US Army Corps of Engineers®
Buffalo District
BUILDING STRONG®

Feasibility Study Report
Revision 0

Former Harshaw Chemical Company Site
Cleveland, Ohio

Volume 1

Formerly Utilized Sites Remedial Action Program

September 2012

Prepared for:

U.S. Army Corps of Engineers - Buffalo District

Contract No: W912QR-08-D-0008
Delivery Order No: DO-0003

Prepared by:

Science Applications International Corporation
8866 Commons Blvd. Twinsburg, Ohio 44087

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ACRONYMS AND ABBREVIATIONS

°C	Degree Celsius
°F	Degree Fahrenheit
$	Dollar
%	Percent
>	Greater than
<	Less than
≤	Less than or Equal to
µg/L	Micrograms per Liter
µrem/hr	Microrems per Hour
1E+00	Example of Exponent Notation meaning 1 can also be expressed as 1×10^0
2-D	Two-Dimensional
3-D	Three-Dimensional
ACM	Asbestos-Containing Material
AEA	Atomic Energy Act of 1954 (as amended)
AEC	United States Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
Am-241	Americium-241
amsl	Above Mean Sea Level
ANL	Argonne National Laboratory
AOC	Administrative Order of Consent
ARAR	Applicable or Relevant and Appropriate Requirement
ArcGIS	Geographic Information System (GIS) Software Suite produced by Esri
BAASS	Bayesian Approaches to Adaptive Spatial Sampling
bgs	Below Ground Surface
BRA	Baseline Risk Assessment
C&D	Construction and Demolition
CAS	Chemical Abstract Service
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	Centimeter
cm^2	Square Centimeters
COC	Constituent of Concern
COPC	Constituent of Potential Concern
Cs-137	Cesium-137
CSM	Conceptual Site Model
CWM	Chemical Waste Management
D&D	Decontamination and Decommissioning
DCGL	Derived Concentration Guideline Level
DD	Decision Document
DoD	United States Department of Defense
DOE	United States Department of Energy
DOT	Department of Transportation
dpm	Disintegrations Per Minute
EarthVision	Three-Dimensional Modeling Sofware produced by Dynamic Graphics,
EM	Engineer Manual

ACRONYMS AND ABBREVIATIONS (CONTINUED)

EPC	Exposure Point Concentration
EU	Exposure Unit
FEHM	Finite Element Heat and Mass Transfer
FEMA	United States Federal Emergency Management Agency
FRTR	Federal Remediation Technologies Roundtable
FS	Feasibility Study
ft	Feet
ft^2	Square Feet
FUSRAP	Formerly Utilized Sites Remedial Action Program
FWEC	Foster Wheeler Environmental Corporation
GCL	Geosynthetic clay liner
gpm	Gallons per Minute
GRA	General Response Action
ha	Hectare
HEPA	High Efficiency Particulate Air
HHRA	Human Health Risk Assessment
HI	Hazard Index
IA	Investigative Area
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
ICSM	Initial Conceptual Site Model
ILCR	Incremental Lifetime Cancer Risk
Kd	Distribution Coefficient
km	Kilometer
LIDAR	Light Detection and Ranging
LLRW	Low-Level Radioactive Waste
m	Meter
m^3	Cubic Meters
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MED	Manhattan Engineer District
mg/kg	Milligram Per Kilogram
mL/g	Milliliter Per Gram
mm	Millimeter
mrem/hr	Millirem Per hour
mrem/yr	Millirem Per Year
mSv	Millisievert
mSv/yr	Millisievert Per Year
MTU	Metric Tons of Uranium
N/A	Not Applicable
NA	Medium is Not evaluated for that receptor
NABIR	Natural and Accelerated Bioremediation Research Program
NAD	North American Datum
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
Np-237	Neptunium-237
NRC	United States Nuclear Regulatory Commission
NUREG	United States Nuclear Regulatory Commission Regulation

ACRONYMS AND ABBREVIATIONS (CONTINUED)

NY	New York
O&M	Operation and Maintenance
OAC	Ohio Administrative Code
ODH	Ohio Department of Health
OH	Ohio
Ohio EPA	Ohio Environmental Protection Agency
OU	Operable Unit
PA	Preliminary Assessment
Pb-210	Lead-210
pCi/g	Picocuries Per Gram
pH	potential Hydrogen
POTW	Publicly Owned Treatment Works
PP	Proposed Plan
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goal
Ra-226	Radium-226
Ra-228	Radium-228
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactivity Computer Code
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RU	Recycled Uranium
S/S	Solidification/Stabilization
SESOIL	Seasonal Soil Compartment
SLERA	Screening Level Ecological Risk Assessment
SOR	Sum of Ratios
TBC	To Be Considered
TEDE	Total Effective Dose Equivalent
Th-228	Thorium-228
Th-230	Thorium-230
Th-232	Thorium-232
TPH-DRO	Total Petroleum Hydrocarbons-Diesel Range Organics
TSCA	Toxic Substances Control Act
TX	Texas
U-234	Uranium-234
U-235	Uranium-235
U-238	Uranium 238
U_3O_8	Triuranium octoxide
UAO	Unilateral Administrative Order
Ub	Urban Land
UCl_4	Uranium tetrachloride
UF_4	Uranium tetrafluoride
UF_6	Uranium hexafluoride
UO_2	Uranium dioxide
UO_3	Uranium Trioxide

ACRONYMS AND ABBREVIATIONS (CONTINUED)

USACE	United States Army Corps of Engineers
USD	Urban Setting Designation
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
VAP	Voluntary Action Program
WAC	Waste Acceptance Criteria
XRF	X-Ray Fluorescence Spectroscopy
yd^3	Cubic Yard

METRIC CONVERSION CHART

To Convert to Metric			To Convert from Metric		
If You Know	Multiply By	To Get	If You Know	Multiply By	To Get
Length					
inches	2.54	centimeters	centimeters	0.3937	inches
feet	30.48	centimeters	centimeters	0.0328	feet
feet	0.3048	meters	meters	3.281	feet
yards	0.9144	meters	meters	1.0936	yards
miles	1.60934	kilometers	kilometers	0.6214	miles
Area					
square inches	6.4516	square centimeters	square centimeters	0.155	square inches
square feet	0.092903	square meters	square meters	10.7639	square feet
square yards	0.8361	square meters	square meters	1.196	square yards
acres	0.40469	hectares	hectares	2.471	acres
square miles	2.58999	square kilometers	square kilometers	0.3861	square miles
Volume					
fluid ounces	29.574	milliliters	milliliters	0.0338	fluid ounces
gallons	3.7854	liters	liters	0.26417	gallons
gallons	0.00378	cubic meters	cubic meters	264.55	gallons
cubic inches	16.3870	cubic centimeters	cubic centimeters	0.061023	cubic inches
cubic feet	0.028317	cubic meters	cubic meters	35.315	cubic feet
cubic yards	0.76455	cubic meters	cubic meters	1.308	cubic yards
Weight					
ounces	28,349,523	micrograms	micrograms	3.527396E-08	ounces
ounces	28.3495	grams	grams	0.03527	ounces
pounds	0.4536	kilograms	kilograms	2.2046	pounds
Temperature					
Fahrenheit	Subtract 32 then multiply by 5/9ths	Celsius	Celsius	Multiply by 9/5ths then add 32	Fahrenheit
Radiation					
picocurie	0.037	Becquerel	Becquerel	27.027027	Picocuries
curie	3.70E+10	Becquerel	Becquerel	2.703E-11	Curies
rem	0.01	sievert	sievert	100	rem
RAD	0.01	Gray	Gray	100	RADs

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EXECUTIVE SUMMARY

The Former Harshaw Chemical Company Site is located in Cleveland, Ohio, approximately 3 miles (4.8 kilometers [km]) south of downtown Cleveland and was used to process various forms of uranium materials for the Manhattan Engineer District (MED)/United States Atomic Energy Commission (AEC). In 1999, the U.S. Department of Energy (DOE) designated it eligible for inclusion in the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established to remediate sites impacted by activities of the AEC in the early years of the nation's atomic energy program.

The United States Army Corps of Engineers (USACE), as the lead Federal agency for the remediation of the Former Harshaw Chemical Company Site, is required by Pub.L 105-245 and 106-60 to execute FUSRAP subject to the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended 42 U.S.C. 9601 et seq., and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300). The feasibility study (FS), yielding an FS Report, is performed to ensure appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options may be presented to the decision-maker, and an appropriate remedy may be selected. Development of the remedial alternatives must take into account site-specific conditions and factors. The NCP [40 CFR §300.430(e)(9)(iii)] requires specific criteria to be evaluated for the proposed remedial alternatives. The remedial alternatives must be protective of human health and the environment. USACE is responsible for ensuring the selected remedies will be protective of human health and the environment and comply with applicable or relevant and appropriate requirements (ARARs).

ES.1 PROJECT BACKGROUND

The Former Harshaw Chemical Company Site produced a number of major and minor uranium products in various forms under contract. Five thousand metric tons of uranium (MTU) were processed under MED/AEC contracts between 1942 and 1954. Major products included uranium tetrafluoride (UF_4) (Green Salt), Uranium hexafluoride (UF_6), and uranium trioxide (UO_3). The major processing plants located within Building G-1 were the Refinery and Brown Oxide Plant, which produced UO_3 and uranium dioxide (UO_2), respectively. Also located in Building G-1 were the UF_4 plant and the UF_6 plant. MED/AEC-related activities were not confined to the currently fenced area, but included the use of the former rail yard adjacent to Building G-1 and the former Foundry (previously designated as Building F-1 and shown as the Foundry in Figure ES-1).

These operations were carried out within the Building G-1 complex, which was built and expanded several times over the period from 1945-1949. The Building G-1 complex lies within a 1.6-acre (0.6 hectare [ha]) fenced area located in the northern portion of the Former Harshaw Chemical Company Site, as shown in Figure ES-1.

The site is located at 1000 Harvard Avenue in Cleveland, Ohio. The site is surrounded by industrial operations and residential areas. The site is located adjacent to the Cuyahoga River and Big Creek within an industrialized area in Cuyahoga County. Neighboring industries include Mittal Steel, Aluminum Company of America, Chemical Solvents, Inc., and CSP Fabricating. The site consists of approximately 55 acres (22.3 ha) and includes several developed and undeveloped land parcels located near the intersection of Harvard Avenue and Jennings Road. Developed site parcels include former production areas and remaining facility buildings, former production area foundations, parking areas associated with previously dismantled buildings, and re-developed, privately-owned commercial properties.

During the remedial investigation (RI), media investigated included: soil, surface water and sediments of Big Creek and the Cuyahoga River, groundwater, and the on-site buildings (Figure ES-1). Results of the RI confirmed the presence of FUSRAP contaminants in soil, groundwater around Building G-1, and buildings in the former process area. Soil and the remaining buildings were identified as media of concern based on potential health risks to critical groups selected for the site.

Based on reasonably foreseeable future land uses for different areas of the site, the site was divided into two separate operable units (OUs). OU-1 is the portion of the site that is north of Big Creek and west of the Cuyahoga River where contamination was confirmed in soil and abandoned or unused buildings. OU-2 is the portion of the site that is south of Big Creek and to the west of the Cuyahoga River where contamination was found in soil only. The reasonably foreseeable future land use for OU-1 is industrial with the critical exposure group being the construction worker. The reasonably foreseeable future land use for OU-2 is residential with the adult resident being defined as the critical exposure group. The extent of contamination within OU-1 is in the area surrounding Building G-1 and a limited area near the Cuyahoga River bank where materials may have been placed. The extent of contamination within OU-2 is isolated to a few areas towards the middle portion of the operable unit.

Investigative Area 06 (IA06), an undeveloped parcel located east of the Cuyahoga River, was another area of the site investigated during the RI. Investigation data for IA06 found FUSRAP constituents at levels acceptable for anticipated future recreational use. As a result, a separate, no action Record of Decision was prepared and accepted by the public for IA06 (USACE 2011).

Based on the RI Report and Baseline Risk Assessment (BRA), constituents of concern (COC) in OU-1 and OU-2 are radium-226, thorium-230, thorium-232, and total uranium for both the soil and buildings. Other hazardous substances, pollutants, or contaminants that may be present and other parts of the site not used in support of the MED/AEC operations are not eligible for FUSRAP and are not addressed in this FS Report.

ES.2 SUMMARY OF REMEDIAL OBJECTIVES

The remedial action objectives (RAOs) developed in this FS Report address soil and building materials for unrestricted land use and restricted land use. The RAOs for the Former Harshaw Chemical Company Site are intended to provide for long-term protection of human health and the environment. To provide this protection, media-specific preliminary remediation goals (PRGs) were developed. These objectives are based on the media of concern, COC, exposure routes, and receptors (e.g. people, animals, plants) and define an acceptable contaminant concentration for the long-term protection of receptors.

The RAOs developed for soil and building materials in OU-1 are as follows:

- To prevent exposure to impacted soil containing concentrations of COCs and ensure the critical group does not receive a total dose equivalent exceeding 25 millirems per year (mrem/yr) above background.

- To prevent exposure to impacted building materials containing concentrations of COCs and ensure the critical group does not receive a total dose equivalent exceeding 25 mrem/year above background.

The RAO developed for the soil in OU-2 is as follows:

- To prevent exposure to impacted soil containing concentrations of COCs and ensure the critical group does not receive a total dose equivalent exceeding 25 mrem/year above background.

The site exposure model used as the basis for the FS Alternative rankings relies on potential pathways to a future construction worker. The distribution of MED-related constituents in groundwater is correlated directly to areas of impacted soils and exhibits little migration due to soil partitioning. Although USEPA MCLs are exceeded in portions of the site, the existing site use (passive industrial) poses no current unacceptable risk to human health and the environment. Consequently, RAOs were not developed for groundwater at this time. Groundwater on and near the site is not usable as a drinking water source because groundwater quality and yield are not suitable for use by industries or residents and current and future residents and industry in the area rely solely on municipal water.

It is premature to develop and evaluate remedial alternatives to address impacted groundwater in this Feasibility Study because the remedial alternative selected for soil contamination may impact the distribution and concentration of groundwater contamination at the site and will affect the alternatives evaluated for addressing groundwater. To ensure complete consideration of impacted media on-site, groundwater conditions will be re-evaluated upon completion of a soils remedy. If the USACE determines that a potential exists for an unacceptable risk from groundwater impacted by FUSRAP-related materials, then, remedial alternatives will be evaluated and a separate Feasibility Study, Proposed Plan and Record of Decision will be completed for groundwater.

ES.2.1 Applicable or Relevant and Appropriate Requirements

Agencies responsible for remedial actions under CERCLA must ensure selected remedies meet ARARs.

The definition of Applicable Requirements per 40 CFR 300.5 reads as follows:

> "Cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than Federal requirements may be applicable."

Relevant and Appropriate Requirements are defined in 40 CFR 300.5 as:

> "Cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or state environmental or facility siting laws that, while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than Federal requirements may be relevant and appropriate."

USACE has identified the following ARARs for remedial activities at the Former Harshaw Chemical Company Site.

10 CFR Part 20 Subpart E - Radionuclides: The standards in 10 CFR Part 20 Subpart E address situations similar to the circumstances of the release at the site and their use is appropriate. The standards in the 10 CFR Part 20 Subpart E are:

- **Unrestricted use:** Total effective dose equivalent (TEDE) limited to 25 mrem/yr above background to the average member of the critical group and demonstrated to be as low as reasonably achievable (ALARA).

- **Restricted use:** 25 mrem/yr above background TEDE to the average member of the critical group and demonstrated to be ALARA relying on durable land-use controls and 100 mrem/yr to the average member of the critical group if land-use controls fail.

These ARARs are for OU-1 and OU-2 with the "unrestricted use" standards being the ARARs for no action or complete removal alternatives and the "restricted use" standards being the ARARs for no action or limited action alternatives. The difference between the OUs is the identification of the critical group. 10 CFR 20.1003 defines the "critical group" as "the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances." The critical groups for OU-1 and OU-2 are the construction worker and the resident, respectively. These critical groups were selected for the following reasons. Future land use at OU-1 is anticipated to be a combination of uses, including industrial, commercial, and recreational. The construction worker was selected to be the critical group for OU-1 since they were the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances. Anticipated land use at OU-2 is expected to remain undeveloped; however, future planning by the city of Cleveland indicates a portion of the OU may be zoned residential. Therefore, it is assumed OU-2 would be available for residential development.

ES.2.2 Selected Media-Specific Preliminary Remediation Goals

PRGs were established for soil and building material to comply with the ARARs stated above. The following table summarizes proposed PRGs for OU-1 and OU-2 soil based on a total of 25 mrem/year for all complete pathways.

COC	CAS Number	*Worker (OU-1)*[a] Construction (pCi/g)	*Resident (OU-2)*[a] Adult (pCi/g)
Ra-226[b]	013982-63-3	9.1E+00	3.6E+00
Th-230	014269-63-7	3.5E+01	1.6E+01
Th-232[c]	013968-55-3	6.0E+00	3.6E+00
U-238[d]	007440-61-1	1.9E+02	1.5E+02

Values represent minimum of RESRAD calculated PRG at years 0, 185, or 1,000 (year of peak dose per nuclide group).
[a]Groundwater was not considered a drinking water source during development of these values.
[b]PRGs for Ra-226 include Pb-210 contribution to dose at time 0.
[c]PRGs for Th-232 include Ra-228 and Th-228 contribution to dose at time 0.
[d]U-238 can be used as surrogate for total uranium DCGL by multiplying total uranium DCGL by U-238's activity fraction (0.489). PRGs for total uranium of 4.0E+02 and 3.0E+02 for OU-1 and OU-2, respectively, include contribution to dose from U-234, U-235, and U-238, assuming natural abundance of uranium isotopes (in activity-based ratio of U-234:U-235:U-238 1:0.046:1).

CAS = Chemical Abstract Service
COC = Constituent of Concern
DCGL = Derived Concentration Guideline Level
OU = Operable Unit
Pb-210 = Lead-210
pCi/g = picoCurie Per Gram
PRG = Preliminary Remediation Goal
Ra-226 = Radium-226
Ra-228 = Radium-228
RESRAD = Residual Radioactivity Computer Code
Th-230 = Thorium-230
Th-232 = Thorium-232
U-234 = Uranium-234
U-235 = Uranium-235
U-238 = Uranium-238

The following table summarizes proposed PRGs for OU-1 building surfaces based on a total of 25 mrem/year for all complete pathways.

Exposure	*Construction Worker (OU-1)*		
	Fixed Activity	**Removable Activity**	**Direct Dose**
	(dpm/100cm^2)	**(dpm/100cm^2)**	**(mrem/hr)**
RME	508	51	0.013

cm^2 = Square Centimeters
dpm = Disintegrations Per Minute
mrem/hr = Millirem Per Hour
OU = Operable Unit
RME = Reasonable Maximum Exposure

ES.3 REMEDIAL ALTERNATIVES

Media-specific alternatives for soil and buildings were identified by combining general response actions (GRAs), technology types, and process options retained from the screening processes. A remedial action decision is required for soil and buildings at OU-1 and for soil at OU-2. The development of alternatives was based on expected future land use where industrial use is likely for the OU-1 area and residential redevelopment is a plausible future land use at the OU-2 area. The alternatives should ensure adequate protection of human health and the environment, achieve RAOs, meet ARARs, and permanently and significantly reduce the volume, toxicity, and/or mobility of site-related contaminants as appropriate. The following alternatives were identified in the FS to be carried forward for consideration.

Alternative 1 - No Action (OU-1)

Alternative 1 leaves the site “as is” with no actions taken regarding access or land-use controls beyond those already in place. This alternative provides no additional protection to human health and the environment over current conditions. This alternative also assumes existing controls and monitoring will not be maintained. The No Action alternative is required under the NCP [40 CFR §300.430(e)(6)] as a baseline against which other alternatives can be compared.

Alternative 2 - Limited Action and Land-Use Controls (OU-1)

Alternative 2 is a limited action alternative consisting of the dismantlement of Building G-1, the off-site disposal of the Building G-1 debris, bank stabilization, land-use controls, site monitoring, and five-year reviews. Under this alternative, Building G-1 would be removed, but the remaining impacted media at OU-1 would be left in place, and no other active remedial measures would be implemented. Under this alternative, several forms of land-use controls, access controls, and informational tools would be used to restrict or limit future uses and activities at the site as well as five-year reviews to assess continued protectiveness of the remedy. Land-use controls would include environmental covenants applied to the land to restrict future uses of the site where concentrations of radionuclides remain above PRGs. Access control measures would be aimed at limiting access to reduce the potential for human exposure to soil located at the site. Access controls, such as fencing, would be implemented under this alternative. Informational tools would include posting signs and placing placards to indicate the presence of hazardous substances and warn against intruding into the site.

Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)

Alternative 3 consists of excavation of impacted soil exceeding the PRGs in OU-1 and subsequent off-site disposal. Building G-1 would be dismantled in order to access impacted soil beneath the building slab/foundation. Contaminated building material above PRGs at the remaining buildings would be removed, and the buildings would be returned to a safe condition. These buildings would not be dismantled, as there is not impacted soil above PRGs under the remaining buildings. This alternative would require close coordination of remediation and monitoring activities with the land owner(s) and/or tenants. This coordination aims to minimize health and safety risks to on-site personnel and the disruption of activities consistent with a safe and effective remediation.

Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)

Alternative 4 consists of excavation of impacted soil exceeding the PRGs in OU-1, ex-situ treatment by solidification/stabilization (S/S), and subsequent off-site disposal. Building G-1 would be dismantled in order to access impacted soil beneath the building slab/foundation. Contaminated building material above PRGs at the remaining buildings would be removed, and the buildings would be returned to a safe condition. These buildings would not be dismantled, as there is not impacted soil above PRGs under the remaining buildings. This alternative would require close coordination of remediation and monitoring activities with the land owner(s) and/or tenants. This coordination aims to minimize health and safety risks to on-site personnel and disruption of activities consistent with a safe and effective remediation.

Alternative 5 - No Action (OU-2)

Alternative 5 leaves the site “as is” with no actions taken regarding access or land-use controls beyond those already in place. This alternative provides no additional protection to human health and the environment over current conditions. This alternative also assumes existing controls and monitoring will not be maintained. The No Action alternative is required under the NCP [40 CFR §300.430(e)(6)] as a baseline against which other alternatives can be compared.

Alternative 6 - Limited Action and Land-Use Controls (OU-2)

Under this alternative, several forms of land-use controls, access controls, and informational tools would be used to restrict or limit future uses and activities at the site as well as five-year reviews to assess continued protectiveness of the remedy. Land-use controls would include environmental covenants applied to the land to restrict future uses of the site where concentrations of radionuclides remain above PRGs. Access control measures would be aimed at limiting access to reduce the potential for human exposure to soil located at the site. Access controls, such as fencing, would be implemented under this alternative. Informational tools would include posting signs and placing placards to indicate the presence of hazardous substances and warn against intruding onto the site.

Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)

Alternative 7 consists of the excavation of impacted soil exceeding the PRGs in OU-2 and subsequent off-site disposal. This alternative would require close coordination of remediation with the land owner(s) and/or tenants in an effort to minimize health and safety risks to on-site personnel.

Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)

Alternative 8 consists of excavation of impacted soil exceeding the PRGs in OU-2, ex-situ treatment using S/S, and subsequent off-site disposal. This alternative would require close coordination of

remediation with the land owner(s) and/or tenants in an effort to minimize health and safety risks to on-site personnel.

ES.4 COMPARISON OF REMEDIAL ALTERNATIVES

An evaluation of each alternative is performed to provide the basis and rationale for identifying a preferred remedy and preparing the Proposed Plan (PP). In accordance with the NCP [40 CFR §300.430(e)(9)(iii)], each alternative is assessed against seven of the nine evaluation criteria in the FS. The eighth and ninth criteria, state acceptance and community acceptance, cannot be fully addressed until after the public comment period on the PP and will be evaluated as part of the Record of Decision development process. Each remedial alternative was evaluated against the following seven criteria:

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

A comparative analysis of the various alternatives was conducted, as summarized in the following paragraphs.

