The most critical chemical-specific ARAR relative to airborne releases for Subunit B materials relates to radon. The maximum permissible flux rate of radon-222, as specified in NESHAP, 40 CFR 61 Subpart Q, is 20 pCi/m^2/s, surface averaged. This requirement is supplemented by 40 CFR 192.02(b) Subpart A, which requires that the concentration of radon-222 in air at or above any location outside the disposal site not increase the annual average by more than 0.5 pCi/L. Requirements for other radionuclides are established in 40 CFR 61 Subpart H and DOE Order 5400.5 Chapter III. Compared to the untreated Subunit B materials, both the vitrified and the cemented waste forms are effective in reducing radon emanation from the treated wastes to less than these prescriptive requirements. Engineered barriers associated with the disposal of treated materials, in either form, would provide additional controls to ensure these chemical-specific ARAR/TBCs are attained.

Alternative 0B - No Action would not meet 40 CFR 61 radon flux requirements based on the current configuration of Silo 3. Also, several criteria for the protection of groundwater would not be met. In the event existing access controls were discontinued and a family farm was established on the FEMP site, exposure limits embodied within DOE Order 5400.5 for members of the general public could be exceeded.

Location-Specific ARARs

Alternatives 3B.1/Vit and 3B.1/Cem would comply with all pertinent location-specific ARARs. Disposal facility siting criteria would not be applicable nor relevant and appropriate to Alternatives 3A.1/Vit and 3A.1/Cem as the alternatives provide for off-site disposal of the treated wastes.

Alternatives 2B/Vit and 2B/Cem would meet all of the location-specific ARARs including those associated with the design and construction of an on-property disposal vault. As discussed in the comparative analysis section for Subunit A alternatives, the Subunit B alternatives which include on-property disposal will attain all State of Ohio solid waste disposal facility design considerations.

Alternative 0B - No Action would not meet all location-specific ARARs. In particular, Subunit B materials are currently at a location on the FEMP site where the glacial overburden is thin compared to the proposed location for the disposal vault. Accordingly, the technical exemption requirements for locating a disposal vault over a sole-source aquifer at its present location would not be met.

Action-Specific ARARs

All Subunit B action alternatives would comply with all pertinent action-specific ARARs. For Alternatives 2B/Vit and 2B/Cem, the above-grade disposal vault would incorporate the design requirements for the disposal of uranium mill tailings (40 CFR 192), and hazardous waste under RCRA, (i.e., the TSDF requirements under 40 CFR 264).

The design of the on-property disposal vault also would include appropriate engineered features that satisfy the requirements of the Clean Water Act (40 CFR 125.100 and 104), the Ohio Water Quality Standards, and RCRA Subtitle C - Hazardous Waste (40 CFR 262.11, 261.7, 262.20, and the 264 Subparts identified in Appendix F).

Alternatives 3B.1/Vit and 3B.1/Cem would comply with all action-specific ARARs identified in Appendix F. Hazardous waste transport requirements would be complied with by following the regulations under 40 CFR 262 and the appropriate DOT shipping standards under 49 CFR 172 and 173.

5.3.2 Primary Balancing Criteria

Those alternatives that satisfy the threshold criteria comparative analysis are carried forward for comparative analysis under the primary balancing criteria. The no-action alternative, Alternative 0B, will be carried forward as the baseline alternative for comparison purposes in accordance with the NCP. Alternatives that will be carried forward include:

- Alternative 0B - No Action
- Alternative 2B/Vit - Removal, Vitrification, and On-Property Disposal

- Alternative 2B/Cem - Removal, Cement Stabilization, and On-Property Disposal
- Alternative 3B.1/Vit - Removal, Vitrification, and Off-Site Disposal at NTS
- Alternative 3B.1/Cem - Removal, Cement Stabilization, and Off-Site Disposal at NTS

5.3.2.1 Long-Term Effectiveness and Permanence

All Subunit B alternatives, with the exception of Alternative 0B - No Action, would ensure long-term protectiveness to human health and the environment. For all alternatives, projected FEMP site residual risk to viable receptors (off-property farmer and recreational user) would be less than 10^{-6} ILCR, and no non-carcinogenic effects (HI less than 0.2) would be indicated for either receptor.