ES.4.1 Overall Protection of Human Health and the Environment

OU-1

Alternative 1 (No Action) provides no increased protection over the current site conditions and would not be protective of human health and the environment over the long term for foreseeable future land uses. The overall levels of protectiveness for Alternatives 2 (Limited Action and Land-Use Controls), 3 (Complete Removal and Off-Site Disposal), and 4 (Complete Removal with Ex-Situ Treatment and Off-Site Disposal) are considered to be the same because each provide for long-term disposal and control of the MED/AEC-related material. Alternative 2 restricts access to the site to preclude the public from coming into contact with the MED/AEC-related materials remaining on-site. Alternatives 3 and 4 involve the isolation of the MED/AEC-related materials off-site in a disposal facility designed to be protective of human health and the environment. Alternatives 2, 3, and 4 would provide adequate protection of human health and the environment.

OU-2

Alternative 5 (No Action) provides no increased protection over the current site conditions and would not be protective of human health and the environment over the long term for foreseeable future land uses. The overall levels of protectiveness for Alternatives 6 (Limited Action and Land-Use Controls), 7 (Complete Removal and Off-Site Disposal), and 8 (Complete Removal with Ex-Situ Treatment and Off-Site Disposal) are considered to be the same because each provide for long-term disposal and control of the MED/AEC-related material. Alternative 6 restricts access to the site to preclude the public from coming into contact with the MED/AEC-related materials remaining on-site. Alternatives 7 and 8 involve the isolation of the MED/AEC-related materials off-site in a disposal facility designed to be protective of human health and the environment. Alternative 6, 7, and 8 would provide adequate protection of human health and the environment.

ES.4.2 Compliance with Applicable or Relevant and Appropriate Requirements

OU-1

At OU-1, only Alternative 1 (No Action) does not comply with the ARARs. Alternative 2 complies with the limited action ARARs, which are the restricted release conditions of 10 CFR 20.1403, and Alternatives 3 and 4 comply with the complete removal ARARs, which are the unrestricted release conditions of 10 CFR 20.1402.

OU-2

At OU-2, only Alternative 5 (No Action) does not comply with the ARARs. Alternative 6 complies with the limited action ARARs, which are the restricted release conditions of 10 CFR 20.1403, and Alternatives 7 and 8 comply with the complete removal ARARs, which are the unrestricted release conditions of 10 CFR 20.1402.

ES.4.3 Long-Term Effectiveness and Permanence

OU-1

Alternative 1 (No Action) does not achieve long-term effectiveness or permanence. Alternative 1 leaves the contaminants in place, which could continue to affect human health and the environment.

Alternatives 3 and 4 remove the contaminated media from the site and result in less residual exposure at OU-1 at the conclusion of the remedial activities than Alternative 2, which addresses residual exposure by dismantlement and removal of Building G-1, implementation of land-use controls, and periodic monitoring. Therefore, Alternative 2 is ranked higher in long-term effectiveness and permanence than Alternative 1 but lower than Alternatives 3 and 4.

Alternatives 3 and 4 were found to be generally comparable with respect to long-term effectiveness and permanence. Both of these alternatives involve the excavation of contaminated soil to achieve the industrial RGs and would eliminate the potential for contaminant exposure. Alternatives 3 and 4 would also include five-year reviews.

OU-2

Alternative 5 (No Action) does not achieve long-term effectiveness or permanence. Alternative 5 leaves the contaminants in place, which could continue to affect human health and the environment.

Alternatives 7 and 8 remove the contaminated media from the site and result in less residual risk at OU-2 at the conclusion of the remedial activities than Alternative 6, which addresses residual risk by implementing land-use controls and periodic monitoring. Therefore, Alternative 6 is ranked higher in long-term effectiveness and permanence than Alternative 5, but lower than Alternatives 7 and 8.

Alternatives 7 and 8 were found to be generally comparable with respect to long-term effectiveness and permanence. Both of these alternatives involve the excavation of contaminated soil to achieve the residential RGs and would eliminate the potential for contaminant exposure.

ES.4.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

OU-1

Alternatives 1, 2, and 3 do not use any treatment technologies to permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances. Waste minimization practices proposed under Alternatives 3 and 4, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal. Alternative 4 uses S/S treatment to reduce the contaminant mobility. However, the volume of the treatment residuals would be greater (by approximately 25 percent [%]) than the original soil volume. S/S treatment would not affect the toxicity of the contaminants.

OU-2

Alternatives 5, 6, and 7 do not use any treatment technologies to permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances. Waste minimization practices proposed under Alternatives 7 and 8, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal. Alternative 8 uses S/S treatment to reduce the contaminant mobility. However, the volume of the treatment residuals would be greater (by approximately 25%) than the original soil volume. S/S treatment would not affect the toxicity of the contaminants.

ES.4.5 Short-Term Effectiveness

OU-1

Alternative 1 (No Action) is rated highest with respect to short-term effectiveness because no remedial activities would be conducted that have the potential to impact the health and safety of workers and the surrounding community. Alternative 2 (Limited Action and Land-Use Controls) is rated higher than the remaining alternatives with respect to short-term effectiveness since there would be minimal risks to the community and workers during the building dismantlement and periodic monitoring activities. For Alternatives 3 and 4, short-term risks for workers and the public are increased as a result of excavation activities. Alternative 3 is rated next in short-term effectiveness because it does not involve treatment but would have increased risks resulting from off-site disposal. Alternative 4 is rated lowest in short-term effectiveness because there would be additional short-term risks to workers due to the treatment activities and increased transportation-related risks due to the higher volume of contaminated materials requiring transport to an off-site disposal location.

Short-term impacts to the environment would occur as a result of excavation activities conducted under Alternatives 3 and 4. The degree of short-term damage to the environment increases with the amount of surface area subjected to disturbance.

Remediation timeframe is the total period of time it takes to complete remedial design, site mobilization/demobilization, actual field remediation (e.g., soil excavation, building dismantlement, treatment, etc.), verification sampling and analysis, loading and transporting the contaminated waste material to the off-site disposal facility, site restoration, and long-term surveillance and maintenance, if appropriate. The longest remediation timeframe is required under Alternative 2, which assumes continued maintenance of land-use controls and performance of site monitoring over a period of 1,000 years. The attainment of the PRGs is estimated to take less than three years under all action alternatives. The remediation timeframes do not vary appreciably for Alternatives 3 and 4 and are approximately two to three years. Some additional time would be required under Alternative 4 for design, approval, construction, and operation of the S/S treatment facility.

OU-2

Alternative 5, the No Action alternative for OU-2, is rated highest with respect to short-term effectiveness because no remedial activities would be conducted that would have the potential to impact the health and safety of workers and the surrounding community. Alternative 6 (Limited Action and Land-Use Controls) is rated higher than the remaining alternatives with respect to short-term effectiveness, since there would be no risk to the community and only minimal risk to workers during the periodic monitoring activities. For Alternatives 7 and 8, short-term risks for workers and the public are increased as a result of excavation activities. Alternative 7 is rated next in short-term effectiveness because it does not involve treatment but would have increased risks resulting from off-site disposal. Alternative 8 is rated lowest in short-term effectiveness because there would be additional short-term risks to workers due to the treatment activities and increased transportation-related risks due to the higher volume of contaminated materials requiring transport to an off-site disposal location.

Short-term impacts to the environment would occur as a result of excavation activities conducted under Alternatives 7 and 8. The degree of short-term damage to the environment increases with the amount of surface area subject to disturbance.

Remediation timeframe is the total period of time it takes to complete remedial design, site mobilization/demobilization, actual field remediation (e.g., soil excavation, building dismantlement, treatment, etc.), verification sampling and analysis, loading and transporting the contaminated waste material to the off-site disposal facility, site restoration, and long-term surveillance and maintenance, if appropriate. The longest remediation timeframe is required under Alternative 6, which assumes continued maintenance of land-use controls and performance of site monitoring over a period of 1,000 years. The attainment of the PRGs is estimated to take less than three years under all action alternatives. The remediation timeframes do not vary appreciably among the remaining alternatives (i.e., Alternatives 7 and 8). The timeframe for these alternatives is approximately two to three years. Additional time would be required under Alternative 8 for design, approval, construction, and operation of the S/S treatment facility.

ES.4.6 Implementability

OU-1

Because it requires no action, Alternative 1 is not rated with respect to the implementability of the action. The remaining OU-1 alternatives are all implementable but vary in their ease of implementation. Alternatives 2, 3, and 4 all involve the dismantlement and shipment off-site for disposal of Building G-1; however, Alternative 2 is rated higher than the remaining alternatives with respect to soil remediation in terms of technical implementability because no active soil remediation is required. Alternatives 3 and 4 are similarly highly implementable from a technical standpoint. Alternatives 3 and 4 are rated lower in technical implementability than Alternative 2 due to the technical difficulties that are associated with the excavation, transportation, and off-site disposal of soil. There would be a slightly higher degree of difficulty in implementing Alternative 4 due to the additional technical requirements for conducting the S/S treatment activities.

The administrative implementability of Alternative 2 is rated lowest because it involves the implementation of land-use controls; therefore, it is administratively more complex than the remaining alternatives. In addition, there may be administrative difficulties implementing land-use controls and scheduling and coordinating monitoring activities due to the multiple land owners. Alternatives 3 and 4 are rated highest in administrative implementability because no significant problems related to obtaining

approvals from other agencies or coordinating remediation activities with land owners are expected for these alternatives.

OU-2

Because it requires no action, Alternative 5 is not rated with respect to the implementability of the action. The remaining OU-2 alternatives are implementable but vary in their ease of implementation. Alternative 6 (Limited Action and Land-Use Controls) is rated higher than the remaining soil alternatives in technical implementability because no active remediation is required. Alternatives 7 and 8 are similarly highly implementable from a technical standpoint. Alternatives 7 and 8 are rated lower in technical implementability than Alternative 6 due to the technical difficulties that are associated with the excavation, transportation, and off-site disposal of soil. There would be a slightly higher degree of difficulty in implementing Alternative 8 due to the additional technical requirements for conducting the S/S treatment activities.

The administrative implementability of Alternative 6 is rated lowest because it involves the implementation of land-use controls and is administratively more complex than the remaining alternatives. In addition, there may be administrative difficulties implementing land-use controls and scheduling and coordinating monitoring activities due to the multiple land owners. Alternatives 7 and 8 are rated highest in administrative implementability because no significant problems related to obtaining approvals from other agencies or coordinating remediation activities with land owners are expected for these alternatives.

ES.4.7 Cost

OU-1

The estimated total costs for the OU-1 alternatives are listed below. Costs for each alternative and itemization of individual components can be found in Appendix C.

Comparison of Costs for OU-1 Remedial Alternatives

	Alternative	Estimated Total (Present Worth) Cost	Estimated Total (Non-Discounted) Cost
1	No Action (OU-1)	$0	$0
2	Limited Action and Land-Use Controls (OU-1)	$12,406,557	$56,604,601
3	Complete Removal with Off-Site Disposal (OU-1)	$55,185,927	$61,829,592
4	Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)	$76,410,747	$83,139,588

$ = Dollar
OU = Operable Unit

OU-2

The estimated total costs for the OU-2 alternatives are listed below. Costs for each alternative and itemization of individual componeznts can be found in Appendix C.

Comparison of Costs for OU-2 Remedial Alternatives

Alternative		Estimated Total (Present Worth) Cost	Estimated Total (Non-Discounted) Cost
5	No Action (OU-2)	$0	$0
6	Limited Action and Land-Use Controls (OU-2)	$2,228,575	$36,047,405
7	Complete Removal with Off-Site Disposal (OU-2)	$6,617,430	$6,617,430
8	Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)	$9,562,520	$9,562,520

$ = Dollar
OU = Operable Unit

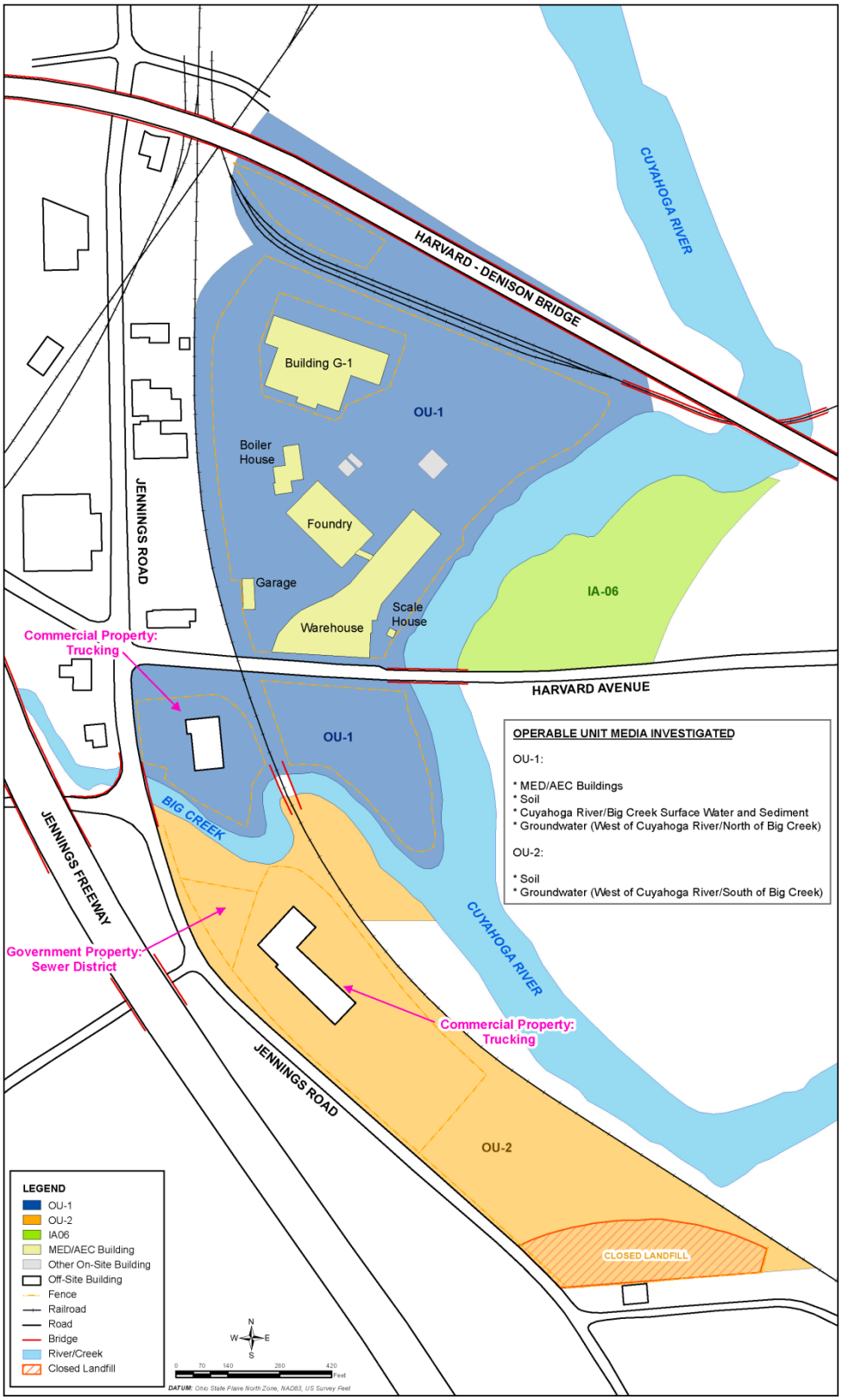

Figure ES-1. Operable Unit Boundaries

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1. INTRODUCTION

In 1974, the Formerly Utilized Sites Remedial Action Program (FUSRAP) was established by the United States Department of Energy (DOE) to identify, investigate, and cleanup or control sites where radioactive contamination remained from the Manhattan Engineering District (MED) and early United States Atomic Energy Commission (AEC) operations. Both MED and AEC were predecessors to the DOE. In 1997, the United States Congress transferred the administration and execution of FUSRAP from the DOE to the United States Army Corps of Engineers (USACE).

Pursuant to a Memorandum of Understanding between the DOE and USACE signed in April 1999, the DOE sent a letter to USACE indicating the Former Harshaw Chemical Company Site was eligible for inclusion into FUSRAP. Subsequent to that letter, USACE determined that contamination that needed to be addressed was present at the site and added the site to the FUSRAP program. Congress required in Pub. L. 105-245 and 106-60, that eligible FUSRAP cleanup would be in accordance with and subject to regulation under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) 42 U.S.C. 9601 et seq. and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR §300).

This Feasibility Study (FS) Report details part of the ongoing evaluation of the Former Harshaw Chemical Company Site located at 1000 Harvard Avenue, Cleveland, Ohio, approximately 3 miles (4.8 kilometer [km]) south of downtown Cleveland (Figure 1-1). The FS is performed to ensure appropriate remedial alternatives are developed and evaluated such that the relevant information concerning the remedial action options may be presented to the decision-maker and an appropriate remedy selected. USACE is the lead Federal agency in the administration and execution of FUSRAP response actions.

The FS process requires the development, screening, and detailed analysis of remedial alternatives. Development of the remedial alternatives must take into account site-specific conditions. The NCP [40 CFR §300.430(e)(9)(iii)] requires the evaluation of specific criteria for the proposed remedial alternatives. USACE is responsible for ensuring the selected remedy(ies) will be protective of human health and the environment and comply with applicable or relevant and appropriate requirements (ARARs).

1.1 PURPOSE, SCOPE, AND ORGANIZATION

1.1.1 Purpose

An FS should evaluate and compare remedial alternatives identified for the site using the nine criteria specified in the NCP [40 CFR §300.430(e)(9)(iii)] as follows:

- Threshold Criteria:
  - Overall protection of human health and the environment; and
  - Compliance with ARARs.

- Balancing Criteria:
  - Long-term effectiveness and permanence;
  - Reduction of toxicity, mobility, or volume;
  - Short-term effectiveness;
  - Implementability; and
  - Cost.

- Modifying Criteria:
  - State Acceptance; and
  - Community acceptance.

Each criterion is described in the following sections.

1.1.1.1 Threshold Criteria

Overall protection of human health and the environment: This evaluation criterion assesses whether each alternative adequately protects human health and the environment. The overall protection assessment is based on an in-depth analysis of each alternative as to the risk to human health and the environment.

Compliance with ARARs: This evaluation criterion determines whether the alternative will meet all of the associated ARARs or will provide the justification for an ARAR waiver allowed under CERCLA section 121(d)(4) and the NCP [40 CFR §300.430(f)(1)(ii)(C)]. ARARs include the following:

- *Chemical-Specific ARARs:* Health/risk-based numerical values or methodologies that establish the acceptable amount or concentration of a contaminant that may remain in or be discharged to the environment;

- *Location-Specific ARARs*: Restrict certain activities or limit concentrations of hazardous substances solely because of geographical or land-use concerns; and

- *Action-Specific ARARs*: Restrictions on the conduct of certain activities or the operation of certain technologies at a particular site.

1.1.1.2 Balancing Criteria

Long-term effectiveness and permanence: This evaluation criterion assesses the ability of an alternative to maintain reliable protection of human health and the environment over time, once remedial action goals have been met (USEPA 1992). The magnitude of residual risk and the adequacy and reliability of controls are addressed for each alternative.

Reduction of toxicity, mobility, or volume: This evaluation criterion assesses the performance of treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of contaminants (USEPA 1988).

Short-term effectiveness: This evaluation criterion examines the effects of the alternative during the construction and implementation phase until remedial response objectives are met (USEPA 1988).

Implementability: This evaluation criterion addresses the technical and administrative feasibility of implementing each alternative. Technical feasibility refers to the ability to construct and operate an alternative.

Cost: This evaluation criterion provides an estimate of the dollar cost for each alternative. The cost includes estimated capital and operation and maintenance (O&M) costs and net present value of capital and O&M costs (USEPA 1992).

1.1.1.3 Modifying Criteria

State Acceptance: This assessment evaluates the technical and administrative issues and concerns the state may have regarding each alternative. This criterion will be addressed in the Record of Decision (ROD) after comments on this FS Report and Proposed Plan (PP) have been received (USEPA 1988).

Community Acceptance: This assessment evaluates the issues and concerns the public may have regarding each alternative. This criterion will be addressed in the ROD after comments on this FS Report and PP have been received (USEPA 1988).

The state acceptance and community acceptance criteria are assessed following comment on the Remedial Investigation (RI)/FS Report and the PP and are fully addressed in the ROD. The preferred alternative selected by USACE at the conclusion of the FS will be the basis for developing a PP and ROD for the site.

1.1.2 Scope

The scope of USACE's remedial action at the Former Harshaw Chemical Company Site is to address residual contamination by radioactive and other hazardous substances resulting from past activities of the MED/AEC conducted in connection with the nation's early atomic energy program. The scope of the FS is confined to remedial alternatives addressing those MED/AEC-related radioactive and hazardous substances. The Former Harshaw Chemical Company Site produced commercial chemicals prior to, during, and after MED/AEC activities were conducted. Any contamination from non-MED/AEC related activities were not included in the scope of the FS. The *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1* (USACE 2009) (herein referred to as the RI Report) concluded that exposures to contaminated materials, including building materials, groundwater, and soil present unacceptable risk or radiological dose to human receptors and required further evaluation in an FS.

1.1.3 Organization

This FS Report is organized as follows:

- **Section 2 - Identification and Screening of Technologies:** Presents the remedial action objectives (RAOs) and general response actions (GRAs) for the FS and presents the initial identification and screening of technology types and process options considered for possible use in site remediation.

- **Section 3 - Development and Screening of Alternatives:** Reviews the identification and screening of technology types and process options considered for possible use in site remediation.

- **Section 4 - Detailed Analysis of Alternatives:** Provides the detailed analysis of the proposed remedial alternatives developed in Section 3.

- **Section 5 - References:** Lists the applicable references cited in this FS Report.

1.2 BACKGROUND INFORMATION

This section provides a summary of the RI Report, including site description, site history, nature and extent of contamination, contaminant fate and transport, and the Baseline Risk Assessment (BRA).

1.2.1 Site Description

The site is located at 1000 Harvard Avenue in Cleveland, Ohio, approximately 3 miles (4.8 km) south of downtown Cleveland. The site is located adjacent to the Cuyahoga River and Big Creek within an industrialized area in Cuyahoga County (Figure 1-1). Neighboring industries include Mittal Steel; Aluminum Company of America; Chemical Solvents, Inc.; and CSP Fabricating. The site consists of approximately 55 acres (22.3 ha) and includes several developed and undeveloped land parcels located near the intersection of Harvard Avenue and Jennings Road. Developed site parcels include former production areas with remaining facility buildings, former production area foundations, parking areas associated with previously demolished buildings, and re-developed, privately-owned commercial properties.

1.2.1.1 Environmental Setting

The following sections describe the environmental setting at the Former Harshaw Chemical Company Site, including climate and land use, geology, hydrogeology, and surface water.

1.2.1.1.1 Climate and Land Use

The climate in Cuyahoga County is temperate. Average temperatures in Cleveland range from a high of 82 degrees Fahrenheit (°F) (27.8 degrees Celsius [°C]) in July to a low of 18°F (-8°C) in January. Mean annual precipitation is 37 inches
(94 centimeters cm).

As shown in Figure 1-2, the site is located in a metropolitan area that is highly industrialized, with residential properties nearby. Industry and commercial businesses primarily surround the site to the north, south, east, and west. A minimal amount of private residences are located adjacent to the site.

Residents and industries in the area rely solely on municipal water supplies. Groundwater is not used for drinking or industrial processes since no potable drinking water wells are located within at least a 2-mile (6.4-km) radius of the site. In addition, the groundwater quality and yield are not suitable for use by industries or residents. The water-bearing zone below the site varies in production (i.e., well yields), and municipal water supplies are in place (and available for expansion), thus precluding the need for groundwater.

Future uses of groundwater from on-site sources are considered unlikely since the Cuyahoga River and Big Creek provide a readily accessible source for usable process and drinking water (with appropriate treatment). Under the state of Ohio's Voluntary Action Program (VAP), the state established areas referred to as Urban Setting Designations (USDs) [Ohio Administrative Code (OAC) 3745-300-10 (c)]. The state recognizes that cleanup of groundwater within a USD to drinking water standards is not necessary given that groundwater is not used for drinking.

Although the site is located within the buffer zone of two USDs for Cleveland, Ohio (Figure 1-3), the presence of the Ohio VAP USDs does not prevent the installation of groundwater wells for drinking or other uses on properties not included in the Ohio VAP. Further, the city of Cleveland does not prevent or regulate the installation of groundwater wells within city boundaries. However the city does require, through ordinance, that dwellings/structures located within city boundaries must be connected to the city municipal water supply system.