Alternatives 3B.1/Vit and 3B.1/Cem include removal and treatment of the source materials, followed by transportation and off-site disposal at NTS. Removal and treatment of the Subunit B materials eliminates the potential for residual risks to remain at the FEMP site following completion of the actions.

Treatability studies demonstrated that both the vitrified and the cement-stabilized waste forms exhibit reduced leachability of constituents compared to the untreated materials. Both treated forms exhibited TCLP leachate concentrations for hazardous constituents which were below relevant and appropriate limitations defined in RCRA. Vitrification and cement stabilization both reduced radon emanation significantly. The vitrification alternatives are anticipated to achieve a better than 50 percent reduction in waste volume requiring disposal. The cement stabilization alternatives would increase volumes requiring disposal by greater than 55 percent due to the addition of additives.

Vitrification is an innovative technology which has not been previously applied to the stabilization of waste materials on the same scale as contemplated under Alternative 2B/Vit and 3B/Vit. The results of treatability tests have repeatedly demonstrated consistent reductions in the leachability of radionuclides and other inorganics. Cement stabilization is a proven technology that has been previously applied to the treatment of similar waste materials. The performance characteristics of the cement-stabilized material in reducing leachability are generally comparable to those of the vitrified material. Vitrification provides added flexibility in processing not afforded by cementation, in that glass exhibiting unacceptable characteristic can be remelted and reformed.

Off-site disposal at NTS would provide protection by eliminating access to the treated materials and preventing migration of constituents from the materials. The NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant migration, and direct contact with contaminants. Because NTS is maintained by DOE and utilized for the disposal of selected low-level wastes from other DOE sites, the uncertainties associated with institutional controls are low. As the result of a low average annual precipitation and depths to groundwater ranging from 157 - 600 m (515 - 2000 ft) below ground surface, impacts to human health and the environment would be mitigated in the event that engineering and institutional controls fail.

Long-term environmental impacts under Alternatives 3B.1/Vit and 3B.1/Cem would include those associated with the removal and treatment activities performed at the FEMP site and disposal activities at the NTS. There are no long-term environmental impacts at the FEMP site pertaining to the removal and treatment processes. Long-term environmental impacts at NTS would include some permanent disturbance of soils (i.e., acquisition of borrow material) associated with disposal activities. No significant long-term impacts would be expected for water quality and hydrology, air quality, biotic resources, socioeconomics and land use, or cultural resources. No wetland or floodplain areas have been delineated at the NTS.

Alternatives 2B/Vit and 2B/Cem include removal and treatment of Subunit B source materials followed by placement in an above-grade disposal vault. The long-term effectiveness afforded by the removal and treatment processes would be identical for both Alternatives 2B/Vit and 2B/Cem. The design features of the disposal vault would provide effective long-term containment of the treated waste form. The vault would use proven technologies and materials of construction. Similar disposal systems are currently being employed for the encapsulation of hazardous wastes, low-level radioactive waste, and uranium mill tailings. Fate and transport modeling was performed to assess leaching of constituents under degradation of the vault (slight degradation of components over 1000 years). The results of this modeling, based on conservative assumptions for infiltration rates, show that the leaching of constituents would not pose a risk to off-site receptors. Exposures to receptors in the event institutional controls were lost would not be expected to be significant due to characteristics of the treated wastes.

Long-term environmental impacts associated with construction of the on-site disposal vault for Alternatives 2B/Vit and 2B/Cem include permanent disruption of up to 4.5 ha (11.1 acres) of land.

No significant long-term impacts are expected for water quality and hydrology, air quality, socioeconomics, or cultural resources. A potential habitat for threatened and endangered species has been identified in the area proposed for the disposal vault. This same area has been identified as forested wetlands. No floodplains would be permanently altered as the result of implementing these two alternatives.

Alternative 0B - No Action would not be protective of human health and the environment in the long term because it would not prevent exposure to the silo residuals. Silo collapse and subsequent loss of containment would lead to increased contamination levels in air, soils, groundwater, surface water, and sediments. Based on the results of the BRA, Alternative 0B would not be adequately protective under all evaluated land use scenarios, except current land use conditions with continuation of access controls. For these land use scenarios, at least one receptor receives risks which are calculated to exceed 10^{-4}.