1.2.1.2 Geology

The Former Harshaw Chemical Company Site is located near the confluence of the Cuyahoga River and Big Creek. Low-lying portions of the site located along the river and creek lie within the Q3 Federal Emergency Management Agency (FEMA) Flood Hazard Area (see RI Report Figure 2-10).

The former production areas are located north of Big Creek and west of the Cuyahoga River. The site is relatively flat, with a slope of less than (<) 1 percent (%) toward the east (where the Cuyahoga River is located) and to the south (where Big Creek is located). The land surface elevation at the site ranges from approximately 594 feet (ft) (181 meter [m]) above mean sea level (amsl) in the northern portion, to approximately 590 ft (179.8 m) amsl near the banks of Big Creek and the Cuyahoga River. The elevation of the river is approximately 575 ft (175.1 m) amsl. The surrounding areas above the floodplain are developed land with relatively low relief at an approximate elevation of 675 ft (205.7 m) amsl.

On average, subsurface geology consists of approximately 22 ft (6.7 m) of unconsolidated material that overlies shale bedrock. Bedrock is relatively shallow beneath the northern part of the property and becomes deeper toward the south, while the thickness of the unconsolidated material increases. This unconsolidated material consists of both anthropogenic (manmade) fill and native fluvial sediment deposits. The native fluvial sediments are indicative of the site's geographic setting within the Cuyahoga River valley.

Boring logs from the RI note the presence of both fluvial (coarse-grained) and floodplain (fine-grained) sediment across the site. The regional glacial moraine deposits common to the surrounding areas are not seen at the site but are presumed to be present in adjacent highlands to the west. The dynamic nature of the post-glacial environment in the Cuyahoga River valley left minimal glacial till material deposits. The native fluvial material has been covered by reworked sediment and other construction-related fill material during what appears to be two major stages of development: the deposition of old fill during the initial development of the site post 1903, and the deposition of new fill during construction and operation of the Former Harshaw Chemical Company Site. The *Soil Survey of Cuyahoga County, Ohio* (USDA 1980) classifies the site soil as urban land (Ub). Classification Ub is defined as areas of 10 acres (4 ha) or more that are flat or gently sloping, and approximately 80% of the surface is covered by buildings and/or manmade surfaces.

1.2.1.3 Hydrogeology

Discussions of site hydrogeology in this section are based on available historical data and data collected during the RI from water level measurements, slug testing, and well development/sampling activities. Groundwater flow across the site is controlled by the nature of the unconsolidated deposits, the topography of the underlying shale bedrock, and the relative elevation of the discharge areas (Cuyahoga River and Big Creek).

Potentiometric maps show groundwater flow in the unconsolidated fluvial material saturated zone to be generally from west to east across the site. Groundwater flow directions across the site appear to be influenced by changes in surface water levels and flow into the Cuyahoga River and Big Creek.

Primary groundwater flow occurs within the fluvial sediment saturated zone, a variably textured alluvium. The fill and alluvium coarsens to the east toward the Cuyahoga River. Due to the highly fractured nature of the uppermost portion of shale bedrock at the site, groundwater in this zone appears to extend into the upper portion of the shale bedrock. Based on geologic boring log descriptions, groundwater within this relatively thin fractured upper bedrock zone is present as a result of direct contact with the overlying

saturated fluvial sediment zone at the site. Groundwater is assumed to extend into the upper few feet of the shale bedrock. A shallow bedrock well near Building G-1 produced very low sampling yields and hydraulic conductivity values.

Regionally, the shale bedrock is not a significant groundwater bearing zone, historically producing 3 to 10 gallons per minute (gpm) (11.4 to 37.9 liters per minute). The similarities observed between groundwater levels within the fluvial sediment and the fractured bedrock zone suggest these zones are hydraulically connected.

The fluvial sediment represents the primary water-bearing zone in the vicinity of the site. The fluvial sediment underlies the fill material and is located above the shale bedrock unit. This unconsolidated material and its associated saturated zone are not used as a drinking water source for the surrounding Cleveland area, which obtains drinking water for the metropolitan area from Lake Erie. Potentiometric maps developed during the RI (see RI Report Figures 6-36 and 6-37) indicate groundwater in the fluvial sediment discharges to the Cuyahoga River and Big Creek.

1.2.1.4 Surface Water

The site is located near the confluence of the Cuyahoga River and Big Creek. Surface water drainage characteristics vary across developed and undeveloped portions of the site. The following sections discuss characteristics of the two main surface water bodies present at the site, as well as surface water runoff and storm sewer drainage.

1.2.1.4.1 Cuyahoga River

Headwaters of the Cuyahoga River originate in Geauga County, Ohio, where the river flows south to the city of Cuyahoga Falls before turning sharply north toward Cleveland. Along the river's approximately 100-mile (161-km) course, the river flows through heavily populated and industrialized areas, including the city of Akron and suburban land south of Cleveland. The Cuyahoga River discharges into Lake Erie at a point located approximately 4 miles (6.4 km) north-northwest of the site.

The normal elevation of water within the Cuyahoga River, as averaged from readings of RI staff gauges, is 574.7 ft (175.2 m) amsl. This elevation is, on average, approximately 20 ft (6 m) below the elevation of the developed portions of the site.

The elevation of the river bottom (bedrock) adjacent to the site was not directly measured during the RI but is assumed to be relatively shallow, based on bedrock elevations on-site and surface water elevations in the river.

1.2.1.4.2 Big Creek

Big Creek headwaters are found in the cities of North Royalton, Ohio (east branch) and Brook Park, Ohio (west branch). Big Creek flows east through the cities of Brooklyn and Cleveland and merges with the Cuyahoga River at the site, approximately 7.5 miles (12 km) upstream from the mouth of the Cuyahoga River. The normal elevation of water within Big Creek is 575.2 ft (175.3 m) amsl, as averaged from readings of RI staff gauges.

Similar to the Cuyahoga River, no direct bedrock elevation measurements of the creek bottom were collected during the RI. The bedrock in the creek was assumed to be shallow, based on bedrock elevations, and exposed bedrock is visible along Big Creek banks.

1.2.1.4.3 Runoff and Storm Sewer Drainage

The topography of the developed land surface in the northern portion of the site is characterized by generally low relief, with a gentle slope toward the Cuyahoga River to the east. Where the site property is bounded by the Cuyahoga River to the east, a relatively steep bank of 25 to 30 ft (7.6 to 9.1 m) is present along the west bank of the river. The land surface in the middle portion of the site is approximately 10 to 15 ft (3 to 4.6 m) higher than the river and creek channel bottoms. Large portions of land surface in the northern portion of the site have been further modified to permit the construction of buildings, paved surfaces, and associated drainage systems. All of the developed parcels within the site boundary have been filled to raise the land surface elevation and limit the potential for flooding.

Numerous catch basins in the northern portion of the site collect precipitation runoff, which is directed to the Cuyahoga River via storm sewers and associated outfalls. Functionality of the storm sewers, catch basins, and outfalls appears to vary, as some sewer line branches are filled with sediment and are inactive. Several storm sewer outfalls were identified in this area along the west bank of the Cuyahoga River; however, only two outfalls were noted with active discharges during the RI.

The southern portion of the site represents mainly undeveloped parcels where no known drainage systems exist. Surface water runoff from this area is controlled by drainage ditches and culverts associated with the adjacent railroad tracks.

1.2.2 Site History

The following summarizes the site ownership of the Former Harshaw Chemical Company Site and the history of government-contracted operations conducted at the site.

1.2.2.1 Site Ownership

The Harshaw Chemical Company property was initially purchased by the Harshaw, Fuller & Goodwin Company in 1905 and was used for the commercial manufacture of chemical solvents, metal salts, fluorides, hydrofluoric acids, and other chemical products. The Harshaw Chemical Company conducted MED/AEC contracted activities from 1942 through 1959.

Site ownership changed several times after the completion of government-contracted operations in 1959. In 1966, Harshaw merged with the Kewanee Oil Company of Bryn Mawr, Pennsylvania, and Kewanee was acquired by the Gulf Oil Corporation in 1977. Gulf organized a joint venture with the Kaiser Aluminum & Chemical Corporation in 1983, combining their two chemical units into the Harshaw/Filtrol Partnership to produce specialty chemicals. In 1988, Kaiser sold the Harshaw/Fitrol partnership to Engelhard, a specialty chemical and metallurgical maker based in Oakland, California. In June 2006, Engelhard was acquired by the German chemical company BASF (CWRU 2004).

Most of the site is currently owned by BASF. Building G-1, the undeveloped parcel located east of the Cuyahoga River (Investigative Area [IA] 06), and the southern undeveloped portion of IA07 are currently owned by the Chevron Corporation. The northern portion of IA07 includes two parcels owned by private commercial entities and one parcel owned by the Northeast Ohio Regional Sewer District.

1.2.2.2 Operational History

The Harshaw Chemical Company produced a number of major and minor uranium products. Uranium processed under MED/AEC contracts was present in various forms such as:

- Uranium tetrafluoride (UF_4);
- Uranium trioxide (UO_3);
- Uranium tetrachloride (UCl_4);
- Uranium dioxide (UO_2);
- Triuranium octoxide (U_3O_8); and
- Uranium hexafluoride (UF_6).

Five thousand metric tons of uranium (MTU) was processed under MED/AEC contracts between 1942 and 1954. Major products included UF_4 (Green Salt), UF_6, and UO_3.

Government-contracted operations were carried out within the Building G-1 complex, also known as Plant C (Chevron-BGD 1997), or more commonly known as the "Harvard-Denison Plant" (CWM 1992), which was built and expanded several times over the period from 1945-1949. The complex lies within a 1.6-acre (0.6 ha) fenced area located in the northern portion of the Former Harshaw Chemical Company Site.

The major processing plants were the Refinery and Brown Oxide Plant, which produced UO_3 and UO_2, respectively. The Refinery and Brown Oxide Plant were located in Building G-1. Also located in Building G-1 were the UF_4 plant and the UF_6 plant. MED/AEC-related activities were not confined to the currently fenced area but included the use of the former rail yard adjacent to Building G-1 and the former Foundry (previously designated as Building F-1). The Foundry was used in the early years at the site, and government-contracted processes used only high-purity UO_2 as feed material.

The Harshaw Chemical Company ended production operations for UF_4 in September 1951, with complete dismantlement of the UF_4 plant by May 1953. The UF_6 production plant was placed on stand-by status as of May 1953. The refinery portion of Building G-1 continued to operate in 1953 and 1954, purifying recycled uranium (RU) from the General Electric Company of Richland Washington at Hanford.

Several radiological surveys were conducted by AEC personnel between 1953 and 1957. These surveys provided information regarding radiological conditions associated with Building G-1 and the remainder of the facility. In addition, these surveys allowed for the scoping of final decontamination activities that would be required prior to the final release and assignment of the primary uranium compound production contract (W-7405-ENG-276) on December 23, 1959. The full scope of the final release activities is not known.

1.2.2.3 Previous Investigations

The following summarizes investigations conducted prior to and including the RI. The previous investigations were reviewed for information to be used in the planning and approach of the RI. In addition, any viable data collected during the review of previous investigations was incorporated into evaluations of the site.

1.2.2.3.1 Historical Investigations

Previous investigations conducted at the Former Harshaw Chemical Company Site primarily addressed radiological contamination associated with government-contracted production operations. Intermittent surveys of the uranium refining operation at the site were conducted by MED/AEC to monitor worker safety. Additional radiological contamination surveys were conducted by AEC upon termination of government work at the site.

The Argonne National Laboratory (ANL) performed a study for the AEC to determine the condition of sites formerly utilized by the MED and AEC. A search of MED/AEC records indicated documentation of remediation at the site was insufficient to determine whether previous decontamination work was adequate to meet AEC remediation guidelines. This study was performed during 1976-1979 and concluded that "significant" levels of contamination were still present in 17 buildings and 32 exterior locations (ANL 1984). Of the 17 buildings with significant levels of contamination, only 6 remain.

In 1992, Chemical Waste Management (CWM) performed a radiological assessment of Building C (Building G-1). This study was performed to determine the extent of contamination within the building.

Foster Wheeler Environmental Corporation (FWEC) performed Decontamination and Decommissioning (D&D) activities on Building G-1 in 1995. As a first phase of this effort, additional characterization was performed to determine the accuracy of previous characterization work performed by ANL and CWM and to quantify the extent of contamination within the building. FWEC contracted Hilbert Associates, Inc. to prepare a report that summarized the FWEC survey results taken in 1995 and compare them with previous characterizations performed on Building G-1 by ANL and CWM.

In the 1990s, numerous radiological contamination surveys of existing buildings and structures were conducted by B. Koh & Associates, Inc. for the current property owners. Survey results were submitted to the United States Nuclear Regulatory Commission (NRC) along with requests for free-release determinations. Many of the free-released buildings and structures were demolished and disposed of accordingly.

B. Koh & Associates, Inc. also conducted environmental investigations of soil, sediment, surface water, and groundwater to characterize radiological conditions associated with past Harshaw Chemical Company operations. The results of these investigations are documented in the Site Characterization Report (B. Koh and Associates, Inc. 1998).

Blasland, Bouck & Lee also conducted chemical soil sampling for former Parcels A, B, and C (defined in the RI Report as portions of IA03/IA04, IA06, and the southern portion of IA07, respectively).

In April 2001, USACE completed a CERCLA Preliminary Assessment (PA) for the site. The PA concluded that although there was no imminent threat to human health or the environment, the site should undergo further investigation. Because the PA indicated an additional site investigation was warranted, USACE decided to forgo a Site Inspection and proceed to an RI of the site.

1.2.2.3.2 Remedial Investigation

The RI was conducted to determine the nature and extent of contamination related to MED/AEC activities at the site and evaluate potential unacceptable risk or radiological dose to human health and ecological receptors in a risk assessment. The RI was completed in six phases that include the following:

- Records review;
- Non-intrusive field work;
- Phase I intrusive field work;
- Phase II intrusive field work;
- Phase III intrusive field work; and
- Phase IV intrusive field work.

Below is a summary of the activities conducted during each phase of the RI. The results of the RI are documented in the RI Report and are summarized in Section 1.2.3 of this FS Report.

Records Review

Over 530 documents containing information pertinent to the Former Harshaw Chemical Company Site were retrieved during a historical records search. The historical information (including relatively extensive environmental sampling data) was reviewed and evaluated to determine the suitability of the data for use in supporting the RI risk analysis or as screening-level data to provide general information to help focus the proposed RI sampling effort.

Non-Intrusive Field Work

Non-intrusive field work was conducted in October 2002 and used site-wide reconnaissance and remote-sensing surveys. The non-intrusive surveys were used to identify areas requiring further investigation during intrusive sampling activities. Locations of potential subsurface anomalies were delineated and mapped using gamma walkover and geophysical survey methods. Site vegetation clearing activities and initial reconnaissance of existing (pre-RI) groundwater monitoring wells were also conducted during the non-intrusive field work.

Phase I Intrusive Field Work

Phase I intrusive field investigations were conducted April through December 2003. Environmental samples, including soil, sediment, surface water, and groundwater were collected from on-site and off-site (background) locations. Samples collected during this phase were submitted for on-site and off-site gamma spectroscopy. The samples were analyzed for MED/AEC-related constituents identified during the review of available historical documentation and previous site characterization results. The Phase I MED/AEC-related constituents included metals (lithium, molybdenum, and uranium), kerosene, and radionuclides (uranium-235, uranium-238, actinium-227, protactinium-231, thorium-228, thorium-232, radium-226, and radium-228).

In addition, focused building characterization radiation surveys were conducted at the following on-site buildings:

- Building G-1;
- Foundry;
- Warehouse;
- Garage;
- Boiler House; and
- Scale House.

Building characterization radiation surveys included the completion of fixed-point alpha/beta activity measurements, removable alpha/beta activity measurements, scan beta surveys, and dose rate gamma measurements. Characterization survey objectives varied between Building G-1 and the Foundry, Warehouse, Garage, Boiler House, and Scale House. The primary objectives of the Building G-1 radiation survey were to provide quantitative data to confirm widespread contamination found during previous investigations and collect data to support the evaluation of remedial alternatives in the FS.

The primary objectives of the radiation surveys at the remaining buildings were to identify radiological contaminants on building surfaces and conduct verification surveys where all previous survey results

were less than the survey instrument minimum detectable count rate. In addition, the collected data were used to establish nature and extent of contamination (if identified) to support the evaluation of remedial alternatives in the FS for the remaining buildings.

Volumetric building samples were collected from Building G-1, the Foundry, and Warehouse to characterize different building media and to provide data to support planning for potential future dismantlement and/or disposal options.

Phase II Intrusive Field Work

A follow-up Phase II intrusive field investigation was conducted May through December 2004 and focused on further delineation of the nature and extent of contamination, based on data gaps identified after the completion of Phase I. Additional environmental media, general site characterization, and building material samples were collected, and additional focused building radiation surveys were conducted.

Phase III Intrusive Field Work

Phase III sampling was conducted November through December 2006 to address several data gaps identified after a review of the initial RI results from the previous phases of investigation. The primary objective was to determine the extent of thorium-230 contamination. Other objectives were: (1) to investigate the possible presence of enriched uranium; (2) to investigate the possibility of radium contamination as a co-contaminant with thorium; (3) to investigate specific locations and infrastructure; and (4) to evaluate the performance of x-ray fluorescence spectroscopy (XRF) field instrumentation for possible future needs.

Phase IV Intrusive Field Work

Phase IV sampling was conducted in July 2007 to investigate the potential presence of radioactive contaminants associated with RU that were not analyzed in previous investigations. Sample locations were selected after a review of process operations and after referring to results for uranium and other previously analyzed contaminants which are associated with uranium recycling. An additional objective of the Phase IV investigation was to conclusively determine if enriched uranium is present at the site, based on unequivocal isotope ratios using mass-spectrometric measurements.

During the RI, the site was divided into 10 IAs designed to aid in the implementation of site characterization activities. The boundaries of each IA were based on several factors, including environmental media, geographic property boundaries, and physical site features. More details regarding IA boundaries are presented in the RI Report.

1.2.3 Nature and Extent of Contamination

Environmental samples collected during the RI to determine nature and extent of contamination focused on the following:

- Buildings;
- Soil;
- Groundwater;
- Surface water;
- Sediment; and

- Sewers and drains.

The following sections summarize the results of the nature and extent sampling conducted during the RI. The RI Report contains a detailed description of sampling activities and results.

1.2.3.1 Buildings

Focused building characterization efforts included radiation surveys at Building G-1, Foundry, Warehouse, Garage, Boiler House, and Scale House to determine the nature and extent of MED/AEC-related radiological contamination and to provide preliminary waste characterization data to support the evaluation of remedial alternatives in the FS.

The RI building radiation survey characterization consisted of the following tasks:

- Surface beta (area) scans to identify the potential for isolated areas of contamination;
- Measurements of total alpha and beta surface activity at systematic grid locations, scan follow-up locations, duplicate locations, and discretionary locations;
- Measurements of removable alpha and beta surface activity; and
- Measurements of external gamma dose rate.

Building radiation survey results for radiological constituents were compared to the following screening levels to identify radiological impacts:

- **Fixed surface alpha/beta activity:** 5,000 disintegrations per minute (dpm)/100 square centimeters (cm^2) (NRC Regulatory Guide 1.86); and
- **Removable alpha/beta activity:** 1,000 dpm/100 cm^2 (NRC Regulatory Guide 1.86).

In general, Building G-1 (identified as IA01 during the RI) is the most significantly impacted of the historical structures. Widespread areas of fixed surface beta activity in excess of surface screening levels were identified on interior and exterior building surfaces. Elevated activity was identified over many areas of the roof and brick exterior. Removable activity in excess of the surface screening level was identified on isolated locations of the interior. Large portions of the building that might be segregated as non-radioactive during a potential dismantlement were not identified. Dose rates ranged from 9 to 50 microrems per hour (µrem/hr) in the interior and from 6 to 12 µrem/hr on the exterior to the building.

Radiation survey results for the Foundry, Warehouse, Garage, Boiler House, and Scale House (included in IA02 during the RI) indicated the following:

- Boiler House interior and exterior surface activity survey results were below screening levels, with the exception of isolated locations, areas of fixed surface beta surface activity on (most) windowsills, and a few exterior wall areas. Radiation dose rates ranged from 5 to 15 µrem/hr.
- Foundry exterior surface activity survey results were below surface activity screening levels, with the exception of isolated areas of fixed beta surface activity on windowsills, the east wall, and the concrete caps over the northeast wall. Roof measurements identified a maximum total beta surface

activity of 12,826 dpm/100 cm^2, while a maximum total beta surface activity of 69,457 dpm/100 cm^2 was identified on the wall caps. Radiation dose rates ranged from 8 to12 µrem/hr.

- Warehouse interior and exterior surface activity survey results were below surface activity screening levels, with the exception of isolated areas of fixed beta surface activity on a windowsill, a roof location, and an exhaust vent. Roof surface measurements were below surface activity screening levels, with the exception of one location on the north side of the roof (fixed-point total beta measurement of 5,867 dpm/100 cm^2). Radiation dose rates ranged from 5 to 18 µrem/hr.

- Garage survey results indicated all exterior surfaces, with the exception of one small area on the west exterior wall, were below the surface activity screening levels. Radiation dose rates ranged from 10 to 15 µrem/hr.

- Scale House survey results indicated no locations above the surface screening levels were identified on interior of exterior surfaces. Radiation dose rates ranged from 10 to 12 µrem/hr.

During the RI, volumetric building material samples were collected from Building G-1, Warehouse, and Foundry to support potential waste disposal characterization for building dismantlement debris.

Volumetric building material sample results for radiological constituents were compared to a volumetric screening level of 13 picoCuries per gram (pCi/g) to identify radiological impacts. This volumetric screening level was based on United States Nuclear Regulatory Commission Regulation (NUREG)-1757. The volumetric building material screening level of 13 pCi/g was calculated using a sum of ratios (SOR) approach and the isotope-specific screening levels for uranium-234, uranium-235, and uranium-238 in Table H.2 of NUREG-1757. These three isotopes were assumed to be present in their naturally-occurring ratios, consistent with the site characterization data collected for the site.

Volumetric building material sample results confirm the presence of widespread contamination throughout Building G-1. Two roof samples from the Foundry were above the volumetric screening level of 13 pCi/g for total uranium. Six roof samples collected from the Warehouse were also above the volumetric screening level of 13 pCi/g for total uranium. No other results collected from the Foundry or Warehouse were above the total uranium volumetric screening level. Table 1-1 presents a summary of the analytical data for MED/AEC-related radiological constituents detected in the building volumetric samples.

Additional information regarding the nature and extent of MED/AEC-related radiological contamination associated with applicable buildings are presented in the RI Report. Specific areas of building radiological contamination are discussed later in this FS Report to support the development and detailed analysis of remedial alternatives.

1.2.3.2 Soil

Soil characterization during the RI was conducted using several soil sample collection methods, including hollow-stem auger drilling/split spoon samplers, Geoprobe drilling/Macrocore samplers, hand augers (surface soil and trenches), and direct grab samples (surface soil and trenches). Soil samples were analyzed for MED/AEC-related radiological parameters at an on-site gamma spectroscopy laboratory and at an off-site subcontracted laboratory. MED/AEC-related chemical parameters were analyzed at the off-site subcontracted laboratory.

Soil characterization efforts conducted during the RI identified the following primary areas of elevated MED/AEC-related radiological constituents:

- North of Building G-1 and north of the former CSX railroad (northern IA03 area);
- North of Building G-1 and south of the former CSX railroad (central IA03 area);
- Vicinity of and beneath Building G-1 (central IA03 area);
- Localized area located between the Warehouse and Foundry (central IA04);
- Northeast portion of main process area along Cuyahoga River west bank (northern IA04 area);
- Several localized areas north of the Cuyahoga River/Big Creek confluence (southern IA05) and along the west bank of the Cuyahoga River (northeastern IA05); and
- Northern portion of the undeveloped land west of the Cuyahoga River and south of Big Creek (south of the Milan Trucking property in IA07).

Most areas of elevated MED/AEC-related radiological constituents were identified in surface soil (0-2 ft [0-0.6 m] below ground surface [bgs]) and shallow subsurface soil (2-13 ft [0.6-4 m] bgs) depths. However, additional areas with elevated MED/AEC-related radiological constituents were noted in deeper soil (up to 16.8 ft [5.1 m] bgs) along the west bank of the Cuyahoga River in the northeast portion of the site. Contaminated fill material also is suspected as the cause for radiological soil contamination identified in the southern portion of IA05 near the confluence of the Cuyahoga River and Big Creek.

Generally, elevated radiological soil contamination appears to be associated with surface releases/spills in the shallower depths and the placement of contaminated fill material during historical site operations in the deeper intervals. During the RI, obvious fill material (e.g., brick, wood, concrete) was observed in many soil samples from the deeper radiological soil contamination areas. More details regarding the nature and extent of MED/AEC-related radiological soil contamination is presented in the RI Report. Specific areas of applicable radiological soil contamination are discussed in this FS Report to support the determination of contaminated soil volume estimates and the development and detailed analysis of remedial alternatives.

Elevated concentrations of MED/AEC-related chemical constituents also were detected sporadically throughout the site during the RI. However, the spatial distribution of the samples did not suggest an obvious process-related source. The concentrations of MED/AEC-related chemical constituents identified during the RI do not pose unacceptable risks to ecological receptors or human receptors associated with current or assumed future land uses (see Section 2.1.3); therefore, theses constituents are not considered further in the FS.

1.2.3.3 Groundwater

The characterization of site groundwater during the RI was conducted using groundwater samples collected from numerous sources, including existing (pre-RI) monitoring wells, new RI monitoring wells, new RI temporary piezometers, and new RI temporary well points. New RI monitoring wells and temporary piezometers were installed using a hollow-stem auger drill rig, and temporary well points were installed using a Geoprobe drill rig. Groundwater samples were collected using low-flow sampling methods or a bailer (for sample locations with very slow recharge). All groundwater samples were

analyzed for MED/AEC-related radiological and chemical parameters at an off-site, subcontracted laboratory.

Groundwater flow directions across the site were identified through the collection of water-level measurements during RI groundwater sampling events. The generalized groundwater surface elevations (also known as the potentiometric surface) developed from these measurements indicate groundwater flows across the site toward the Cuyahoga River.

The groundwater characterization effort conducted during the RI identified a single plume of elevated MED/AEC-related radiological constituents contained with the unconsolidated material beneath and in the vicinity of Building G-1. The radiological contaminant plume appears to originate in contaminated sub-floor material beneath Building G-1 and extends to the north-northeast. The radiological contaminant plume does not extend beyond the site boundary.

Elevated concentrations of a MED/AEC-related chemical constituent also were detected in IA10 groundwater during the RI. Lithium concentrations of 451 micrograms per liter (µg/L) were detected in groundwater in IA03 and IA04 (generally north of the Boiler House/Foundry/Warehouse and south of the Harvard-Denison Bridge). The lithium groundwater impacts are located in the same general area as the radiological impacts described previously; however, lithium contamination is more widespread (likely due to the relatively high mobility of lithium in groundwater as compared to the radiological constituents).

Although groundwater impacts due to MED/AEC-related radiological and chemical constituents were identified during the RI, the detected concentrations pose unacceptable risks to only the most conservative future land-use receptors (i.e., subsistence farmer). No unacceptable risks to ecological receptors from groundwater contamination were identified during the RI.

Groundwater characterization during the RI was limited to the portion of the site associated with the former process area. The groundwater evaluation area (also identified as IA10 during the RI) included the area to the west of the Cuyahoga River and north of Big Creek. The river and creek act as hydrologic boundaries that prevent the migration of groundwater contamination within unconsolidated material to the east or south. Groundwater to the south of Big Creek (IA07) was not evaluated during the RI due to the lack of historical evidence of contamination or potential sources for groundwater contamination. Soil contamination identified in the southern portion of IA07 is located in shallow soil and is not present in sufficient quantities to represent a significant potential source for groundwater contamination in this area.

Groundwater modeling conducted during the RI evaluated the fate and transport of radiological groundwater contamination at the site. The contaminant transport analyses indicated the contamination plume near Building G-1 is migrating toward the Cuyahoga River (consistent with the overall groundwater flow direction across the northern portion of the site). The groundwater model evaluation indicated the radiological contaminant plume will not reach the river with above-background concentrations for approximately 900 years.

Although elevated concentrations of radiological and chemical MED/AEC-related groundwater contaminants were identified during the RI, the contamination levels in groundwater do not pose unacceptable risk or radiological dose to ecological receptors or human receptors associated with current future land uses. However, as with all other site media, the protection of groundwater will be considered during the development and detailed analysis of remedial alternatives for soil contamination. Also, it is considered likely that future remedial actions to address soil contamination beneath and in the vicinity of

Building G-1, as well as soil contamination located in other areas of the site, will have a beneficial impact on the level of radiological groundwater contaminants.

More information regarding the nature and extent of MED/AEC-related radiological groundwater contamination are presented in the RI Report. Specific areas of applicable radiological groundwater contamination and groundwater flow characteristics are discussed in Appendix D of this FS Report to support the development and detailed analysis of remedial alternatives for soil contamination.

1.2.3.4 Surface Water, Sediment, and Sewers and Drains

Surface water and sediment from the Cuyahoga River and Big Creek adjacent to the site (IA08) and associated with the on-site storm/sanitary sewer system (IA09) were evaluated as part of the RI characterization effort.

Surface water samples were collected as grab samples from the river, creek, and sewer system. River and creek water samples were collected directly into the required laboratory sample containers, while sewer line water samples were collected using a bailer or peristaltic pump. Sediment samples were generally collocated with surface water samples and were collected with a scoop, hand auger (deeper sediment), or Ponar dredge. Sewer line samples were collected from accessible manholes or catch-basins. Sewer line sediment samples also were collected from directly beneath each identified outfall pipe along the river/creek banks in IA04 and IA05.

One sediment sample collected from the Cuyahoga River during the RI contained elevated MED/AEC-related radiological constituents. This sample was collected proximate to the area of deep soil contamination, in the northeast portion of IA04 along the west bank of the Cuyahoga River. Although MED/AEC-related chemical constituents were also detected in surface water and sediment, the concentrations of MED/AEC-related radiological and chemical constituents do not pose unacceptable risk or radiological dose to ecological receptors or human receptors associated with current or assumed future land uses, and therefore, are not considered further in the FS.

Soil associated with the IA09 sewers and drains backfill material was evaluated in the RI as part of the soil dataset (according to the location where the sample was collected). More information regarding the nature and extent of MED/AEC-related radiological groundwater contamination in surface water and sediment are presented in the RI Report.

1.2.3.5 General Characterization

The following sections summarize evaluations that were performed for contaminant transport and original project assumptions regarding the composition and sources of radiological contamination expected at the site during the RI.

1.2.3.6 Airborne Uranium Contamination Transport

In the RI Report (USACE 2009), an evaluation of potential historical airborne uranium contamination transport included the review of collocated, near-surface soil split sample (0-0.5 ft [0-0.2 m] bgs) and surface soil sample (0-2 ft [0-0.6] bgs) results generated from IA03 - IA06. The evaluation found no evidence of historical airborne transport. Based on a statistical comparison between the two datasets, no significant statistical differences between the near-surface soil and surface soil data were identified; thus indicating no significant airborne deposition of contamination to soil.

1.2.3.7 Enriched Uranium

As discussed in the RI Report, the RI soil dataset was evaluated to characterize uranium contamination at the Former Harshaw Chemical Company Site and validate the original project assumption that primarily non-enriched (natural) uranium was processed at the facility. The results of the evaluation did not indicate the site wide presence of low enriched uranium in soil. The soil data evaluation was generated using three different analytical procedures; gamma spectroscopy, alpha spectroscopy and inductively coupled plasma mass spectrometry (ICP MS). The ICP-MS was conducted to provide more accurate results considering the limitations associated with both gamma and alpha spectroscopy as discussed in Sections 3.2.1.2 and 6.1.1.2 of the RI Report (USACE 2009).

The soil evaluation consisted of calculating sample specific uranium 235/uranium 238 activity ratios for on site and off site (background) data for comparison to the expected uranium 235/uranium 238 ratio of 0.046:1. Activity ratios statistically greater than 0.046:1 may indicate the presence of enriched uranium, while ratios of less than 0.046:1 may indicate the presence of depleted material.

A detailed evaluation of all results is contained in Section 6.1.1.2 of the RI Report and the conclusions of the evaluation are presented in Section 9.1.2.2 of the RI Report (USACE 2009). The evaluation of enriched uranium concluded that the uranium isotope ratios in site soil, groundwater, and surface water measured by ICP MS indicate the presence of residuals of slightly depleted uranium. Measured uranium 235/uranium 238 mass ratios are similar to documented mass ratios in Hanford feed, which suggests the source of the depleted uranium may be from the processing of RU from Hanford. Conversely, there is no evidence of the presence of enriched uranium in any of the same samples (USACE 2009).

1.2.3.8 Thorium-230 Distribution

Historical information collected prior to the field investigation did not indicate the presence of a significant thorium-230 waste source separate from uranium at the site. Higher-than-expected concentrations of thorium-230 were discovered on-site during the initial phase of the RI. Further research into historical documentation indicated thorium-230 was present as an impurity in the uranium concentrates sent to the site. Almost all of the elevated thorium-230 activity concentrations encountered to date are associated with uranium-238 activity concentrations above background levels. This suggests the contamination is the result of disposing waste stream material in the same place uranium-238 impacts were present, or that material jointly contaminated by waste stream material and product (e.g., used equipment, decontamination and dismantlement building debris) was stored or disposed of in specific areas.

1.2.3.9 Recycled Uranium Constituents

Documents uncovered during RI sampling events indicated RU from Hanford processed at the site might have contained higher levels of radiological contaminants than originally thought. In order to investigate the possibility that residuals of these contaminants in site media might pose a risk that would require remediation, sampling and analysis was conducted on new and archived RI samples in potentially affected areas. Contaminants of interest included technetium-99, europium-152, europium-154, neptunium-237, plutonium-238, plutonium-239, plutonium-240, and americium-241. In addition, the isotopes uranium-233 and uranium-236 were of interest as markers of RU.

The results of sample analysis confirmed the presence of RU, as well as very low levels of several radiological contaminants associated with it. The presence of RU was confirmed primarily from the presence of the isotope uranium-236 in several locations. Uranium-236 is not found in natural uranium.

While the uranium-236 detections were few and low level, the samples were generally collocated with similarly low-level detections of technetium-99, plutonium-239/240, and americium-241. In general, the ratios of uranium-236/uranium-238 were in line with expected ranges in RU. Taken together, these results indicate residuals of RU are present in the site soil.

Uranium-236 was found in only 1 of 21 groundwater samples at a barely detectable level. A few sporadic detections of similarly low levels of RU contaminants were found in groundwater, including isolated detections of technetium-99, plutonium-239/240, and americium-241. In contrast to soil detections, however, these constituents of RU were not collocated with individual groundwater samples. Thus, while trace levels of RU constituents appear to be sporadically present in groundwater, the evidence for RU contamination is not as strong as that for soil, where constituents tended to be collocated.

1.2.4 Contaminant Fate and Transport

Based on the results of the RI, MED/AEC-related contamination requiring remedial action during the completion of the FS is limited to radiological constituents in soil and associated with historical existing buildings.

Although radioactive constituents decay naturally, this process is very slow for the various radionuclides of interest at the Former Harshaw Chemical Company Site. The half-lives of uranium-238 and radium-226, for example, are 4.47 billion years and 1,602 years, respectively. The half-life represents the time required for one-half of a mass of a radioactive material to naturally decay to the next radionuclide in the decay chain. Considering the long half-lives of the MED/AEC-related radiological constituents of interest at the site, the contamination could remain in perpetuity.

The lack of current or anticipated future production activities associated with radiological constituents at the site preclude the continued transport of contamination via process operations (e.g., dust emissions, spills, leaks). Although process operations are no longer being conducted, other mechanisms of physical contaminant transport do exist and include:

- Contaminated media relocated as construction fill or debris;
- Contaminated soil, sediment, dust, or other media relocated by surface water runoff;
- Contaminated soil, sediment, dust, or other media relocated by wind erosion;
- Contaminant leaching from saturated soil to groundwater; and
- Contaminant leaching from unsaturated soil to groundwater.

The relocation of contaminated media (soil or building material) as the result of on-site construction activities conducted prior to the completion of a remedial action is not considered likely based on the current ownership and use of the site.

The ongoing transport of contaminated media via surface water runoff or wind erosion may be present at the site, although the overall impact of these transport mechanisms is considered to be minor, based on current site conditions and the results of the RI. For example, the transport of contamination present in surface soil is not significant due to the presence of vegetation or pavement (limiting airborne transport) and the land surface elevation of the site relative to the Cuyahoga River (limiting surface water transport due to flooding). Groundwater monitoring has demonstrated that groundwater contamination is not reaching the site boundaries. Analytical results associated with soil, sediment, surface water, and groundwater samples collected during the RI support these conclusions.

Contaminant leaching from saturated soil or fill material is thought to represent the primary source for groundwater contamination in the vicinity of Building G-1. Significantly-elevated MED/AEC-related radionuclide concentrations identified within saturated subfloor material beneath the building strongly suggest direct contaminant transport to groundwater in this location.

The leaching of radiological contamination from unsaturated material (i.e., shallow or surface soil) to groundwater is not considered to be a primary transport pathway at the site. Because the results of soil leaching modeling using the Seasonal Soil Compartment (SESOIL) model indicate the spatially averaged contaminant loading to saturated soil (and thus groundwater) does not match the loading needed to produce the contaminant concentrations observed in site groundwater. Higher contamination levels may have leached to groundwater through other geologic conditions not accounted for in the lithologically averaged SESOIL contamination soil profile. Based on this limitation associated with the SESOIL modeling completed for the RI, additional modeling efforts were completed for the FS and are discussed in the following paragraphs.

The groundwater model revision process conducted during the FS included the use of Finite Element Heat and Mass Transfer (FEHM) in place of SESOIL to provide an additional assessment of soil to groundwater transport of uranium. FEHM is considered to be a more robust numerical simulator and was used to determine uranium migration rates to groundwater for incorporation into the revised FS groundwater flow and transport model.

As mentioned previously, the fate and transport of MED/AEC-related radiological groundwater contamination at the site was evaluated using a numerical groundwater flow, particle tracking, and solute transport computer model during the RI to estimate near-term and future risks from groundwater. The calibrated, steady-state condition was used as the basis for the transient-state particle-tracking and contaminant transport models used to predict flow pathways and contaminant fate. Early in the RI modeling process, uranium was considered the most ubiquitous and mobile soil and groundwater contaminant collocated with other, less mobile MED/AEC-related radiological constituents; therefore, only uranium fate was modeled as a conservative indicator to the fate of other, less mobile MED/AEC-related radiological constituents.

The groundwater transport pathway analysis indicates a groundwater extraction system, located in the vicinity of Building G-1 and operated by BASF, is a sink for upgradient and on-site groundwater west of Building G-1; whereas the Cuyahoga River is the primary groundwater sink in the balance of the model. The sanitary sewer line sink influences the western site area and the western half of the Building G-1 area, while the Cuyahoga River and Big Creek receive groundwater from the balance of the site. The particle tracking model also shows groundwater travel times vary throughout the site and generally require approximately 5 years to flow advectively from the Building G-1 area to adjacent surface waters.

The RI contaminant transport analyses indicate the uranium contamination plume near Building G-1 is migrating toward the Cuyahoga River within the 1,000-year period [per 10 Code of Federal Regulations (CFR) 20.1401(d)]; however, the plume may not impact the river with above-background uranium concentrations for approximately 900 years. Together, continued operation of the groundwater extraction system in the vicinity of Building G-1 and site-specific soil partitioning of uranium tend to slow uranium groundwater contaminant migration from the Building G-1 area. Also, the transport pathway predicted in the RI Report for uranium migration from the Building G-1 area appears coincident with the existing distribution of relatively highly mobile lithium-impacted groundwater, thus indicating the groundwater model is an acceptable tool for predictive purposes. More information regarding the groundwater modeling process and results are presented in Section 7 of the RI Report.

The groundwater model developed during the RI was reviewed and updated during the FS with applicable data collected during post-RI data collection and annual groundwater sampling activities. The updated groundwater model was used as part of the detailed evaluation for each remedial alternative, taking into account residual radioactivity in the soil to ensure the remedial alternatives are protective of groundwater.

Additionally, detailed discussions of the revised groundwater flow model and contaminant transport model are provided in Appendix D. The results of groundwater flow and transport modeling simulations conducted as part of the detailed analysis of remedial alternatives are presented in Appendix D.

1.2.5 Baseline Risk Assessment

The BRA for the Former Harshaw Chemical Company Site is detailed in Section 8 of the RI Report and summarized below. The BRA was conducted to provide an analysis of the potential unacceptable risk or radiological dose to human health and environmental receptors associated with past MED/AEC activities at the site if no FUSRAP remediation were to occur. The BRA consisted of three components:

- **Human Health Risk Assessment (HHRA):** An evaluation of the potential for unacceptable risk or radiological dose to human receptors from radioactive and chemical constituents remaining in environmental media at the site as a result of on-site MED/AEC activities;

- **Building HHRA:** An evaluation of the potential unacceptable risk or radiological dose to human receptors from radiological contamination remaining within the buildings at the site; and

- **Screening Level Ecological Risk Assessment (SLERA):** An evaluation of the potential hazard to ecological receptors from MED/AEC-related chemical and radioactive constituents remaining in environmental media.

The HHRA, Building HHRA, and SLERA evaluated the potential for unacceptable risk or radiological dose to applicable human receptors for environmental media (i.e., soil, groundwater, surface water, and sediment) and building materials, and ecological receptors for environmental media. The BRA evaluated the site characterization data for all applicable media in terms of exposure units (EUs). Each EU represents the portion of the site, environmental media, or building for which the exposure to contaminants is evaluated for applicable receptors.

The following sections provide a summary of each component of the RI BRA.

1.2.5.1 Human Health Risk Assessment

The following sections summarize the results of the HHRA for environmental media and buildings.

1.2.5.1.1 Human Health Risk Assessment for Environmental Media

The MED/AEC-related constituents addressed in the HHRA were identified through an evaluation of RI sample results for environmental media. The RI data were grouped according to media and EU, based on data collected during the site characterization process. The evaluation consisted of three tasks:

- Comparison to calculated RI background values;
- Frequency-of-detection determination; and
- Risk-based screening.

Detailed discussions of the HHRA are provided in the RI Report (Section 8.2).

The table below identifies all MED/AEC-related constituents (i.e., identified in more than 5% of samples above background and risk-based screening values) evaluated in the HHRA for environmental media. The constituents listed were included in at least one EU; however, not all constituents were included in all EUs.

Soil	Surface Water	Sediment	Groundwater
Cs-137	U-234	Pb-210	Pb-210
Np-237	U-238	Ra-226	Th-230
Pb-210	Total Uranium*	Th-230	U-234
Ra-226	Lithium*	Th-232	U-235
Ra-228	Molybdenum*	U-234	U-238
Th-228	TPH-DRO*	U-235	Total Uranium*
Th-230		U-238	Lithium*
Th-232		Total Uranium*	Molybdenum*
U-234		TPH-DRO*	TPH-DRO*
U-235			
U-238			
Total Uranium*			
Lithium*			
Molybdenum*			
TPH-DRO*			

* Denotes chemical constituent
TPH-DRO = Total Petroleum Hydrocarbons-Diesel Range Organics

The HHRA evaluated potential exposure to the following human receptor populations that may be exposed to MED/AEC-related constituents:

- Maintenance worker (current);
- Trespasser/recreational user (current/future) adult and adolescent;
- Industrial worker (future);
- Construction worker (future);
- Resident (future) adult and child; and
- Subsistence farmer adult and child.

The BRA evaluated how calculated radiological risks compare to the upper range of acceptable incremental lifetime cancer risks (ILCR) of 1E-04[1], as indicated in the NCP (USEPA 1990), and the annual dose rate applicable for unrestricted release (25 millirems per year [mrem/yr]), following decommissioning of a United States NRC-licensed site (as specified in Subpart E of 10 CFR 20). EU-specific risks and doses presented in the RI Report (USACE 2009) are summarized in Tables 1-2 and 1-3.

The only non-cancer chemical risk found to have a hazard quotient exceeding the acceptable limit of 1 was for the hypothetical scenario of a subsistence farmer exposed to uranium by drinking groundwater from the site. Based on an analysis of likely future land use, farming is not expected to occur at this

[1] 1E-04 is scientific notation for 0.0001, and is used here to represent an estimate of the probability of a cancer effect occurring in a receptor exposed over their lifetime. In this case, the potential risk of cancer would be one in 10,000. 4E-03 would be 0.004 and would indicate that the potential risk of cancer would be four in 1,000.

property in the future; therefore, risks associated with drinking groundwater at this site is not considered to be applicable. The groundwater at the site is not a significant source of drinking water due to the following: relatively poor quality and slow production rate; close proximity of Lake Erie provides a large, steady supply for the public drinking water in the area; the location of the site within the buffer zones of two Ohio VAP USDs; and the requirement for occupied dwellings to be connected to the city of Cleveland municipal water supply system. Based on these conditions, it is not reasonable to believe there is any unacceptable risk or radiological dose associated with on-site groundwater.

In the RI Report, unacceptable risks (i.e., ILCR above 1E-04) were noted for the industrial worker, maintenance worker, resident, and resident farmer receptors for soil in and around Building G-1(EU-1), the Southside Complex (EU-3) and the Westside (EU-5). Unacceptable risks were also noted for the resident and resident farmer receptors for soil in the Northside Complex (EU-2) and Eastside (EU-4). As explained in the ROD for EU 4 (IA06), potential risks to residents in EU 4 (IA06) are equivalent to those risks posed by backround levels of the same radionuclides, or within acceptable risk levels. There were no unacceptable risks to the construction worker or recreational adult or adolescent at any EU. There were no unacceptable risks associated with any receptor for surface water, sediment, or sewers and drains. The only unacceptable risk associated with groundwater was for the subsistence farmer receptor.

Unacceptable radiological doses (i.e., above 25 mrem/yr) were noted for the maintenance worker, resident, and resident farmer receptors for soil in and around Building G-1 (EU-1). Unacceptable radiological doses were noted for the construction worker for media associated with sewers and drains (EU-8). Unacceptable radiological doses were also noted for the resident farmer receptors for soil in the Northside Complex (EU-2), Southside Complex (EU-3), Westside (EU-5), and groundwater. There were no unacceptable radiological doses to the industrial worker or recreational adult or adolescent at any EU. There were no unacceptable radiological doses associated with any receptor for surface water and sediment. The only unacceptable radiological dose associated with groundwater was for the subsistence farmer receptor.

1.2.5.1.2 Human Health Risk Assessment for Building Media

A separate assessment of the human health risks associated with exposures to radioactive contamination on existing building surfaces was performed. The radiological constituents evaluated in the HHRA for building media were expected to be the same as those identified in environmental media and included:

- Lead-210;
- Radium-226;
- Radium-228;
- Thorium-228;
- Thorium-230;
- Thorium-232;
- Uranium-234;
- Uranium-235; and
- Uranium-238.

Receptors potentially exposed to building contamination include the industrial worker, construction worker, and maintenance worker.

Calculated cancer risks and radiation doses are largest for exposures in Building G-1. The highest calculated cancer risk to any worker was 5E-03 for an industrial worker exposed for 25 years in Building

G-1. The annual dose to a construction worker in this building is calculated to be 7,500 mrem/yr. The calculated cancer risks and radiation doses in the other buildings addressed in this assessment (Boiler House, Foundry, Warehouse, Garage, and Scale House) are significantly lower.

The following list summarizes the unacceptable cancer risks and radiation doses calculated in the RI BRA for receptors at the existing buildings:

- Building G-1 interior and exterior (cancer risk and radiological dose);
- Boiler House interior (cancer risk and radiological dose) and exterior (radiological dose);
- Foundry exterior (cancer risk and radiological dose);
- Warehouse interior (cancer risk) and exterior (radiological dose);
- Garage exterior (radiological dose); and
- Scale House interior (cancer risk and radiological dose) and exterior (radiological dose).

Detailed results are presented in Section 8.3 of the RI Report and summarized in Tables 1-2 and 1-3.

1.2.5.2 Screening Level Ecological Risk Assessment

The purpose of the SLERA was to evaluate the potential hazard to ecological receptors resulting from MED/AEC-related constituents remaining in environmental media at the site. The SLERA was performed for the site following guidance from USEPA, Ohio Environmental Protection Agency (Ohio EPA), and DOE to evaluate potential hazards to ecological receptors using site analyte concentrations in soil, sediment, and surface water.