5.3.2.2 Reduction of Toxicity, Mobility, or Volume

Alternatives employing vitrification would exhibit a greater overall reduction in the toxicity, mobility, and volume of the waste. Alternatives 2B/Vit and 3B.1/Vit use the vitrification process to treat the contaminated material. This technology will physically bind the contaminants in a glass-like matrix, which will significantly reduce contaminant mobility and material volume. Mobility would be reduced since the contaminants would be bound in the matrix and the volume of the treated material would be approximately 62 percent of the untreated Subunit B material volume. Vitrification would also reduce the toxicity of or eliminate entirely organic contaminants in the material that has been treated. Although most contaminants in the treated material would be incorporated into the vitrified product to reduce mobility over the long term, some contaminants would be released during the vitrification process and must be treated through the off-gas treatment system. The material generated through the off-gas treatment system may require additional stabilization to limit subsequent contaminant mobility.

Alternatives 2B/Cem and 3B.1/Cem use the cement stabilization process to treat the contaminated material. This technology would physically and chemically bind the contaminants in a cement-like matrix, so the mobility of contaminants via leaching from in this treated material would be greatly reduced. However, the inherent toxicity of the material would not be reduced because no contaminants would be destroyed, and the total volume of material would increase by approximately 50 to 68 percent as a result of adding the cement stabilizing and setting agents.

No treatment occurs under Alternatives 0B; therefore, the reduction of toxicity, mobility, or volume of contaminated material is not applicable.

5.3.2.3 Short-Term Effectiveness

Alternative 2B/Cem provides the fewer short-term impacts due to reduced emissions during treatment and minimal transportation related risks. The short-term effectiveness of removal is higher for Alternatives 3B.1/Vit and 3B.1/Cem than Alternatives 2B/Vit and 2B/Cem due to the additional risks of transporting the treated material to NTS. Alternative 3B.1/Cem will have higher risk due to transporting the larger volume of treated material to NTS.

Under Alternatives 2B/Vit, 2B/Cem, 3B.1/Vit, and 3B.1/Cem, short-term disturbance of soil would occur. Fugitive dust and exhaust emissions, as a result of excavation and construction activities, could temporarily result in minimal impacts to air quality and water quality at the FEMP site and/or NTS. However the proper engineering controls and mitigative measures should limit these impacts. Minimal impacts to biotic resources is expected at both NTS and/or the FEMP site. In addition, minimal impacts to wetlands and floodplains would occur.

The time required to implement either treatment alternative is approximately six years.

The short-term effectiveness for Alternative 0B would remain unchanged from the current conditions so that no significant changes in potential exposure are to be expected. The estimated risks are summarized in Appendix G.

5.3.2.4 Implementability

Alternative 2B/Cem represents the most implementable alternative due to use of proven treatment and disposal technology in addition to use of existing FEMP site controlled property for disposal.

The removal and treatment activities in Alternatives 2B/Cem and 3B.1/Cem could be implemented with standard equipment, procedures, and readily available resources. Pneumatic removal is a standard technology that is normally reliable and uses readily available equipment. The cement stabilization technology has been applied successfully at a number of remedial sites. EPA considers cement stabilization a demonstrated treatment technology and has approved its use in the final remedy for many NPL sites. This technology has been also applied at other sites that are radioactively

contaminated. The cement stabilization process would require large quantities of cement, flyash, and blast furnace slag, which are readily available.

Although the removal and disposal aspects are the same for Alternatives 2B/Vit and 3B.1/Vit as for Alternatives 2B/Cem and 3B.1/Cem, the treatment component (vitrification) of these alternatives is more difficult to implement. The vitrification process would require fewer chemical reagents than for the cement stabilization process but larger amounts of energy (electricity). In addition, the vitrification process equipment would be more complex to construct and operate than that of the cement stabilization process. There is limited experience available for the types and quantities of the material from the silo on which to base an assessment of the likely performance of the vitrification technology. The vitrification technology is not as widely available as the cement stabilization technology. Off-gas treatment is also an additional complexity with vitrification where delays could occur. The combination of these complexities makes implementation of Alternatives 2B/Vit and 3B.1/Vit is more difficult than Alternatives 2B/Cem and 3B.1/Cem. However, operational experience is being gained as part of the structured treatability studies and from the vitrification pilot facility currently in start-up.

Alternative 2B/Vit and 2B/Cem are less difficult to implement due to the straightforward disposal vault design. Administrative feasibility is less difficult than Alternatives 3B.1/Vit and 3B.1/Cem because no outside state agencies or regional EPA office agencies would become involved.

Alternatives 3B.1/Vit and 3B.1/Cem would not require an on-property disposal vault. Off-site transportation would be technically straightforward, and the necessary resources are available. For disposal, NTS has the resources and capacity to accept the treated Silo 3 material. Off-site transport and disposal would be subject to coordination with various state and federal agencies to address transport. Approval to dispose the Silo 3 11(e)2 by-product material at NTS would need to be received from NTS and DOE-HQ.

5.3.2.5 Cost

The categories of costs developed were capital, short-term O&M (during remediation), and long-term O&M (post-remediation). Total present worth costs were developed for each alternative, assuming a discount rate of seven percent, so that all alternatives with costs incurred over differing time periods could be compared on an equivalent basis. Capital and O&M costs for each Subunit B alternative evaluated in the detailed analysis (Section 4.0) are presented in Table 5-8.

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TABLE 5–8

SUBUNIT B ALTERNATIVE COSTS

Alternative	COST[a]			
	Capital	O&M During Remediation	Post–Remediation O&M	Total Present Worth
0B	0	0	0	0
2B/Vit	25,221,500	4,923,000	3,162,000	27,971,300
2B/Cem	35,932,600	4,923,000	3,207,000	37,358,600
3B.1/Vit	25,212,200	4,923,000	0	26,655,300
3B.1/Cem	34,730,400	4,056,000	0	34,169,900

[a]Values are given in dollars ($).

There are no capital or O&M costs associated with Alternative 0B-No Action. Alternative 3B.1/Vit is the least expensive action alternative. The present worth cost of Alternative 2B/Vit is approximately $1.3M higher than that of Alternative 3B.1/Vit. This is due to the higher cost of constructing an on-property above-grade disposal vault as compared to off-site transportation and disposal at NTS. Alternatives 3B.1/Cem and 2B/Cem are approximately 31 percent and 39 percent more expensive, respectively, than Alternative 3B.1/Vit.

Alternative 3B.1/Cem is more expensive than Alternative 3B.1/Vit primarily due to the additional packaging, transportation, and disposal of the larger volume of the cement-stabilized material. Use of the cement stabilization treatment process results in over six times the volume that the vitrification process generates.

Sensitivity Analysis of Present Worth Costs

Some factors that can greatly impact present worth costs are the extent of remediation required, i.e., scope of project, duration of construction, remediation, or O&M, and discount rate. The quantity of material included in Subunit B (Silo 3 material) is fairly well defined. A detailed construction schedule was developed for the duration of construction and remediation, so these factors are not likely to change significantly. Since the relative cost of post-remediation O&M is relatively low in comparison to the capital and short-term O&M costs, a change in the post-remediation time period is not likely to have a major impact on present worth cost. Therefore, discount rate is one factor that can be varied at this time to provide a sensitivity analysis on present worth costs.

A range of three to ten percent for the discount rate was analyzed. Results are provided in Table 5-9. The sensitivity analysis indicates that the relative cost comparison presented for a discount rate of seven percent does not significantly change for the other discount rates evaluated in the sensitivity analysis.

5.4 SUBUNIT C

Subunit C alternatives compared include:

- Alternative 0C - No Action
- Alternative 2C - Demolition, Removal, On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, Off-Site Disposal at NTS.