The EUs utilized in the RI BRA represent different types of exposures for both human and ecological receptors. The same EU designations were used for both the HHRA and the SLERA, except EU-8 (IA09) was not evaluated in the SLERA, as there is assumed to be no direct exposure to ecological receptors in underground utilities. Exposure and risk from discharges from these utilities to other media are captured in the risk characterization of the other terrestrial and aquatic EUs.

Unacceptable radiological dose due to MED/AEC-related radionuclide constituents was evaluated using the DOE's graded approach for evaluating radiation doses to biota. This approach is analogous to the USEPA and Ohio EPA tiered approach for ecological risk assessments and begins by screening site-related concentrations of radionuclides against biota concentration guidelines developed to ensure radiological dose limits protective of ecological receptors are not exceeded. The concentrations of radionuclides did not exceed these protective concentrations in each medium in any EU.

Risks due to chemical exposure were evaluated for hypothetical terrestrial (plants, terrestrial invertebrates [earthworms], rabbits, voles, shrews, robins, foxes, and hawks) and aquatic (benthic invertebrates and aquatic biota) receptors. Calculated ecological hazard indices (HIs) for each of the EUs ranged from 4 to 95. However, background concentrations contributed significantly to these elevated HIs, indicating the toxicity reference values and/or exposure assumptions used in developing the HIs were overly conservative. Refinement of the initial screening level risk characterization that considered contribution from background, site-specific area use factors, availability of habitat, and ecological management goals for the site was performed and the results of the SLERA indicate no further action is warranted with respect to ecological receptors.

There are no sensitive habitats or threatened and endangered species on the site that warrant special consideration or protection. Available habitat at the site is limited under current use conditions, and much of it is paved. Future development of the site may not necessarily continue to be industrial, but any future

development would be for human benefit. In addition, no ecosystem or habitat restoration is planned for the site, although USACE fully supports green and sustainable remedial actions that positively affect the long-term viability of the remedy. All of these considerations support the conclusion that no further action is needed to protect ecological receptors at the site.

1.3 UPDATES IN SUPPORT OF THE FEASIBILITY STUDY

1.3.1 Operable Units

40 CFR Section 300.5 defines an operable unit (OU) as a discrete action that comprises an incremental step toward comprehensively addressing site problems. This discrete portion of a remedial response manages migration, or eliminates or mitigates a release, threat of a release, or pathway of exposure. The cleanup of a site can be divided into a number of OUs, depending on the complexity of the problems associated with the site.

To evaluate remedial alternatives in the FS, the site was organized into two OUs: OU-1 and OU-2 (Figure 1-4). OU-1 consists of soil, buildings, and groundwater within the site boundary located west of the Cuyahoga River and north of Big Creek and surface water/sediment within the Big Creek and Cuyahoga River adjacent to the entire site. OU-2 consists of soil and groundwater within the site boundary and located south of Big Creek.

The basis for defining each OU was dependent upon one or more of the following factors:

- Historical operations;
- Site development;
- Geographical location and physical boundaries;
- Current and potential future land use; and
- Risk assessment results.

Table 1-4 summarizes the OUs selected for the site and the rationale for each selection.

The RI did not identify any unacceptable risk or radiological dose to human or ecological receptors related to MED/AEC activities in IA06 (EU4, Eastside Soil), located east of the Cuyahoga River and north of Harvard Avenue. IA06 was addressed under a separate PP and ROD; therefore, it is not considered further in this FS.

Although the RI considered the site in terms of IAs during the field data collection program and in terms of EUs for the BRA human and ecological risk evaluations, these site designations were intended to meet specific objectives of the RI and BRA and no longer apply to the FS. All applications of site characterization data in the FS will be based upon the physical location of the data within the FS OUs and will not be affected by previous IA or EU designations. From this point forward, all discussions of the site areas will be in terms of OUs with the exception of Section 2.2.1, which discusses USACE's approach to developing the soil volumes used in the FS. This approach evaluated hard (i.e., analytical data) and soft information (e.g., field observations or information from historical aerial photographs) to determine potential boundaries of the extent of contamination at the site. This information was input into the soil volume approach based on IAs and will be discussed as such in that section.

Figure 1-5 summarizes the relationship between IAs, EUs, and OUs and lists the specific components of each designation as the RI and FS have progressed.

1.3.2 Updates to the Groundwater Flow and Contaminant Transport Modeling

The groundwater flow and contaminant transport model presented in Section 7 of the RI Report, as well as related models (including the geologic framework model and vadose zone leaching models) were updated to predict saturated zone transport of total uranium in OU-1 under the conditions of the various FS alternatives. A summary of the modeling updates is presented in this section and the complete Groundwater Flow and Contaminant Transport Modeling Report is included in Appendix D.

The scope of this modeling included the following:

- Update and refine the site conceptual flow and transport model, including incorporating boring logs, groundwater quality data, and water level data collected subsequent to original model development in the RI Report.

- Translate the updated site conceptual model into a numerical flow and transport model.

- Use the numerical model to predict transport of total uranium in OU-1 groundwater under the conditions of the various OU-1 FS soil remedial alternatives.

- Perform appropriate sensitivity/uncertainty simulations for total uranium transport in OU-1 groundwater with the numerical model.

- Evaluate potential thorium transport in OU-1 groundwater qualitatively, taking into consideration quantitative total uranium transport predictions and relative mobility, plume footprint, and continuing sources for thorium versus total uranium.

- Evaluate whether the OU-1 and OU-2 proposed soil preliminary remediation goals (PRGs) for total uranium, thorium-230, thorium-232, and radium-226 are protective of groundwater. The model was only indirectly used to evaluate the OU-2) criteria as it only includes OU-1.

Geologic Model Summary

As described in Section 3.3.2 of Appendix D, the three-dimensional (3-D) geologic model developed to support RI/FS activities was revised with data from 14 new groundwater monitoring wells installed in 2008 and soil borings in OU-1 and OU-2. Recent topography data derived from Light Detection and Ranging (LIDAR) data was also incorporated into the revised 3-D geologic model, and a weathered bedrock zone was added as a distinct geologic unit to support the groundwater model. Additionally, some geologic data from OU-1 borings were revised or re-evaluated to ensure consistency/quality in the revised 3-D geologic model, and the surface of the bedrock was extended using regional bedrock data to conform to the extent of the groundwater model.

This updated geologic model provides the framework for the updated groundwater flow and transport model.

Numerical Groundwater Flow Model Summary

From the conceptual model, a two-layer numerical groundwater flow model, which simulates groundwater flow in the overburden (layer 1) and weathered bedrock (layer 2), was developed to support the evaluation of groundwater flow and contaminant transport in the model area (Section 5 of Appendix D). The numerical flow model was developed by integrating all available field data and was calibrated

under steady-state conditions. Sensitivity analyses were performed to aid in specification of parameter values and understanding of the flow system, and uncertainties were identified with respect to hydraulic parameters, boundary conditions, and model calibration data.

Major conclusions from the groundwater flow model development include:

- Vertical gradients are not evident across the overburden units, and these units can therefore be represented together as one model layer;
- The flow model was successfully calibrated and is suited for evaluation of future contaminant migration; and
- The uncertainties identified do not significantly impact the usefulness of the flow model.

Numerical Contaminant Transport Model Summary

The numerical transport model was constructed from the conceptual flow and transport model (Section 6 of Appendix D). While total uranium data and release history do not support contaminant transport model calibration, consistency of the model with observed travel times and velocities was verified by comparing particle tracking predictions to known site history, timeframes, and groundwater quality data for lithium.

The numerical groundwater flow and transport model was then used to predict future transport of total uranium in the model area for three scenarios which together represent predicted future groundwater effects from the five FS alternatives for OU-1 soil. Transport predictions were controlled by the strong affinity of total uranium to sorb to site soil. All of the transport simulations resulted in very similar predictions, whether with continuing leaching source (three different simulations) or without. These simulations confirm that all of the FS alternatives for OU-1 soil meet the objective of preventing further degradation of groundwater from total uranium contamination.

For transport simulations representing the groundwater effects for FS alternatives involving soil excavation, it is very reasonable to expect no further groundwater degradation, regardless of the total uranium sorption conditions. Excavation of above-criteria soil will remove the most significant potential continuing leaching sources of total uranium, which have been in place for up to 60 to 70 years. If these soil were a significant source of contamination to groundwater in the past, excavation would tremendously diminish this contribution.

A sensitivity simulation was executed with an order of magnitude reduction in the equilibrium distribution coefficient (K_d) to explore the impacts of uncertainty in the baseline total uranium K_d. Under this highly conservative sensitivity simulation, insignificant further degradation of groundwater was predicted.

Future transport of thorium in OU-1 groundwater was qualitatively evaluated through comparison to model-predicted transport of total uranium in OU-1. As with total uranium, no further degradation of OU-1 groundwater is predicted to occur due to thorium.

Proposed soil PRGs for total uranium, thorium-230, thorium-232, and radium-226 in OU-1 and OU-2 were evaluated and found to be protective of groundwater.

Finally, uncertainties were identified with respect to transport parameters, initial conditions, and continuing contaminant sources. The greatest uncertainty was in the K_d, which controls predictions of total uranium transport. As stated above, a sensitivity simulation demonstrated that a greatly reduced K_d still results in prediction of insignificant further degradation of groundwater.

Modeling Conclusions

Major conclusions from the groundwater flow and contaminant transport model development and simulations include:

- Available site-specific and literature data present a consistent picture of a total uranium plume that is relatively immobile today.

- Total uranium transport in OU-1 groundwater was likely more significant at and near the time of contaminant release, due to a temporary lowering of the total uranium Kd caused by release of process acids to the environment.

- Model simulations predict very little transport of or change in this total uranium plume over the 1,000-year period of the FS alternatives. These simulations predict no further degradation of groundwater occurs for all FS alternatives.

- For transport simulations representing the groundwater effects for FS alternatives involving soil excavation, it is very reasonable to expect no further groundwater degradation, regardless of the total uranium sorption conditions. Excavation of above-criteria soil will greatly diminish any future leaching to groundwater.

- A sensitivity simulation with a greatly reduced total uranium Kd (100 milliliters per gram (mL/g) versus the baseline value of 1,000 mL/g) also predicts insignificant further degradation of groundwater.

- The proposed soil PRGs for total uranium, thorium-230, thorium-232, and radium-226 in OU-1 and OU-2 are protective of groundwater.

1.3.3 Updates to the Risk Assessment Based on the Operable Units

The EU-specific radiological doses that were evaluated in the RI Report were updated once operable units (OUs) were developed for the FS. OU-wide radiological doses are calculated in the FS for the purpose of evaluating compliance with ARARs identified in the FS. This update involved re-grouping all environmental media according to the two OUs evaluated for this FS and re-calculating exposure point concentrations (EPCs). This re-grouping was necessary, since the OU designation split some EUs (IAs) and combined others (Table 1-2), so a direct translation from EU to OU risks and doses cannot be made. The method for calculating EPCs for the OUs was modified from that presented in Section 8.2.3.4.1 of the RI Report for the EUs (USACE 2009).

All data within the database were sorted according to OU, and data for every medium were extracted from the database and entered into ProUCL version 4.1 (USEPA 2010). This software includes statistical methods that can be used to estimate EPC terms for datasets with non-detect observations. Specifically, most of the statistical methods described and recommended in *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002) have been incorporated into ProUCL. The ProUCL recommended 95% upper confidence limit on the mean of each dataset was

chosen as the EPC. Using the ProUCL software provides an advantage over the method of calculating EPCs used for the RI Report (Section 8.2.3.4.1 of the RI Report) (USACE 2009), as more statistical methods are available in ProUCL than previously utilized. As discussed in Section 8.2.7.2 of the RI Report, the previous method tended to underestimate the 95th percentile upper confidence limits of the means for some constituent datasets (USACE 2009). The previous EU-based risk assessment (USACE 2009) indicated ARARs would be met in the EUs which comprise OU-2 without any remedial action. This may have been due to an underestimation of the EPC for some constituents in some EUs.

Table 1-5 presents the EPCs developed on an OU-specific basis with those on an EU-specific basis used for this FS Report. Although the maximum detected concentrations of several radionuclides (radium-226, thorium-230, and uranium-238) are found in OU-1, the EPCs for OU-2 tend to be greater because of the greater number of sample results available in OU-1 versus OU-2 (i.e., several hundred samples were obtained in OU-1, while less than a hundred sample results are available for OU-2). A smaller dataset increases the uncertainty surrounding calculation of the true mean of the dataset, and this increases the upper confidence limit on the mean used in developing the EPC. Table 1-6 presents updated risks and doses for the FS on an OU-specific basis, along with the EU-specific risks and doses presented in the RI Report (USACE 2009).

Trespassers have recently begun accessing abandoned on-site buildings (as evidenced by graffiti); therefore, in addition to re-calculating dose on an OU-specific basis, potential radiological doses were calculated for a trespasser exposed to building media at Building G-1. These results are included in Table 1-6.

When the data are grouped according to OU and updated EPCs are used, doses above 25 mrem/yr could potentially occur for all receptors exposed to soil except the recreational users (trespassers) in OU-1 and OU-2 and the industrial worker in OU-1 (Table 1-6). Calculated radiological doses for exposure to building material at Building G-1 by a trespasser also exceed 25 mrem/yr.

The SLERA was not re-evaluated on an OU-specific basis, as the RI concluded no further action was needed to protect ecological receptors at the site from exposure to MED/AEC contamination.

The specific MED/AEC-related constituents to be addressed in the FS are discussed in more detail in Section 2.1.4.

Table 1-1. Summary of Volumetric Building Material Sample Results

Building	Sample No.	Ra-228 (pCi/g)	Th-228 (pCi/g)	Th-230 (pCi/g)	Th-232 (pCi/g)	Total Uranium (pCi/g)
Building G-1	HSBM0002	0.20 (U)	0.84 (U)	39.20	0.21 (U)	**4,291.00**
Building G-1	HSBM0013	0.30 (U)	0.55 (U)	2.87	0.42	**552.80**
Building G-1	HSBM0012	0.00 (U)	1.14	10.40	0.20 (U)	**2,315.30**
Building G-1	HSBM0004	0.00 (U)	0.22 (U)	2.13	0.20	**74.34**
Building G-1	HSBM0001	0.30 (U)	0.02 (U)	2.46	0.07 (U)	**2,138.70**
Building G-1	HSBM0003	0.16 (U)	0.14 (U)	0.33	0.21 (U)	6.09
Building G-1	HSBM0011	1.25	1.01	1.70	0.93	**844.10**
Building G-1	HSBM0026	0.28	1.00 (U)	2.05	0.34	**226.90**
Building G-1	HSBM0025	0.60	1.00 (U)	1.26	0.77	**72.76**
Building G-1	HSBM0024	0.50 (U)	1.00 (U)	0.73	1.00 (U)	**774.70**
Building G-1	HSBM0023	0.50 (U)	1.00 (U)	1.02	0.42	**167.66**
Building G-1	HSBM0022	0.18	0.46 (U)	31.10	0.34 (U)	**359.31**
Building G-1	HSBM0021	0.00 (U)	0.74 (U)	1.70	0.40	**1,610.20**
Building G-1	HSBM0019	0.29	0.31 (U)	1.91	0.26 (U)	**87.85**
Building G-1	HSBM0020	0.31 (U)	0.55 (U)	833.00	3.28	**13,381.00**
Building G-1	HSBM0009	0.00 (U)	0.14 (U)	0.79	0.60	**359.90**
Building G-1	HSBM0010	0.65	0.68	2.65	0.76	**743.50**
Building G-1	HSBM0005	0.16 (U)	0.03 (U)	1.47	0.13 (U)	**313.50**
Building G-1	HSBM0006	1.90	2.09	33.60	1.82	**419.70**
Building G-1	HSBM0007	0.00 (U)	0.73	92.90	0.64	**734.10**
Building G-1	HSBM0067	0.00 (U)	0.81	11.50	0.44	**2,358.80**
Building G-1	HSBM0068	0.47	0.60	5.00	0.58	**247.38**
Foundry	HSBM0048	0.22 (U)	0.08 (U)	3.14	0.11 (U)	**540.90**
Foundry	HSBM0049	0.07 (U)	0.58 (U)	1.03	0.26	**124.75**
Foundry	HSBM0050	0.19 (U)	0.41 (U)	0.27 (U)	0.19 (U)	2.15
Warehouse	HSBM0046	0.12 (U)	0.12 (U)	0.26 (U)	0.19 (U)	2.47
Warehouse	HSBM0074	0.05 (U)	0.30 (U)	0.37	0.02 (U)	**17.93**
Warehouse	HSBM0078	0.20 (U)	0.48 (U)	0.88	0.62	0.00
Warehouse	HSBM0073	0.00 (U)	0.07 (U)	0.24 (U)	0.25	0.00
Warehouse	HSBM0076	0.11 (U)	0.24 (U)	0.59	0.25	2.74
Warehouse	HSBM0047	0.19 (U)	0.40 (U)	0.68	0.53	0.44
Warehouse	HSBM0071	0.73	1.05	2.74	0.88	**89.21**
Warehouse	HSBM0072	0.85	1.02	4.45	1.11	**30.70**
Foundry	HSBM0102	0.13 (U)	0.25	0.50	0.16	7.17
Warehouse	HSBM0103	0.35	1.07	1.48	0.74	**15.60**
Warehouse	HSBM0105	0.74	0.77	1.54	0.81	**20.82**
Warehouse	HSBM0106	0.47	0.63	1.58	0.75	**12.85**
Warehouse	HSBM0104	0.14	0.14	0.45	0.21	6.01

Bold indicates results above screening level of 13 pCi/g of Total Uranium.
pCi/g = PicoCuries Per Gram
U = Non-detect

Table 1-2. Radiological Risk (ILCR) Summary for Baseline, RME by Exposure Unit

Receptor	Year	EU-1	EU-2	EU-3	EU-4	EU-5	EU-6[1]	EU-7[2]	EU-8[3]
		Surface Soil (0-2 ft bgs)					*Surface water and Sediment*	*Groundwater*	*Surface water, Sediment, and Soil*
Residential Adult/Child	0	NA	NA	NA	NA	NA	NA	NA	NA
Residential Adult/Child	185	NA	NA	NA	NA	NA	NA	NA	NA
Residential Adult/Child	1000	NA	NA	NA	NA	NA	NA	NA	NA
Industrial worker	0	9.E-05	5.E-05	2.E-04	3.E-05	2.E-04	NA	NA	NA
Industrial worker	1000	5.E-04	3.E-05	2.E-04	1.E-05	2.E-04	NA	NA	NA
Maintenance worker	0	2.E-04	1.E-04	3.E-04	5.E-05	4.E-04	NA	NA	NA
Maintenance worker	1000	1.E-03	5.E-05	4.E-04	3.E-05	4.E-04	NA	NA	NA
Construction worker	0	NA	NA	NA	NA	NA	NA	NA	NA
Construction worker	1000	NA	NA	NA	NA	NA	NA	NA	NA
Recreational Adult	0	1.E-05	7.E-06	2.E-05	3.E-06	3.E-05	8.E-08	NA	NA
Recreational Adult	1000	6.E-05	3.E-06	2.E-05	2.E-06	2.E-05	8.E-08	NA	NA
Recreational Adolescent	0	4.E-06	2.E-06	7.E-06	1.E-06	9.E-06	1.E-08	NA	NA
Recreational Adolescent	1000	2.E-05	1.E-06	8.E-06	6.E-07	8.E-06	1.E-08	NA	NA
Subsistence Farmer Adult	0	NA	NA	NA	NA	NA	NA	NA	NA
Subsistence Farmer Adult	185	NA	NA	NA	NA	NA	NA	NA	NA
Subsistence Farmer Adult	335	NA	NA	NA	NA	NA	NA	NA	NA
Subsistence Farmer Adult	1000	NA	NA	NA	NA	NA	NA	NA	NA
		Total Soil (0-13 ft bgs)					*Surface water and Sediment*	*Groundwater*	*Surface water, Sediment, and Soil*
	Year	**EU-1**	**EU-2**	**EU-3**	**EU-4**	**EU-5**	**EU-6[1]**	**EU-7[2]**	**EU-8[3]**
Residential Adult/Child	0	4.E-04	4.E-04	5.E-04	1.E-04	6.E-04	1.E-08	NA	NA
Residential Adult/Child	185	7.E-04	5.E-04	6.E-04	1.E-04	6.E-04	NA	NA	NA
Residential Adult/Child	1000	1.E-03	4.E-04	6.E-04	8.E-05	6.E-04	1.E-08	NA	NA
Industrial worker	0	NA	NA	NA	NA	NA	NA	NA	NA
Industrial worker	1000	NA	NA	NA	NA	NA	NA	NA	NA

Table 1-2. Radiological Risk (ILCR) Summary for Baseline, RME by Exposure Unit (continued)

Receptor	Year	EU-1	EU-2	EU-3	EU-4	EU-5	EU-6[1]	EU-7[2]	EU-8[3]
		Total Soil (0-13 ft bgs)					*Surface water and Sediment*	*Groundwater*	*Surface water, Sediment, and Soil*
Maintenance worker	0	NA	NA	NA	NA	NA	NA	NA	NA
Maintenance worker	1000	NA	NA	NA	NA	NA	NA	NA	NA
Construction worker	0	9.E-06	8.E-06	8.E-06	2.E-06	7.E-06	0.E+00	1.E-08	4.E-05
Construction worker	1000	2.E-05	7.E-06	9.E-06	1.E-06	9.E-06	0.E+00	NA	2.E-06
Recreational Adult	0	NA	NA	NA	NA	NA	NA	NA	NA
Recreational Adult	1000	NA	NA	NA	NA	NA	NA	NA	NA
Recreational Adolescent	0	NA	NA	NA	NA	NA	NA	NA	NA
Recreational Adolescent	1000	NA	NA	NA	NA	NA	NA	NA	NA
Subsistence Farmer Adult	0	1.E-03	1.E-03	1.E-03	4.E-04	2.E-03	1.E-08	5.E-04	NA
Subsistence Farmer Adult	185	4.E-03	4.E-03	3.E-03	6.E-04	2.E-03	NA	NA	NA
Subsistence Farmer Adult	335	2.E-03	1.E-03	2.E-03	3.E-04	2.E-03	NA	NA	NA
Subsistence Farmer Adult	1000	3.E-03	1.E-03	2.E-03	2.E-04	2.E-03	1.E-08	NA	NA

	Building EUs											
	B-1	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**B-10**	**B-11**	**B-12**
Industrial Worker	0E+00	5E-03	3E-03	5E-03	0E+00	3E-04	0E+00	0E+00	2E-04	0E+00	0E+00	3E-04
Construction Worker	2E-04	6E-04	3E-04	7E-04	5E-05	1E-05	1E-04	1E-05	7E-06	2E-05	1E-05	1E-05
Interior Maintenance Worker	0E+00	2E-03	9E-04	2E-03	0E+00	9E-05	0E+00	0E+00	5E-05	0E+00	0E+00	9E-05
Exterior Maintenance Worker	2E-04	0E+00	0E+00	0E+00	4E-05	0E+00	7E-05	2E-05	0E+00	2E-05	2E-05	0E+00
Interior/Exterior Maintenance Worker	2E-04	2E-03	9E-04	2E-03	4E-05	9E-05	7E-05	2E-05	5E-05	2E-05	2E-05	9E-05

[1]EU-6: Sediment and surface water (IA08) in the Cuyahoga River and Big Creek (non-RESRAD calculation)
[2]EU-7: Area groundwater within unconsolidated aquifer, north of Big Creek/west of the Cuyahoga River (IA10) (non-RESRAD calculation).
[3]EU-8: Underground utilities, site-wide
Risks >1E-04 are indicated in **bold**.

bgs = below ground surface
EU = Exposure Units
ft = Feet
ILCR = Incremental Lifetime Cancer Risk

NA = Medium is not evaluated for that receptor
RME = Reasonable Maximum Exposure

B-1 = G-1
B-2 = G-1
B-3 = G-1
B-4 = G-1
B-5 = Boiler House
B-6 = Boiler House
B-7 = Foundry
B-8 = Warehouse