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TABLE 5-9

SENSITIVITY ANALYSIS
SUBUNIT B PRESENT WORTH COSTS

Discount Rate (%)	PRESENT WORTH COST[a]			
	Alternative 2B/Vit	Alternative 2B/Cem	Alternative 3B.1/Vit	Alternative 3B.1/Cem
3	30,629,900	40,759,900	28,555,300	36,689,100
4	29,888,400	39,822,100	28,057,200	36,027,500
5	29,199,600	38,944,800	27,571,000	35,384,900
6	28,565,600	38,129,800	27,106,500	34,769,600
7	27,971,300	37,358,600	26,655,300	34,169,900
8	27,410,600	36,628,300	26,216,000	33,589,300
9	26,875,800	35,927,800	25,785,100	33,020,200
10	26,377,200	35,270,900	25,375,900	32,478,400

[a]Values are given in dollars ($).

- Alternative 3C.2 - Demolition, Removal, Off-Site Disposal at a Permitted Commercial Disposal Site

A summary of the Subunit C comparative analysis is presented in Table 5-3.

5.4.1 Threshold Criteria

5.4.1.1 Overall Protection of Human Health and the Environment

Assessment of protectiveness for Operable Unit 4 alternatives adopts the use of continued federal ownership of the FEMP site and evaluates risk to the recreational user for the on-property disposal alternatives; the assessment also evaluates risk to the recreational user and off-site resident for off-site disposal alternatives. The summary of remedial alternatives and both short-term and long-term radiological ILCRs is provided in Table 5-5.

All of the Subunit C alternatives, except 0C - No Action, would provide overall protection of human health and the environment. All of the action alternatives (Alternatives 2C, 3C.1, and 3C.2) would limit exposure to contaminants by decontaminating, demolishing, and removing the material to either an on-property disposal vault or off-site disposal facility, and excavation of contaminated soils and placement of a clean cover over residual contaminated subsurface soils. These alternatives would prevent direct access to contaminated soil and debris and would mitigate the migration of contaminants to the air, surface soil, and groundwater. Exposure to direct radiation above protective levels would also be prevented. The basic difference between the action alternatives is the disposal options. On-property disposal would be an above-grade disposal vault. Off-site disposal options include NTS, a DOE-owned facility (for Alternative 3C.1), or disposal at a permitted commercial disposal site (for Alternative 3C.2).

The on-property disposal vault design would include sufficient barrier to withstand 1,000 years of potential erosion with little or no maintenance. Permanent markers would be used to deter purposeful or inadvertent human destruction of the facility's engineered protective features. Although long-term effectiveness is uncertain because of eventual degradation of the facility cap and leachate collection system, fate and transport modeling using conservative assumptions concludes that long-term protection would still be maintained.

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NTS and the commercial disposal facility incorporate engineering controls to ensure protectiveness. Both are located in a climatic, demographic, and hydrogeologic setting which favors minimization of contaminant migration to human or environmental receptors. In the event of degradation of engineered features or loss of institutional controls, these site characteristics would help to ensure continued protectiveness.

Alternative 0C would not provide protection of human health and the environment. Long-term risks to on-property receptors would not be within the 10^{-4} to 10^{-6} acceptable risk range.

Short-term risks to the public and workers are slightly greater for the off-site disposal options due to the increased risks of transportation accidents resulting in injuries or radiation exposure.

5.4.1.2 Compliance with ARARs

Alternatives 2C, 3C.1, and 3C.2 would meet all pertinent ARARs. Appendix F includes a comprehensive list of potential ARARs, TBCs, and DOE Orders and how each alternative meets the intent of the regulatory requirement. For the on-property disposal option, compliance with the OAC 3745-27-07 prohibition on siting a solid waste disposal facility over a sole source aquifer would be based on demonstrating attainment of the substantive technical criteria for an exemption to this requirement. Because the material associated with Subunit C poses fewer hazards than the material in Subunits A and B, the on-property disposal vault would require less stringent engineering designs to meet the requirements established in 40 CFR 192.

Alternative 0C would not comply with all pertinent chemical-, location-, and action-specific ARARs.