B-9 = Warehouse
B-10 = Garage
B-11 = Scale House
B-12 = Scale House

Table 1-3. Radiological Dose Summary for Baseline, RME, by Exposure Unit

Receptor	Year	EU-1	EU-2	EU-3	EU-4	EU-5	EU-6[1]	EU-7[2]	EU-8[3]
		Surface Soil (0-2 ft bgs)					***Surface water and Sediment***	***Groundwater***	***Surface Water, Sediment, and Soil***
Residential Adult	0	NA	NA	NA	NA	NA	NA	NA	NA
Residential Adult	185	NA	NA	NA	NA	NA	NA	NA	NA
Residential Adult	1000	NA	NA	NA	NA	NA	NA	NA	NA
Industrial worker	0	2.1E+00	1.4E+00	5.3E+00	5.2E-02	7.1E+00	NA	NA	NA
Industrial worker	1000	2.3E+01	6.6E-01	6.9E+00	1.2E-01	6.8E+00	NA	NA	NA
Maintenance worker	0	4.4E+00	2.9E+00	1.1E+01	1.1E-01	1.5E+01	NA	NA	NA
Maintenance worker	1000	**4.7E+01**	1.4E+00	1.4E+01	2.4E-01	1.4E+01	NA	NA	NA
Construction worker	0	NA	NA	NA	NA	NA	NA	NA	NA
Construction worker	1000	NA	NA	NA	NA	NA	NA	NA	NA
Recreational Adult	0	2.2E-01	1.5E-01	5.8E-01	5.6E-03	7.8E-01	8.8E-03	NA	NA
Recreational Adult	1000	2.5E+00	7.3E-02	7.5E-01	1.3E-02	7.5E-01	8.8E-03	NA	NA
Recreational Adolescent	0	2.4E-01	1.6E-01	5.9E-01	6.0E-03	7.8E-01	4.5E-03	NA	NA
Recreational Adolescent	1000	2.5E+00	7.4E-02	7.6E-01	1.3E-02	7.6E-01	4.5E-03	NA	NA
Subsistence Farmer Adult	0	NA	NA	NA	NA	NA	NA	NA	NA
Subsistence Farmer Adult	185	NA	NA	NA	NA	NA	NA	NA	NA
Subsistence Farmer Adult	335	NA	NA	NA	NA	NA	NA	NA	NA
Subsistence Farmer Adult	1000	NA	NA	NA	NA	NA	NA	NA	NA
		Total Soil (0-13 ft bgs)					***Surface water and Sediment***	***Groundwater***	***Surface Water, Sediment, and Soil***
Residential Adult	0	4.4E+00	7.6E+00	5.6E+00	8.7E-02	7.1E+00	1.6E-03	NA	NA
Residential Adult	185	1.7E+01	9.7E+00	8.5E+00	2.9E-01	9.2E+00	NA	NA	NA
Residential Adult	1000	**4.2E+01**	8.8E+00	1.2E+01	5.2E-01	1.1E+01	1.6E-03	NA	NA
Industrial worker	0	NA	NA	NA	NA	NA	NA	NA	NA
Industrial worker	1000	NA	NA	NA	NA	NA	NA	NA	NA
Maintenance worker	0	NA	NA	NA	NA	NA	NA	NA	NA
Maintenance worker	1000	NA	NA	NA	NA	NA	NA	NA	NA
Construction worker	0	5.3E+00	5.3E+00	4.7E+00	3.6E-01	4.9E+00	0.0E+00	4.5E-02	**5.7E+01**
Construction worker	1000	1.9E+01	4.0E+00	6.0E+00	2.4E-01	6.0E+00	0.0E+00	NA	2.4E+00
Recreational Adult	0	NA	NA	NA	NA	NA	NA	NA	NA

Table 1-3. Radiological Dose Summary for Baseline, RME, by Exposure Unit (continued)

Receptor	Year	EU-1	EU-2	EU-3	EU-4	EU-5	EU-6[1]	EU-7[2]	EU-8[3]
Recreational Adult	1000	NA	NA	NA	NA	NA	NA	NA	NA
Recreational Adolescent	0	NA	NA	NA	NA	NA	NA	NA	NA
		Total Soil (0-13 ft bgs)					***Surface Water and Soil***	***Groundwater***	***Surface Water, Sediment, and Soil***
Recreational Adolescent	1000	NA	NA	NA	NA	NA	NA	NA	NA
Subsistence Farmer Adult	0	1.5E+01	**2.9E+01**	1.4E+01	2.8E-01	1.8E+01	1.6E-03	**6.2E+01**	NA
Subsistence Farmer Adult	185	**3.4E+02**	**4.9E+02**	**2.4E+02**	1.2E+01	**6.4E+01**	NA	NA	NA
Subsistence Farmer Adult	335	**1.0E+02**	**1.0E+02**	**4.5E+01**	1.8E+00	**3.2E+01**	NA	NA	NA
Subsistence Farmer Adult	1000	**2.6E+02**	**3.2E+01**	**4.3E+01**	1.9E+00	**3.5E+01**	1.6E-03	NA	NA

Building EUs

	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12
Industrial Worker	0	2234	1062	2313	0	33	0	0	15	0	0	33
Construction Worker	2551	7214	3357	7473	464	61	1162	49	20	67	54	58
Interior Maintenance Worker	0	698	332	723	0	10	0	0	5	0	0	10
Exterior Maintenance Worker	55	0	0	0	11	0	25	2	0	3	2	0
Interior/Exterior Maintenance Worker	55	698	332	723	11	10	25	2	5	3	2	10

[1]EU6 - Sediment and surface water (IA08) in the Cuyahoga River and Big Creek (non-RESRAD calculation)
[2]EU7 - Area groundwater within unconsolidated aquifer, north of Big Creek/west of the Cuyahoga River (IA10) (non-RESRAD calculation).
[3]EU 8 - Underground utilities, site-wide
Doses >25mrem/year are indicated in bold.
bgs = below ground surface
ft = Feet
NA = Medium is not evaluated for that receptor
RME = Reasonable Maximum Exposure

B-1 = G-1
B-2 = G-1
B-3 = G-1
B-4 = G-1
B-5 = Boiler House
B-6 = Boiler House
B-7 = Foundry
B-8 = Warehouse
B-9 = Warehouse
B-10 = Garage
B-11 = Scale House
B-12 = Scale House

Table 1-4. Harshaw FS OUs and Rationale

OU	IA	Description	Rationale
OU-1	IA01 IA02 IA03 IA04 IA05 (north of Big Creek)	Buildings, soil, groundwater, sediment, and surface water located north of Big Creek and west of the Cuyahoga River	• Contiguous property within which the uranium processing operations were conducted • Common geographical location and physical boundaries isolated by Big Creek and Cuyahoga River • Potential future land-use receptor is the Construction Worker (additional information may be found in Section 2.1.3 of this FS Report)
OU-2	IA05 (south of Big Creek) IA07	Soil and groundwater south of Big Creek	• Separated from historical main processing location with geographical location and physical boundaries isolated by Big Creek and Cuyahoga River • Numerous privately-owned parcels • Potential future land use is Residential (additional information may be found in Section 2.1.3 of this FS Report)

FS = Feasibility Study
IA = Investigative Area
OU = Operable Unit

Table 1-5. Summary of Radiological EPCs (pCi/g)

Nuclide	SB Background	SS Background	OU-1 SB	OU-1 SS	OU-2 SB	OU-2 SS
Am - 241	0	0	0	0	0	0
Cs - 137	5.40E-01	4.29E-01	1.54E+00	1.23E-01	7.57E-02	9.41E-02
Np - 237	0	0	0	0	0	0
Pb-210	1.41E+00	1.45E+00	1.58E+00	2.09E+00	1.62E+00	2.25E+00
Ra-226	1.41E+00	1.45E+00	1.58E+00	2.09E+00	1.62E+00	2.25E+00
Ra-228	1.79E+00	1.87E+00	2.23E+00	3.64E+00	6.59E+00	1.07E+01
Th-228	1.41E+00	1.41E+00	4.38E+00	7.78E+00	1.10E+01	1.87E+01
Th-230	1.21E+00	1.21E+00	4.80E+01	5.92E+01	4.29E+00	5.28E+00
Th-232	1.41E+00	1.41E+00	2.89E+00	5.04E+00	8.57E+00	1.44E+01
U-234	2.42E+00	1.98E+00	7.51E+01	1.39E+02	1.29E+02	3.03E+02
U-235	1.06E-01	8.71E-02	3.67E+00	6.60E+00	7.97E+00	2.77E+01
U-238	2.42E+00	1.98E+00	7.51E+01	1.39E+02	1.29E+02	3.03E+02

Gross EPC, no background subtracted
SB = 0-13 ft (0-4 m)
SS = 0-2 ft (0-0.6 m)
EPC = Exposure Point Concentration
A zero in background indicates the constituent was not detected.
A zero in on-site EU indicates that the constituent is not a COPC in that medium/EU (see RI Report Table 8-6).

Table 1-6. Radiological Dose (mrem/yr) Summary for Baseline, RME, by OU

Receptor	Year	OU-1	OU-2
Surface Soil (0-2 ft [0-0.6 m] bgs)			
Residential Adult	0	NA	NA
Residential Adult	185	NA	NA
Residential Adult	1000	NA	NA
Industrial worker	0	1.1E+01	**3.1E+01**
Industrial worker	1000	2.1E+01	2.1E+01
Maintenance worker	0	2.3E+01	**6.5E+01**
Maintenance worker	1000	**4.4E+01**	**4.5E+01**
Construction worker	0	NA	NA
Construction worker	1000	NA	NA
Recreational Adult	0	1.2E+00	3.4E+00
Recreational Adult	1000	2.3E+00	2.4E+00
Recreational Adolescent	0	1.2E+00	3.5E+00
Recreational Adolescent	1000	2.3E+00	2.4E+00
Subsistence Farmer Adult	0	NA	NA
Subsistence Farmer Adult	185	NA	NA
Subsistence Farmer Adult	335	NA	NA
Subsistence Farmer Adult	1000	NA	NA
Total Soil (0-13 ft [0-4 m] bgs)			
Residential Adult	0	2.2E+01	**6.3E+01**
Residential Adult	185	**4.5E+01**	**7.1E+01**
Residential Adult	1000	**8.1E+01**	**5.0E+01**
Industrial worker	0	NA	NA
Industrial worker	1000	NA	NA
Maintenance worker	0	NA	NA
Maintenance worker	1000	NA	NA
Construction worker	0	2.3E+01	**4.5E+01**
Construction worker	1000	**3.9E+01**	**3.0E+01**
Recreational Adult	0	NA	NA
Recreational Adult	1000	NA	NA
Recreational Adolescent	0	NA	NA
Recreational Adolescent	1000	NA	NA
Subsistence Farmer Adult	0	**5.8E+01**	**1.6E+02**
Subsistence Farmer Adult	185	**1.2E+03**	**2.0E+03**
Subsistence Farmer Adult	335	**2.5E+02**	**3.0E+02**
Subsistence Farmer Adult	1000	**5.4E+02**	**1.4E+02**
	Building OUs		
	Building G-1 (B-1)		**Building G-1 (B-2)**
Trespassor	**160**		**450**

Doses >25mrem/yr are indicated in bold.
>= Greater than
bgs = Below Ground Surface
OU =Operable Unit
ft = Feet
m = Meter
mrem/yr = Millirem Per Year
NA = Medium is not evaluated for that receptor
RME = Reasonable Maximum Exposure

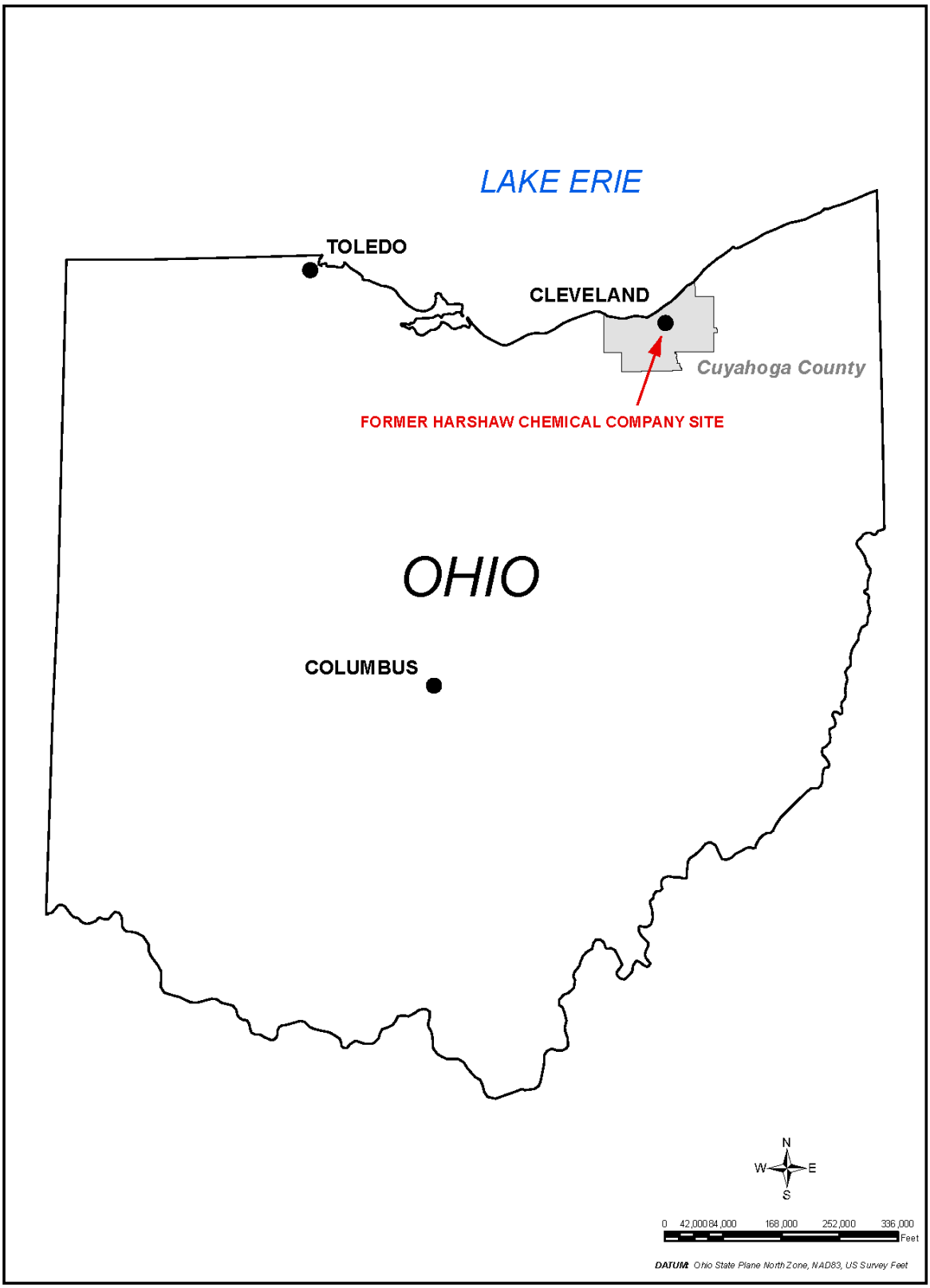


Figure 1-1. General Site Location Map

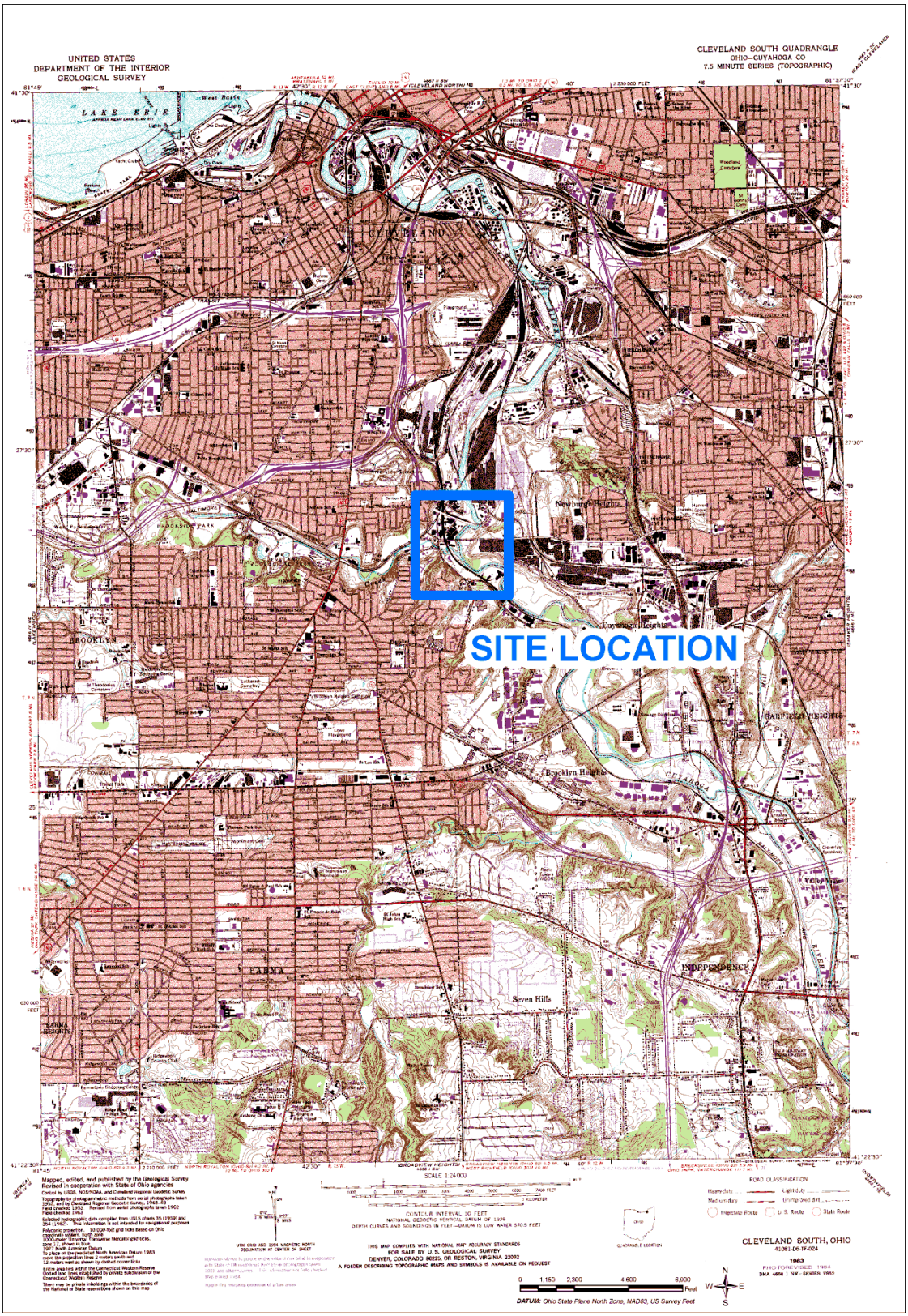
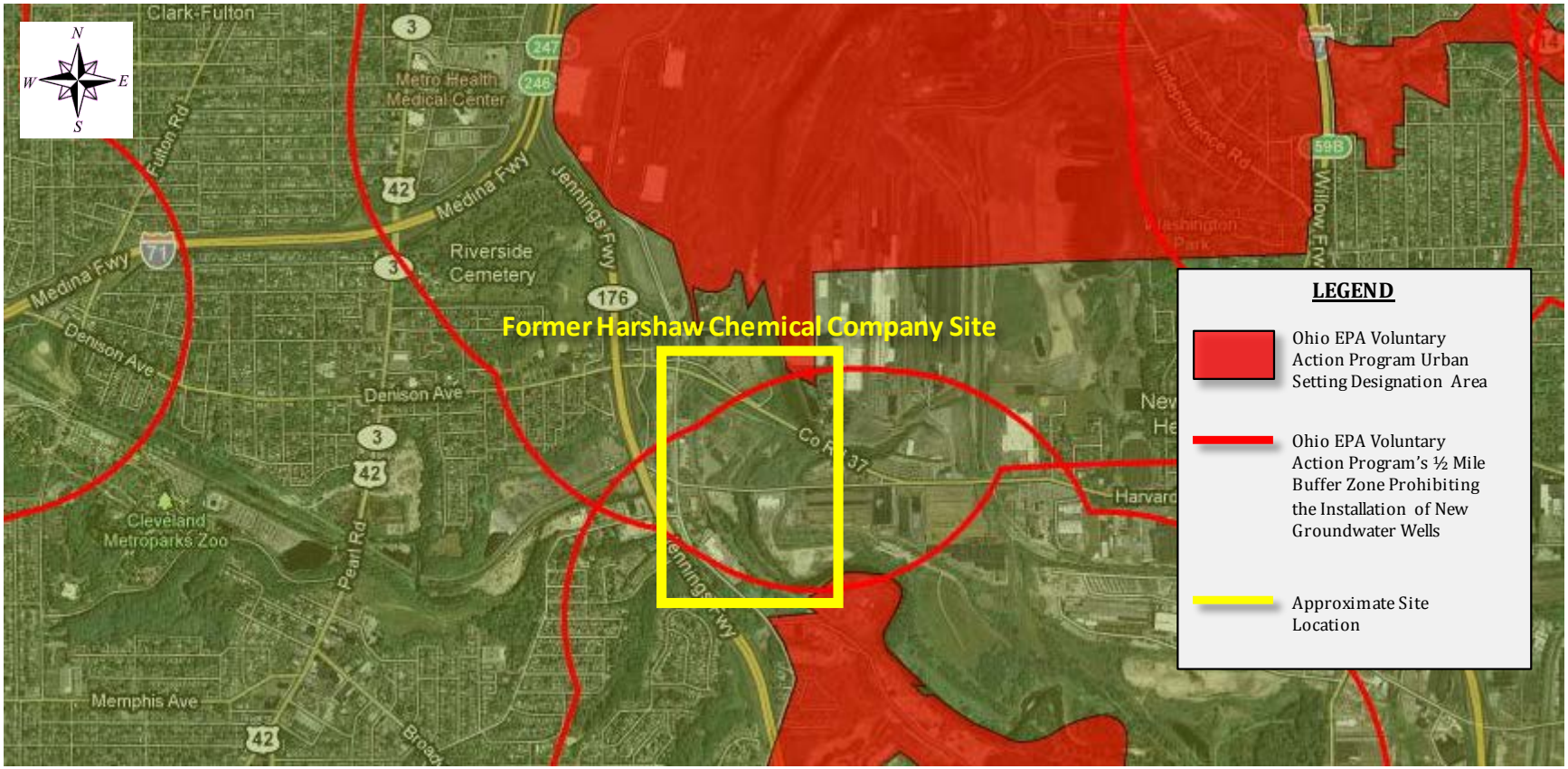


Figure 1-2. USGS 7.5 Minute Quadrangle - Cleveland South 1984



Note: Image provided by Ohio EPA

Figure 1-3. Ohio Voluntary Action Program - Urban Setting Designation Area Boundaries