5.4.2 Primary Balancing Criteria

Those alternatives that satisfy the threshold criteria of compliance with ARARs and overall protection of human health and environment were carried forward for comparative analysis under the primary balancing criteria. The no-action alternative was carried forward for comparison purposes in accordance with the NCP. Those alternatives include:

- Alternative 0C - No Action
- Alternative 2C - Demolition, Removal, On-Property Disposal
- Alternative 3C.1 - Demolition, Removal, Off-Site Disposal at NTS

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- Alternative 3C.2 - Demolition, Removal, Off-Site Disposal at a Permitted Commercial Disposal Site

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5.4.2.1 Long-Term Effectiveness and Permanence

All action alternatives, Alternatives 2C, 3C.1, and 3C.2 provide long-term effectiveness associated with contaminated material. The application of each of the action alternatives reduces the residual risk to viable receptors to a HI of less than 0.2 and an ILCR of less than 10^{-6}. Although residual contamination would remain at the site in the soil, the level of risk from the residual soil would be controlled by excavating soil that exceeds PRGs that are protective of a recreational user and by placing clean soil over the excavated areas.

The difference between the action alternatives is the final disposition of contaminated materials. The issues with the different disposal options are the adequacy and reliability of controls and the long-term environmental impacts. The disposal vault in Alternative 2C significantly reduces leachate formation by limiting infiltration and consequently exfiltration. Institutional controls would preclude the establishment of an on-site residence or farm. In the absence of institutional controls, the on-property vault would continue to provide adequate protection from the most highly contaminated Operable Unit 4 soils. However, off-site disposal at NTS has enhanced reliability because the facility is currently used by DOE for low-level radioactive waste disposal. The institutional controls and potential for adequate facility maintenance are likely to be more reliable at NTS and the permitted commercial disposal site than on property. Also, the climatic, hydrologic, and geologic characteristics at both off-site disposal facilities would considerably reduce the potential for contaminant migration in the event of a release.

Construction of the on-property disposal vault would permanently disturb 4.7 ha (11.6 acres) of property at the FEMP site. Off-site disposal would result in permanent disturbance at the respective facilities rather than at the FEMP site.

Alternative 0C does not provide risks within the acceptable 10^{-4} to 10^{-6} range for either the on-property or off-property receptors.

5.4.2.2 Reduction of Toxicity, Mobility, or Volume

Alternatives 0C, 2C, 3C.1, and 3C.2 do not include treatment of the contaminated silo structures, berm material, or soils. Therefore, no reduction in toxicity, mobility, or volume would be achieved

through treatment. However, as part of the remedial action work plan preparation for the action alternatives (Alternatives 2C, 3C.1, and 3C.2), an approach would be developed to reduce the volume of material requiring management as radioactive waste. Following decontamination, some of the concrete and other structural materials might be suitable for free-release off site.

5.4.2.3 Short-Term Effectiveness

This evaluation criterion addresses the effects of alternatives during the construction and implementation of the remedial action. For the no-action alternative (Alternative 0C), no remedial action will be taken; therefore, there will be no increase in short-term risks. For the action alternatives (Alternatives 2C, 3C.1, and 3C.2), the various demolition and removal activities would result in increased short-term exposures compared with the no-action alternative (Alternative 0C). However, through a combination of engineering controls and access controls, all of the action alternatives would be protective of the community during implementation.

There would be added risk to the public through transporting the soil and debris off site (Alternatives 3C.1 and 3C.2). Because of the overall low radiological activity of the soil and debris, there would be no estimated increase in radiation to the public during transportation to NTS or the permitted commercial disposal site.

5.4.2.4 Implementability

Implementability includes technical feasibility, administrative feasibility, and availability of services and materials. The technical feasibility of all other alternatives would be similar, and all alternatives should not be difficult to implement. Alternative 0C would be the easiest to implement in the short term because no construction activities are required.

Alternatives 3C.1 and 3C.2 are more administratively difficult to implement than Alternative 2C because of the off-site disposal involved and agency approvals and coordination that would be required for interstate shipments of material to the off-site facilities. Opposition by the public and state agencies may require extensive negotiations with the regulatory agencies to facilitate the use of this facility. There would be no long-term maintenance associated with Alternatives 3C.1 and 3C.2 at the FEMP site.