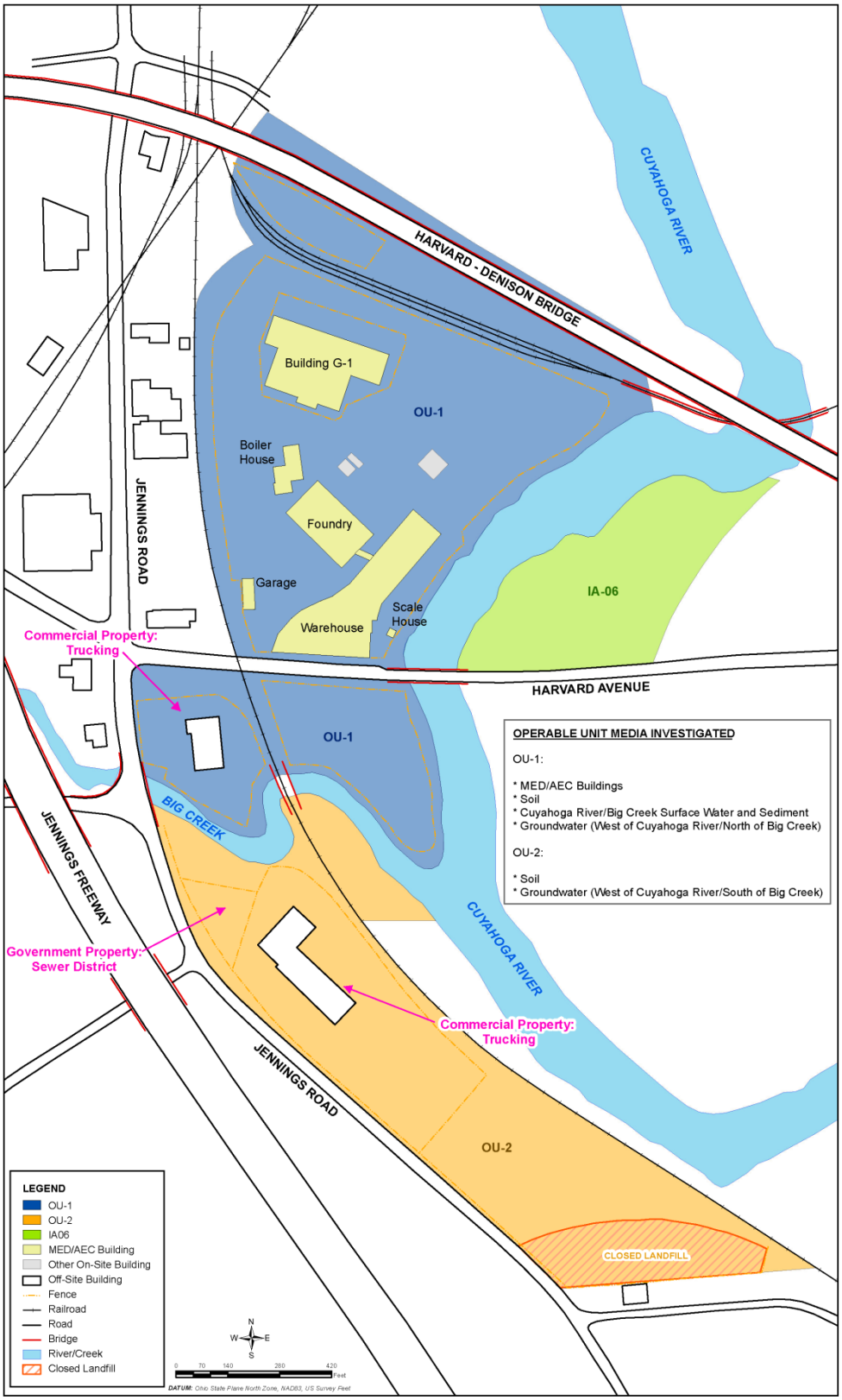


Figure 1-4. Operable Unit Boundaries

Investigative Area (IA)		Exposure Unit (EU)	Operable Unit (OU)	
01	Building G-1	EU B1-B4	1[a]	Northside
02	Other Existing Buildings	EU B5-B11		
03	Building G-1 Soil	EU1		
04	Northside Complex Soil	EU2		
05	Southside Complex Soil (North of Big Creek)	EU3		
07	Westside Soil (North of Big Creek)	EU5		
09	Sewers and Drains	EU8		
10	Groundwater	EU7		
05	Southside Complex Soil (South of Big Creek)	EU3	2[a]	Southside
07	Westside Soil (South of Big Creek)	EU5		
06[b]	Eastside Soil	EU4		

NOTE:

a The Baseline Risk Assessment (BRA) concluded that IA08 (EU6) Surface Water and Sediment did not pose unacceptable risks to human health or the environment

b The BRA concluded that IA06 (EU4) Eastside Soil did not pose unacceptable risk to human health or the environment. IA06 is being addressed under a separate Proposed Plan/ROD

Figure 1-5. Correlation between Investigative Areas, Exposure Units, and Operable Units

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2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section presents the RAOs and GRAs for the FS and presents the initial identification and screening of technology types and process options considered for possible use in site remediation. Section 2.1 defines the RAOs for soil and buildings and the methodology used to develop the RAOs, including land use and potential receptors for the site, constituents of concern (COCs), ARARs, and the PRGs. Section 2.2 presents the GRAs, including a description of the extent and estimated volume of impacted material for remedial action. Section 2.3 identifies, evaluates, and screens remedial technologies potentially capable of achieving the RAOs for the Former Harshaw Chemical Company Site.

2.1 REMEDIAL ACTION OBJECTIVES

RAOs are established to protect human health and the environment and provide the basis for selecting appropriate technologies and developing and evaluating remedial alternatives for the site. The RAOs specify requirements that remedial alternatives must fulfill in order to protect human health and the environment from contaminants and provide the basis for identifying and evaluating remedial alternatives. The RAOs for the Former Harshaw Chemical Company Site are intended to provide for long-term protection of human health and the environment. To provide this protection, media-specific objectives that identify major contaminants and associated media-specific PRGs were developed. These objectives are specified based on the COCs, exposure routes, and receptors, and define an acceptable contaminant concentration for the long-term protection of receptors.

As discussed in Section 1.2.5, the RI BRA concluded several MED/AEC-related radiological constituents present in soil and building materials posed potential unacceptable radiological dose to human receptors. Therefore, RAOs were developed for the following media and OUs:

- Soil (OU-1 and OU-2); and
- Building Materials (OU-1).

The site exposure model used as the basis for the FS Alternative rankings relies on potential pathways to a future construction worker. The distribution of MED-related constituents in groundwater is correlated directly to areas of impacted soils and exhibits little migration due to soil partitioning. Although USEPA MCLs are exceeded in portions of the site, the existing site use (passive industrial) poses no current unacceptable risk to human health and the environment. Consequently, RAOs were not developed for groundwater at this time. Groundwater on and near the site is not usable as a drinking water source because groundwater quality and yield are not suitable for use by industries or residents and current and future residents and industry in the area rely solely on municipal water as previously described in Sections 1.2.3.3 and 1.3.2 and summarized below.

- Current site operations do not use local groundwater for drinking or industrial processes. The water-bearing zone below the site varies in production (i.e., well yields) and municipal water supplies are in place (and available for expansion), thus precluding the need for groundwater.

- No potable drinking water wells are currently located in the vicinity (i.e., within at least a 2-mile radius) of the site. Future urban residents or commercial/industrial tenants will not be exposed to groundwater because a municipal source for drinking water is available at the site to be supplied for any residential development.

- Future uses of groundwater are unlikely since the Cuyahoga River, Big Creek, and Lake Erie provide readily accessible and usable process and drinking water with treatment.

- Groundwater on and near the Former Harshaw Chemical Company Site is not usable or potable due to high turbidity, high nickel concentration, and unsuitable potential Hydrogen (pH) and the groundwater extraction system installed to remove nickel-impacted groundwater precludes site groundwater use for operations or consumption.

- This area is located within the buffer zone of two USD areas identified by the state of Ohio's VAP. The presence of the Ohio VAP USDs does not in itself prevent the installation of groundwater wells for drinking or other uses on properties not included in the Ohio VAP, and the city of Cleveland does not regulate the installation of groundwater wells within city boundaries. However the city does require, through ordinance, that dwellings/structures located within city boundaries must be connected to the city municipal water supply system.

- The depth to groundwater (greater than [>] 10 ft) indicates that human exposure to surface seepage is unlikely.

- The groundwater model predicts no further degradation of groundwater occurs for all alternatives (Appendix D).

It is premature to develop and evaluate remedial alternatives to address impacted groundwater in this Feasibility Study because the remedial alternative selected for soil contamination may impact the distribution and concentration of groundwater contamination at the site and will affect the alternatives evaluated for addressing groundwater. To ensure complete consideration of impacted media on-site, groundwater conditions will be re-evaluated upon completion of a soils remedy. If the USACE determines that a potential exists for an unacceptable risk from groundwater impacted by FUSRAP-related materials, then, remedial alternatives will be evaluated and a separate Feasibility Study, Proposed Plan and Record of Decision will be completed for groundwater.

Overall protection of human health and the environment and compliance with ARARs are CERCLA threshold criteria. Only those remedial alternatives that provide adequate protection for human health and the environment and comply with ARARs (or justify a waiver) are eligible for selection.

The RAOs described below include the following key components for each FS OU:

- ARARs;
- Current and assumed future land uses;
- Potential current and future receptors; and
- COCs and their associated PRGs.

The RAOs developed for the soil and building materials in OU-1 are as follows:

- To prevent exposure to impacted soil containing concentrations of COCs to ensure the critical group does not receive a total dose equivalent exceeding 25 mrem/yr above background.

- To prevent exposure to impacted building materials containing concentrations of COCs to ensure the critical group does not receive a total dose equivalent exceeding 25 mrem/yr above background.

The RAO developed for the soil in OU-2 is as follows:

- To prevent exposure to impacted soil containing concentrations of COCs to ensure the critical group does not receive a total dose equivalent exceeding 25 mrem/yr above background.

The RAOs above will be achieved using COC-specific PRGs developed for the critical group for OU-1 and OU-2. For soil and building materials in OU-1, the critical receptor, based on assumed industrial future land use, is defined as the construction worker. For soil in OU-2, the critical receptor based on assumed the residential future land use is defined as the adult resident.

The following sections describe each of the key components of the RAOs.

2.1.1 ARARs

Remedial actions pursuant to CERCLA must meet ARARs. The following sections describe the ARARs for cleanup of the Former Harshaw Chemical Company Site.

2.1.1.1 Definitions

The definition of Applicable Requirements per 40 CFR 300.5 is as follows:

> "cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than Federal requirements may be applicable."

Relevant and Appropriate Requirements are defined in 40 CFR 300.5 as:

> "cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental or state environmental or facility siting laws that, while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than Federal requirements may be relevant and appropriate."

Determining whether a rule is relevant and appropriate is a two-step process. First, determine whether the rule is relevant based on the situation at the CERCLA site and, if so, then determine whether it is appropriate. A requirement is relevant if it addresses problems or situations sufficiently similar to the circumstances of the remedial action contemplated. It is appropriate if it is well suited to the site. In determining whether a requirement is both relevant and appropriate, the following factors may be considered:

- The purpose of the requirement and the purpose of the CERCLA action;

- The medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site;

- The substances regulated by the requirement and the substances found at the CERCLA site;

- The actions or activities regulated by the requirement and the remedial action contemplated at the CERCLA site;

- Any variances, waivers, or exemptions to the requirement and their availability for the circumstances at the CERCLA site;

- The type of place regulated and the type of place affected by the release or CERCLA action;

- The type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the CERCLA action; and

- Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resources at the CERCLA site.

In addition to ARARs, the lead agency may at their discretion, identify other advisories, criteria, or guidance "to be considered" (TBC) for a particular release in the absence of ARARs. The TBC category consists of advisories, criteria, or guidance developed by Federal agencies or states that may be useful in developing CERCLA remedies.

State standards that are promulgated, are identified by the state in a timely manner and are more stringent than Federal requirements may be applicable or relevant and appropriate. For purposes of identification of state standards, the term "promulgated" means the standards are of general applicability and are legally enforceable.

2.1.1.2 Evaluation of ARARs

During the development of this FS Report, the following Federal regulations were evaluated as potential ARARs for the Former Harshaw Chemical Company Site:

- 40 CFR 192, Subparts A, B and C: Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings;

- 10 CFR 40, Appendix A: Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Waste Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content;

- 10 CFR 61: Licensing Requirements for Land Disposal of Radioactive Waste;

- 10 CFR 20, Subpart E: Radiological Criteria for License Termination; and

- 40 CFR 191: Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-level, and Transuranic Radioactive Wastes.

This analysis of the potential ARARs evaluated for the Former Harshaw Chemical Company Site is based on the criteria outlined in 40 CFR 300.400(g) - *Identification of applicable or relevant and appropriate requirements*. A detailed description of the analysis for each potential ARAR is described below.

40 CFR 192: Subparts A, B and C: Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings

(i) *Purpose:* The specific purpose of 40 CFR 192 Subpart A is to provide for the long-term stabilization (containment or disposal) of uranium/thorium mill tailings at closed or inactive uranium/thorium processing or milling operations. Specifically, 40 CFR 192.02 (a) (b) (c) provides for defining the time frame for long-term effectiveness, establishing radon emissions criteria, and defining the criteria for groundwater protection. 40 CFR 192.12 provides the cleanup standards for remedial actions involving the removal of radioactive materials from a uranium ore processing site. The specific purpose of the remedial action at the site are to select and implement a final remedial action that complies with ARARs, protects human health and the environment, and presents the best balance of the other remedy selection criteria. Potential remedial alternatives range from land-use controls to excavation of the contaminated material at the Former Harshaw Chemical Company Site. Use of this requirement at the site would be to provide standards for for removal/excavation of waste material to a level that would allow for unrestricted release of the property. Use of the requirement at the Former Harshaw Chemical Company Site is consistent with the purpose of the requirement in the CERCLA action.

(ii) *Medium:* Of the media regulated under the requirement (air, soil, and groundwater), only soil (uranium) would be regulated at the site given air and groundwater are not media of concern.

(iii) *Substances regulated:* The regulated waste includes residual radioactive waste material from inactive uranium processing sites and addresses primarily radium, radon and uranium contaminants. The regulated waste, uranium ore processing residues (byproduct material), from the processing of uranium mill tailings are not present at the Former Harshaw Chemical Company Site. Uranium ore concentrates from other milling sites were shipped as feed to the site for further processing and consisted mostly of uranium with little to no radium. Thus, the substances at the site are not sufficiently similar to the substances being regulated.

(iv) *Actions or activities regulated:* The requirement covers long-term containment and protection of groundwater as well as cleanup standards for radium in the soils. The standards in 40 CFR 192.02 are not applicable to the Former Harshaw Chemical Company Site as on-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report). The standards in 40 CFR 192.12 address removal actions and therefore could be considered relevant for the Former Harshaw Chemical Company Site.

(v) *Variances/Waivers:* Variances are allowed if it is possible that a long-term containment situation may be an interim remedial action, particularly if the human health and environmental consequences of moving the waste material are more harmful than the consequences of leaving the material in place. However, moving the waste material at the Former Harshaw Chemical Company Site would not be more harmful than leaving the material in place.

(vi) *Type of place:* The requirement covers inactive milling operation or disposal sites. Usually the mill tailings are spread out over a large area (approximately 250 acres), and consist of low activity, low-level residual radioactive material, primarily radium with some uranium. The Former Harshaw Chemical Company Site was not a uranium ore processing site. The majority of the volume of the material at the Former Harshaw Chemical Company Site is not spread out over a large area such as a ore processing site. Instead, the material is contained within the 55 acres of the site and is primarily located near Building G-1 where the concentrated uranium feed materials were refined. Therefore, the type of place regulated is not similar to the type of place that will be addressed by the CERCLA action at the Former Harshaw Chemical Company Site.

(vii) *Type and size of structure or facility:* This rule covers inactive or closed mill tailings operation with uranium/thorium processing waste typically spread out over a large area, with poor access controls. These radioactive waste are generally large volume, low activity waste containing mostly radium and some uranium. The Former Harshaw Chemical Company Site was not a uranium ore processing site. At the Former Harshaw Chemical Company Site, there are low activity levels of uranium contamination of moderate volumes. Therefore, the type and size of structure or facility regulated is not sufficiently similar to the type and size that will be addressed by the CERCLA action at the Former Harshaw Chemical Company Site.

(viii) *Consideration of use or potential use of affected resources:* The requirement covers inactive mill tailing sites that will either remain in government control or be released to the public (if a site meets the 5/15 pCi/g criteria). Assumptions for future land use for the Former Harshaw Chemical Company Site range from industrial to residential use. The property is not currently owned by the Federal government.

10 CFR 40, Appendix A: Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Waste Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content

(i) *Purpose:* The specific purpose of 10 CFR 40 Appendix A is to provide standards for long-term management and disposal of 11e.(2) byproduct material or residual radioactive material, consisting of mill tailings and other waste, from active mill processing facilities or inactive facilities subject to NRC licensing requirements, in a manner that is protective of human health and the environment. On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report). Therefore, this requirement is not consistent with the remedial alternatives for the Former Harshaw Chemical Company Site.

(ii) *Medium regulated:* Of the media regulated under the requirement (air, soil, and groundwater), only soil (uranium) would be regulated at the site given air and groundwater are not media of concern.

(iii) *Substances regulated:* The rule covers waste associated with uranium mill tailings defined as 11e.(2) byproduct material, or uranium mill tailings generated before 1978 that are subject to NRC licensing requirements and primarily contain radium and some urnaium. Substances to be addressed in the IWCS are not uranium mill tailings or waste associated with the processing of uranium ores. Instead, the wastes at the Former Harshaw Chemical Company Site are associated with the further processing and refining of ore concentrates received as feed from ore processing sites as well as other feed materials and contain primarily uranium with little to no radium. Thus, the substances at the site are not consistent with the substances being regulated.

(iv) *Actions regulated*: 10 CFR 40 Appendix A establishes technical, financial, ownership, and long-term site surveillance criteria relating to the siting, operation, decontamination, decommissioning, and reclamation of mills and tailings or waste systems and sites at which such mills and systems are located. On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report). Therefore, this requirement is not consistent with the remedial alternatives for the Former Harshaw Chemical Company Site. The standards in Criterion 6(6) address removal actions and therefore could be considered relevant for the Former Harshaw Chemical Company Site.

(v) *Variances/Waivers*: No variances/waivers are discussed for this requirement.

(vi) *The type and place*: The requirement covers active uranium or thorium mill processing facilities. The Former Harshaw Chemical Company Site is not an active uranium or thorium mill processing

facility. Therefore, the type of place envisioned under the rule is not sufficiently similar to the type of place regulated at the site.

(vii) *The type and size of structure or facility*: This requirement covers milling facilities with waste (primarily radium with some uranium) typically contained onsite in some manner. On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report). Therefore, the requirements regarding on-site disposal are not consistent with the remedial alternatives for the Former Harshaw Chemical Company Site. With respect to the cleanup criteria in Criterion 6(6) which addresses the principal mill tailing contaminant, radium and other minor contaminants such as uranium, the Former Harshaw Chemical Company Site was not a uranium ore processing site. Radium is not a principal radiological contaminants at the Former Harshaw Chemical Company Site. Instead, there are low activity levels of uranium contamination of moderate volumes. Therefore, the type and size of structure or facility regulated is not sufficiently similar to the type and size that will be addressed by the CERCLA action at the Former Harshaw Chemical Company Site.

(viii) *Consideration of use or potential use of affected resources*: The Former Harshaw Chemical Company Site property is not currently owned by the Federal government and this FS report does not assume the Federal government will purchase the property; therefore, this rule is inconsistent with the conditions of the site.

10 CFR 61: Licensing Requirements for Land Disposal of Radioactive Waste

(i) *Purpose:* The specific purpose of 10 CFR 61 is to establish requirements for near-surface disposal of Class A, B, and C low-level radioactive waste. Near-surface disposal is disposal within 30 meters of the earth's surface. Requirements are established in the rule for disposal site, disposal design, and disposal facility operations (including equipment, facilities, and procedures), disposal site closure, and post-closure institutional controls. The purpose for which these requirements would be considered as an ARAR for the Former Harshaw Chemical Company Site remedial action is to provide standards for long-term containment of the low activity residual contamination remaining at the site. However, on-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report). Use of the requirement at the Former Harshaw Chemical Company Site is not consistent with the purpose of the requirement in the CERCLA action.

(ii) *Medium regulated:* Of the media regulated under the requirement (air, soil, and groundwater), only soil (uranium) would be regulated at the site given air and groundwater are not media of concern.

(iii) *Substances regulated:* The regulated waste includes low-level radioactive waste containing source, special nuclear, or byproduct material. Low-level radioactive waste has the same meaning as in the Low-Level Radioactive Waste Policy Act; that is, radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in section 11(e)(2) of the Atomic Energy Act (uranium or thorium tailings and waste). Substances at the Former Harshaw Chemical Company Site include primarily uranium with lower levels of thorium-230, thorium-232, and radium-226 resulting from the uranium refining operations conducted at the site. This waste would be consistent with other low-level radioactive waste covered by this rule.

(iv) *Actions or activities:* This rule covers long-term disposal of low-level radioactive waste. On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report). The long-term containment of the waste for contaminated material at the Former Harshaw Chemical Company Site is not consistent with this rule.

(v) *Variances/Waivers:* Variances are not being considered for this requirement.

(vi) *Type of place:* This rule covers near-surface disposal site for the disposal of Class A, B, or C or similar to Class C radioactive material. However, on-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report).

(vii) *Type and size of structure or facility:* On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report).

(viii) *Consideration of use or potential use of affected resources:* This rule requires that the Federal Government will assume the long-term care of the site, and that the site can be used for other purposes as On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report).

10 CFR 20, Subpart E: Radiological Criteria for License Termination

(i) *Purpose*: 10 CFR 20, Subpart E is applicable to NRC-licensed facilities where NRC is the successor to the AEC for licensing of nuclear materials and facilities. 10 CFR 20, Subpart E applies to any facility licensed by the NRC to manage special nuclear, source, or byproduct radionuclide material undergoing decontamination and remediation for release of the property for reuse. The regulation was promulgated by the NRC to ensure consistent standards for determining the extent to which lands must be remediated at facilities before remediation can be considered complete and the NRC license terminated. The Former Harshaw Chemical Company Site does not have a current NRC license; therefore this requirement is not applicable at the site.

(ii) *Medium regulated*: Of the media regulated under the requirement (air, soil, and groundwater), only soil (uranium) would be regulated at the site given air and groundwater are not media of concern.

(iii) *Substances regulated*: The radioactive COCs at the site are generally the same or similar to those found at sites subject to the regulation.

(iv) *Actions or activities*: The regulation was promulgated by the NRC to ensure consistent standards for determining the extent to which lands must be remediated at facilities before remediation can be considered complete and the NRC license terminated. The Former Harshaw Chemical Company Site does not a have a current NRC license; therefore this requirement is not applicable at the site.

(v) *Variances/waivers*: Variances are not being considered for this requirement.

(vi) *Type of place*: This rule applies to the decommissioning of facilities licensed by NRC to process radioactive material. While the Former Harshaw Chemical Company Site does not hold an NRC license, the site was involved in the processing of radioactive materials for the NRC predecessor agency, AEC. Therefore, this requirement is sufficiently similar for the Former Harshaw Chemical Company Site.

(vii) *Type and size of structure or facility*: The type and size of the Former Harshaw Chemical Company Site is consistent with the type and size of a facility regulated by 10 CFR 20 Subpart E.

(viii) *Consideration of use or potential use of affected resources*: The Former Harshaw Chemical Company Site property is not currently owned by the Federal government and this FS report does not assume the Federal government will purchase the property; therefore, this rule is inconsistent with the conditions of the site.

40 CFR 191: Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-level, and Transuranic Radioactive Wastes

(i) *Purpose:* These rules establish standards for management, storage, and disposal of spent nuclear fuel, high-level radioactive waste, and transuranic radioactive waste. In 40 CFR 191.02(i) transuranic radioactive waste is waste containing more than 100 nanocuries (100,000 pCi) per gram of waste of alpha-emitting transuranic isotopes, with half-lives greater than twenty years where TRU refers to those elements with atomic numbers greater than 92. There is no spent nuclear fuel, high-level radioactive waste, or transuranic radioactive waste at the Former Harshaw Chemical Company Site.

(ii) *Medium:* The waste at the Former Harshaw Chemical Company Site is not spent nuclear fuel and are not comprised of the radionuclides which make up high-level waste or TRU waste. Thus, the substances at the site are not consistent with the media described in this requirement.

(iii) *Substances regulated:* This regulation covers spent nuclear fuel, high-level waste and transuranic waste. Spent nuclear fuel is typically nuclear fuel from nuclear reactors. High-level waste is traditionally solid and liquid waste from reprocessing spent nuclear fuel. Transuranic waste is usually items that have become contaminated as a result of activities associated with the production of nuclear weapons (e.g., rags, equipment, tools, and contaminated organic and inorganic sludges). Waste from the Former Harshaw Chemical Company Site is not spent nuclear fuel, high-level waste, or TRU waste.

(iv) *Actions or activities:* The management, storage, and disposal activities associated with the requirement is not similar to the potential remedial alternatives for the Former Harshaw Chemical Company Site.

(v) *Variances/Waiver:* Variances/waivers are not being considered for this requirement.

(vi) *Type of place:* This requirement covers disposal facilities for spent nuclear fuel, high-level and transuranic radioactive waste. The disposal standards under 40 CFR 191 are intended to apply to disposal by any method, except disposal directly into the oceans or ocean sediment. On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report); therefore, this requirement is not consistent with the remedial alternatives for the Former Harshaw Chemical Company Site.