5.4.2.5 Cost

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The categories of costs developed were capital, short-term O&M (during remediation), and long-term O&M (post-remediation). Total present worth costs were developed for each alternative, assuming a discount rate of seven percent, so that all alternatives with costs incurred over differing time periods could be compared on an equivalent basis. Capital and O&M costs for each Subunit C alternative evaluated in the detailed analysis (Section 4.0) are presented in Table 5-10.

There are no capital or O&M costs associated with Alternative 0C-No Action. Alternative 2C, which includes an on-property disposal, is the least expensive action alternative. Transportation to NTS (Alternative 3C.1) or to a permitted commercial disposal facility (Alternative 3C.2) are both more expensive than constructing an on-property vault. However, the overall cost of disposal at a permitted commercial disposal facility is anticipated to be approximately 40 percent higher than the cost of disposal at a DOE-owned facility. The unit cost for disposal at a DOE-owned facility is approximately 30 percent of the unit cost for disposal at a commercial facility.

Sensitivity Analysis of Present Worth Costs

Some factors that can greatly impact present worth costs are the extent of remediation required, i.e., scope of project, duration of construction, remediation, or O&M, and discount rate. The quantity of material included in Subunit C, particularly, could not be well defined based on the existing soils analytical data. Excavation of surface soils to a depth of 15 cm (6 in.) was assumed for cost estimating purposes since analytical data indicated the presence of contamination at this depth at various parts of the site.

A detailed construction schedule was developed for the duration of construction and remediation, so these factors are not likely to change significantly. Since the relative cost of post-remediation O&M is relatively low in comparison to the capital and short-term O&M costs, a change in the post-remediation time period is not likely to have a major impact on present worth cost. Therefore, the discount rate is another factor that can be varied at this time to provide a sensitivity analysis on present worth costs.

Sensitivity analyses varying soil quantities or discount rate were performed. Total present worth costs were estimated for each alternative assuming excavation of surface soils to a depth of 0.3 m (1 ft) and 0.45 m (1.5 ft) (using a seven percent discount rate). As indicated in Table 5-11, increasing the quantity of surface soils has an impact on present worth costs because surface soil is a major

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TABLE 5-10

SUBUNIT C ALTERNATIVE COSTS

Alternative	COST[a]			
	Capital	O&M During Remediation	Post-Remediation O&M	Total Present Worth
0C	0	0	0	0
2C	62,576,400	0	3,567,000	58,044,500
3C.1	65,846,600	0	0	59,525,300
3C.2	91,168,700	0	0	82,416,500

[a]Values are given in dollars ($).

TABLE 5-11

SENSITIVITY ANALYSIS-
IMPACT OF SURFACE SOIL VOLUME
SUBUNIT C PRESENT WORTH COSTS

Surface Soil Excavation Depth (inches)	PRESENT WORTH COST[a]		
	Alternative 2C	Alternative 3C.1	Alternative 3C.2
6	58,044,500	59,525,300	82,416,500
12	59,487,800	60,984,800	84,002,700
18	61,031,500	62,543,300	85,709,100

[a]Values are given in dollars ($), estimated assuming seven percent discount rate.

component of Subunit C materials.

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A range of three to ten percent for the discount rate was analyzed. Results are provided in Table 5-12. The sensitivity analysis indicates that the relative cost comparison presented for a discount rate of seven percent does not significantly change for the other discount rates evaluated in the sensitivity analysis.

TABLE 5-12

SENSITIVITY ANALYSIS-
IMPACT OF DISCOUNT RATE ON
SUBUNIT C PRESENT WORTH COSTS

Discount Rate (%)	PRESENT WORTH COST[a]		
	Alternative 2C	Alternative 3C.1	Alternative 3C.2
3	62,184,300	62,982,300	87,202,900
4	61,065,500	62,093,300	85,972,100
5	59,992,500	61,204,400	84,741,300
6	58,988,000	60,348,400	83,556,100
7	58,044,500	59,525,300	82,416,500
8	57,125,500	58,702,200	81,276,900
9	56,257,500	57,912,100	80,182,900
10	55,437,200	57,154,500	79,134,400

[a]Values are given in dollars ($).

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