(vii) *Type and size of structure or facility:* The type of facility regulated is a disposal facility for spent nuclear fuel, high-level and transuranic radioactive waste. However, the guidance for implementation of 40 CFR 191 (Appendix C of 40 CFR 191) specifically states that "several sections apply only to disposal in mined geologic repositories and would be inappropriate for other types of disposal systems." On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report); therefore, this requirement is not consistent with the remedial alternatives for the Former Harshaw Chemical Company Site.

(viii) *Consideration of use or potential use of affected resources:* In this requirement the Federal Government is to assume long-term care of the site, and that the site can be used for other purposes as long as the integrity of the disposal site is not breached. On-site disposal has not been retained as a technology/process option for the site (refer to Section 2.3.1.5.1 of the FS Report); therefore, this requirement is not consistent with the remedial alternatives for the Former Harshaw Chemical Company Site.

Conclusion

Of these potential ARARs, only 10 CFR 20, Subpart E was considered relevant and appropriate for the site. The other potential ARARs were found not to be relevant and/or appropriate based on the following reasons:

- 40 CFR 192 Subparts A, B and C and 10 CFR 40 Appendix A were determined not to be relevant and/or appropriate since the regulations focus primarily on contamination related to mill tailing operations (primarily Radium-226) and the major contaminants at the Former Harshaw Chemical Company Site are uranium and thorium not associated with milling operations or mill tailings;

- 40 CFR 191 was determined not to be relevant and/or appropriate given that the Former Harshaw Chemical Company Site did not engage in the management and disposal of spent nuclear fuel or high-level and transuranic radioactive wastes; and

- As discussed in Section 2.3.1.5.1 of this FS Report, on-site disposal was not retained for consideration as a remedial technology; therefore 10 CFR 61 is not relevant and/or appropriate for the site.

A detailed discussion of the selected ARAR, 10 CFR 20, Subpart E is provided below.

2.1.1.3 10 CFR Part 20 Subpart E - Radionuclides

USACE has determined that portions of 10 CFR 20 Subpart E are chemical-specific relevant and appropriate for remedial activities at the Former Harshaw Chemical Company Site. 10 CFR Part 20 Subpart E is applicable to NRC-licensed facilities where NRC is the successor to the AEC for licensing of nuclear materials and facilities. 10 CFR Part 20 Subpart E applies to any facility licensed by the NRC to manage special nuclear, source, or byproduct radionuclide material undergoing decontamination and remediation for release of the property for reuse. The regulation was promulgated by the NRC to ensure consistent standards for determining the extent to which lands must be remediated at facilities before remediation can be considered complete and the NRC license terminated.

The Former Harshaw Chemical Company Site is an industrial facility that conducted chemical and radiological compound research and production activities under contract to the MED/AEC from 1942 through 1959. The site held numerous AEC licenses between 1957 and 1968 that authorized the possession and use of radioactive materials. The primary radiological production process conducted under government contract involved the refining of uranium oxide feed material to produce numerous uranium-based materials. The radioactive residuals at the site are those associated with the uranium oxide processing operations. The Former Harshaw Chemical Company Site does not have a current NRC license; therefore, the rule is not applicable at the site.

The type and size of the Former Harshaw Chemical Company Site is consistent with the type and size of a facility regulated by 10 CFR 20 Subpart E, and the media to be remediated and radioactive COCs at the site are generally the same or similar to those found at sites subject to the regulation. The relevant and appropriate requirements in the 10 CFR 20, Subpart E are:

Section 20.1401(d):

"When calculating [total effective dose equivalent] TEDE to the average member of the critical group the licensee shall determine the peak annual TEDE dose expected within the first 1,000 years after decommissioning."

Section 20.1402:

"A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25millisievert [mSv]) per year, including that from groundwater sources of drinking water, and the residual radioactivity is reduced to levels which are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal."

Section 20.1403:

"A site will be considered acceptable for license termination under restricted conditions if:

(a) The licensee can demonstrate that further reductions in residual radioactivity necessary to comply with the provisions of 20.1402 would result in net public or environmental harm or were not being made because the residual levels associated with restricted conditions are ALARA. Determination of the levels which are ALARA must take into account consideration of any detriments, such as traffic accidents expected to potentially result from decontamination and waste disposal;

(b) The licensee has made provisions for legally enforceable institutional controls that provide reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem (0.25 mSv) per year;

(c) *(section not applicable)*

(d) *(section not applicable)*

(e) Residual radioactivity at the site has been reduced so that if the institutional controls were no longer in effect, there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is ALARA and would not exceed either:

(1) 100 mrem (1 mSv) per year; or

(2) 500 mrem (5 mSv) per year provided the licensee:

(i) Demonstrates that further reductions in residual radioactivity necessary to comply with the 100 mrem/yr (1 mSv/yr) value of paragraph (e)(1) of this

section are not technically achievable, would be prohibitively expensive, or would result in net public or environmental harm;

(ii) Makes provisions for durable institutional controls; and

(iii) (section not applicable)"

10 CFR 20.1003 is relevant and appropriate with respect to the definition of "Critical Group" as it applies in 10 CFR 20, Subpart E. "Critical Group" is defined as "the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances." As discussed in Section 2.1.3 of this FS, the critical groups for OU-1 and OU-2 are the construction worker and the resident, respectively.

In summary, 10 CFR 20 Subpart E is relevant and appropriate for use in the development of media-specific PRGs at the site. The rule addresses situations sufficiently similar to the circumstances of the release at the Former Harshaw Chemical Company Site and its use is appropriate to the circumstances of the release. The rule requires the critical group to be identified and the standards and related requirements for unrestricted and restricted use to be implemented.

2.1.2 Other Potential ARARs

Ohio EPA provided a list of potential ARARs to USACE on February 11, 2010, that consisted of 110 citations from the Ohio Revised Code and the OAC. Each of the potential ARARs was reviewed to determine the following criteria:

- Applicable;
- Relevant and appropriate; and
- Type (chemical/location/action-specific).

The list of potential ARARs from the state of Ohio (including the results of the review described above) is provided in Appendix A. As indicated in Appendix A, none of the 110 citations were identified as ARARs.

Even though Ohio is an agreement state, the reason their decommissioning regulation (OAC 3701:1-38-22) is not identified as an ARAR in Appendix A is because, in accordance with the NCP [40 CFR §300.5], only state requirements that are more stringent than the Federal requirements are identified as ARARs and none were identified to be more stringent.

2.1.3 Land-Use and Potential Receptors

The Conceptual Site Model (CSM) helps to identify and visually organize potential exposure pathways and receptors and to identify those pathways which are complete and could lead to exposures to COCs at the site. The CSM presented in the RI Report was created during the planning stages of the RI. The CSM was updated to more accurately represent site conditions and the extent of contamination observed during the RI. The CSM has been further updated in this FS Report based on the results of the RI BRA. For example, exposure media/pathways shown to have minor impact on potential unacceptable radiological dose have been identified. The updated CSM is presented in Figure 2-1.

2.1.3.1 OU-1 and OU-2 Land-Use and Potential Receptors

The following sections present a summary of the current and future land uses and potential receptors for OU-1 and OU-2.

2.1.3.1.1 Current Land-Use and Potential Receptors

OU-1 is currently a combination of undeveloped industrial properties, open fields, and wooded riparian areas along the Cuyahoga River and Big Creek. Although not currently used for industrial operations, the site is periodically visited by maintenance workers who mow grass, maintain the groundwater treatment system for nickel control, and perform basic maintenance of on-site buildings. Of the remaining buildings at the site, the Warehouse and Foundry buildings are currently used for warehousing operations, and the Boiler House is used for equipment storage.

Currently, OU-2 consists mainly of undeveloped industrial properties and open fields. However, commercial and municipality-owned properties are located in the northwest portion of OU-2. This portion of the OU-2 is visited by industrial/maintenance workers who work at the properties and perform basic maintenance of on-site buildings.

Current potential receptors for OU-1 and OU-2 include the following:

- Adult maintenance worker;
- Adult trespasser; and
- Adolescent trespasser.

The adult maintenance worker may be exposed to contaminated soil and contaminated building surfaces. Although the maintenance worker may also be exposed to contaminated groundwater at the groundwater treatment system for nickel control, groundwater exposure to this receptor did not show unacceptable risk or radiological dose in the RI BRA; therefore, it is not evaluated further in this FS.

The trespasser receptors may contact contaminated surface soil and building surfaces. Although this receptor may also contact sediment, surface water, and fish from the Cuyahoga River and Big Creek, exposure to these media did not show unacceptable risk or radiological dose in the RI BRA.

2.1.3.1.2 Future Land-Use and Potential Receptors

Future land use in OU-1 is likely to remain industrial. Alternately, all or portions of OU-1 may be developed for recreational use. Future land use in OU-2 is also likely to remain industrial. However, future planning by the city of Cleveland indicates a portion of OU-2 may be zoned residential. Therefore, future residential development is evaluated to provide a baseline for unrestricted use of the property.

Future potential receptors for OU-1 and OU-2 include the following:

- OU-1:
  - Adult maintenance worker (similar to the current maintenance worker);
  - Adult industrial worker;
  - Adult and adolescent recreational user (similar to the current trespasser); and
  - Construction worker.

- OU-2:
  - Adult maintenance worker (similar to the current maintenance worker);
  - Adult industrial worker;
  - Adult and adolescent recreational user (similar to the current trespasser);
  - Construction worker;
  - Adult resident; and
  - Child resident.

Industrial workers could be exposed to contaminated surface soil and building materials while on-site. One potential future recreational use of the site identified by the Ohio Canal Corridor includes a museum (OU-1). The industrial worker scenario also serves as a conservative surrogate for museum workers. Industrial workers will not be exposed to groundwater. Industrial/commercial properties in this area are supplied with municipal water by the city of Cleveland. Additional water for high volume uses, such as by Mittal Steel (located adjacent to the site), comes from the Cuyahoga River.

Since future redevelopment of the site for additional industrial or new recreational use would require construction activities, the potential for unacceptable risk and radiological dose to construction workers was also evaluated. Construction workers could be exposed to contaminated soil; surface water, sediment, and soil in and around sewer lines; and contaminated building materials. Construction workers may also be exposed to shallow groundwater in an excavation; however, groundwater exposure to this receptor did not show unacceptable risk or radiological dose in the RI BRA.

Residential (single and multi-family) housing is currently present within 0.5 mile (0.8 km) of the site. Future residential development would result in mixing of the soil column to an assumed depth of 13 ft (4 m) bgs. Urban residents could be exposed to contaminated total soil, including consumption of produce grown in contaminated soil. Groundwater on and near the site is generally not usable as a drinking water source due to high turbidity, high nickel concentration, and unsuitable pH from surrounding industrial sources. Other uses, such as crop irrigation, and industrial use are also unlikely. As previously noted, groundwater in this area is not potable and more easily accessible irrigation and industrial water supplies are available via surface water courses. Residents may contact sediment, surface water, and fish from the Cuyahoga River and Big Creek; however, the calculated exposure did not result in unacceptable risk or radiological dose in the RI BRA.

Three receptors (industrial worker, construction worker, and maintenance worker) were considered in the RI for potential exposures to building materials. It is assumed that site buildings will only be used for industrial purposes (i.e., residential or recreational use would require dismantlement and redevelopment); therefore, residential and recreational exposures were not considered for exposure to radionuclides on building surfaces. Trespassers have recently begun accessing abandoned on-site buildings (as evidenced by graffiti); therefore, radiological doses were calculated for the FS to address potential trespasser exposures to building materials.

2.1.3.2 Critical Group

A “critical group” was identified for each of the OUs from all of the potential land uses and receptors described above. The term “critical group” is defined in 10 CFR Part 20.1003 to mean “the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.” Based on current and reasonable assumed future land use, the following critical group receptors have been identified for soil in the FS:

- **OU-1:** Construction worker; and

- **OU-2:** Resident adult.

These critical groups were selected because future land use at OU-1 is anticipated to be a combination of industrial, commercial, and recreational (including trespasser). Within these land uses, the group reasonably expected to receive the greatest exposure is the construction worker based on the results of the risk assessment. Anticipated land use at OU-2 is expected to remain undeveloped; however, because other activities (e.g., recreational) are not planned for this area, and residential properties are located nearby, it is assumed OU-2 is available for residential development.

The CSM presented in the RI included a hypothetical subsistence farmer scenario that included pumping groundwater for domestic and irrigation uses. This subsistence farmer does not represent the "critical group" because the site is not a candidate for agricultural use. As documented in the Future Land Use Checklist for the Former Harshaw Chemical Company Site (Appendix B), the site is located in the city of Cleveland in an area dominated by active industrial (e.g., Mittal Steel, Aluminum Company of America, CSP Fabricating, CSI Recycling, Republic Waste Services) and heavy commercial (e.g., Cleveland Welding Supply, Milan Express Trucking, Carson Paving) activity.

Adjacent land uses also include transportation right-of-ways (active railroads, Harvard-Denison Bridge, Jennings Freeway) as well as the Cuyahoga River and Big Creek. The larger surrounding area includes industrial, commercial, and high-density residential land use as well as property identified for the Ohio and Erie Canal recreational reservation. The site is not suitable for raising livestock due to the high concentration of industrial, commercial, and high density housing, and as previously noted, groundwater is not, and will not be, used as a potable, irrigation, or industrial water supply.

2.1.4 Constituents of Concern

The COCs addressed in this FS are identified as exceeding dose-based criteria or ARAR-based standards and are limited to constituents associated with MED/AEC-related activities. These COCs will be the focus of the remedial effort evaluated in the FS and do not necessarily represent the final list of COCs that will apply to site remediation. The final COCs identified for remediation at the site will be identified in the ROD.

The following table summarizes the MED/AEC-related radiological constituents evaluated in the HHRA that represent unacceptable radiological dose to the applicable critical group in each FS OU:

OU	Critical Group/Receptor	Soil Constituents
OU-1	Construction Worker	Pb-210[a] Th-232 Ra-226 U-234 Ra-228 U-235 Th-228 U-238 Th-230
OU-2	Resident (Adult)	Pb-210[a] Th-232 Ra-226 U-234 Ra-228 U-235 Th-228 U-238 Th-230

[a]Pb-210 is assumed to be equilibrium with Ra-226.
OU = Operable Unit
Pb = Lead-210
Ra-226 = Radium-226
Ra-228 = Radium-228
Th-228 = Thorium-228
Th-230 = Thorium-230
Th-232 = Thorium-232
U-234 = Uranium-234
U-235 = Uranium-235
U-238 = Uranium-238

Lithium and kerosene (chemical constituents) were included in the RI due to their association with the historical production processes conducted at the site. Lithium was identified as a potential impurity present due to the lithium fluoride production in Building G-1 and its use in the uranium refining process, Kerosene was used as a solvent in the wet uranium refining process.

Although lithium and kerosene (total petroleum hydrocarbons-diesel range organics [TPH-DRO]) were identified in the RI BRA as posing unacceptable non-cancer risks from exposure to soil for a subsistence farmer child scenario in EU-1, the critical receptors for the site do not include a subsistence farmer. Therefore, these constituents are not evaluated further in the FS. Furthermore, lithium and kerosene are not CERCLA hazardous substances and did not meet the NCP [40 CFR §300.5] definition of a CERCLA pollutant or contaminant that would require these contaminants to be addressed in this response action. The radiological dose-based FS PRGs are considered to be protective of the chemical risk-based exposures for total uranium. A comparison of radiological dose-based PRGs to their respective chemical risk-based PRGs developed for the same receptors in the RI BRA was made in the RI Report (see Tables 8-27 and 8-28 from the RI Report [USACE 2009]). The radiological dose-based PRGs are lower than the chemical-based PRGs for total uranium for all comparable receptors.

The COCs for soil carried forward for evaluation in the FS are:

- Radium-226;
- Thorium-230;
- Thorium-232; and
- Total Uranium.

All radionuclides identified in the table above are considered in the development of the PRGs for these four radionuclides through the use of a SOR approach, as described in Section 2.1.5 and 2.1.5.2. This approach will address all radiological contamination present in site soil and will ensure the total dose remaining after remediation will achieve the RAOs presented in Section 2.1. MED/AEC-related radiological constituents posing unacceptable radiological dose to human receptors from building surfaces were identified through an analysis of volumetric samples of building materials, fractionating the activity to the applicable radionuclides (i.e., establishing what fraction of the total activity is associated with a specific radionuclide based on the volumetric and total activity results), and comparing of isotopic surface activity for a given isotope to conservative screening levels developed by the NRC. Given that building

surface contamination has resulted from the same constituents present in site soil, building surface COCs are consistent with those applicable to soil.

2.1.5 Preliminary Remediation Goals

PRGs are developed early in the site cleanup process and are based on readily available information. PRGs are modified as necessary, as additional information becomes available through the RI/FS process. PRGs are receptor/COC/media-specific concentrations associated with acceptable levels of chemical or radionuclide exposure. PRGs were calculated for all MED/AEC-related constituents posing a potentially unacceptable radiological dose to human receptors as presented in Section 8 of the RI Report. Using the methodology as presented in the *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part B* (USEPA 1991), the PRGs were developed using residual radioactivity computer code (RESRAD)-derived dose-to-source ratios consistent with the methodology. These PRGs are used to evaluate the remedial effort in the FS. The final remediation goals for remediation of the site will be identified in the ROD.

The following table summarizes proposed PRGs for OU-1 and OU-2 soil, based on a total of 25 mrem/yr for all complete pathways:

COC	CAS Number	Worker (OU-1)[a] Construction (pCi/g)	Resident (OU-2)[a] Adult (pCi/g)
Ra-226[b]	013982-63-3	9.1E+00	3.6E+00
Th-230	014269-63-7	3.5E+01	1.6E+01
Th-232[c]	013968-55-3	6.0E+00	3.6E+00
U-238[d]	007440-61-1	1.9E+02	1.5E+02

Values represent minimum of RESRAD-calculated PRG at years 0, 185, or 1,000 (year of peak dose per nuclide group).
[a]Groundwater was not considered a drinking water source during development of these values.
[b]PRGs for Ra-226 include Pb-210 contribution to dose at time 0.
[c]PRGs for Th-232 include Ra-228 and Th-228 contribution to dose at time 0.
[d]U-238 is being used as surrogate for total uranium Derived Concentration Guideline Level by multiplying total uranium DCGL by U-238's activity fraction (0.489). PRGs for total U of 4.0E+02 and 3.0E+02 for OU-1 and OU-2, respectively, include contribution to dose from U-234, U-235, and U-238, assuming natural abundance of uranium isotopes (in activity-based ratio of U-234:U-235:U-238 1:0.046:1).

CAS = Chemical Abstract Service
COC = Constituent of Concern
pCi/g = PicoCuries Per Gram
Pb-210 = Lead-210
PRG = Preliminary Remediation Goal
RESRAD = Residual Radioactivity Computer Code

Ra-226 = Radium-226
Ra-228 = Radium-228
Th-230 = Thorium-230
Th-232 = Thorium-232
U-234 = Uranium-234
U-235 = Uranium-235
U-238 = Uranium-238

The following table summarizes proposed PRGs for OU-1 building surfaces, based on a total of 25 mrem/yr for all complete pathways:

Exposure	*Construction Worker (OU-1)*		
	Fixed Activity ($dpm/100cm^2$)	**Removable Activity ($dpm/100cm^2$)**	**Direct Dose (mrem/hr)**
RME	508	51	0.013

cm^2 = Square Centimeters
dpm = Disintegrations Per Minute
mrem/hr = Millirems Per Hour
OU = Operable Unit
RME = Reasonable Maximum Exposure

As discussed in Section 2.1.1, 10 CFR 20 Subpart E was determined to be an ARAR for the Former Harshaw Chemical Company Site. This ARAR limits residual radioactivity such that the annual dose from residual radioactivity distinguishable from background to the average member of the critical group does not exceed 25 mrem/yr for unrestricted use. In addition, the ARAR limits residual radioactivity for restricted release such that legally enforceable institutional controls provide reasonable assurance that residual radioactivity distinguishable from background will not exceed 25 mrem/yr and will not exceed 100 mrem/yr (or 500 mrem/yr, as applicable) if the institutional controls were no longer in effect. In addition, residual levels of contamination for both restricted and unrestricted release must be reduced to levels that are ALARA. PRGs for site radiological COCs were derived using this 25 mrem/yr standard together with conservative, site-specific parameters.

Section 2.1.3 defined the current and future land use scenarios for OU-1 and OU-2 along with the current and future potential receptors for these OUs. The construction worker is representative of anticipated future land-use and is the critical receptor for the OU-1, while the resident adult provides a baseline for evaluation of unrestricted land-use and is the critical receptor for OU-2.

The four COCs identified for soil and building media pose risks above USEPA guidelines under an industrial use scenario, which has been identified as the reasonable future use scenario for OU-1. Due to the fact that some of the buildings may be demolished and/or reconfigured at a future time, and any industrial future use would likely require construction of new facilities, a construction worker receptor has been selected as the critical group for which the soil PRGs were developed.

2.1.5.1 Decay Chain Products

The COCs presented in the tables above account for all radionuclides identified as significant soil constituents of potential concern (COPCs) (i.e., lead-210, radium-226, thorium-230, radium-228, thorium-228, thorium-232, uranium-234, uranium-235, and uranium-238). However, as some of the individual radionuclides are within the same decay chain as other radionuclides, the number of COCs for which soil PRGs were developed could be reduced based on site-specific considerations. For the Former Harshaw Chemical Company Site, it is reasonable (and slightly conservative) to assume lead-210 is currently in secular equilibrium with radium-226, and thorium-228 and radium-228 are in secular equilibrium with thorium-232. This is reasonable given the half-lives of lead-210 (22 years), thorium-228 (1.9 years), and radium-228 (5.8 years) and the length of time (about 60 years) since government-contracted activities at the site ended.

The doses were previously determined to be the maximum for all five of these radionuclides using RESRAD at the beginning of the evaluation period (time zero). Hence, the maximum dose for radium-226 (including the contribution from lead-210) and thorium-232 (including the contributions from thorium-228 and radium-228) would also occur at time zero. The approach used to determine the dose at

the beginning of the evaluation period was accomplished by adding in the dose contribution for daughter products to the dose which results from the parent alone so that the combined soil PRG is protective of the parent and daughter(s). For example, the lead-210 dose at the beginning of the RESRAD evaluation period (time zero) was added to the dose for radium-226 (at time zero) in developing a radium-226 soil PRG. The same was done for the three radionuclides in the thorium-232 decay series.

RESRAD was also used to determine the time of the peak dose that would occur for radium-226 if lead-210 was not initially present. The maximum dose was determined to occur at about 60 years in the future from lead-210 ingrowth. The dose at that time was determined to be about 14% lower than for the case with lead-210 being initially present at time zero. This is reasonable because lead-210 would be at about 85% of its maximum (secular equilibrium) value at that time due to ingrowth. Hence, the assumption of lead-210 being in secular equilibrium is a conservative approach. That is, if all lead-210 was removed during uranium processing at the site and only radium-226 was initially present, the soil PRG would be slightly higher (about 14%) since complete ingrowth of lead-210 would not yet have occurred.

In a similar manner, the doses from exposure to radium-228 and thorium-228 were added to the dose from exposure to thorium-232 (all at time zero) to determine the total dose for thorium-232 and its radioactive decay products. Finally, all uranium isotopes were combined to develop a total uranium soil PRG. The RI Report indicates the majority of uranium contamination at the Former Harshaw Chemical Company Site consists of material with natural isotopic ratios, so the soil PRG for total uranium combined isotopic soil PRGs using ratios of uranium isotopes as found in natural abundance. This is a reasonable approach for use in developing PRGs at the site based on the analysis of uranium isotopes during the RI. It is proposed that uranium-238 will be used as a surrogate for the total uranium soil PRG, as it can be more easily and directly measured in the field during remediation efforts. The uranium-238 soil PRG is about half of the total uranium soil PRG (by activity) for natural uranium and would be used to ensure all uranium isotopes present would meet the overall dose limit when remediation is complete. The use of these conservative assumptions in developing soil PRGs for fewer radionuclides than those listed in the RI Report should result in a site cleanup that is fully protective of human health and the environment.

2.1.5.2 Sum of Ratios

The PRGs are based on a dose of 25 mrem/yr for each radionuclide. Due to a mixture of radionuclides present in site soil, the SOR must be applied to ensure the total dose resulting from exposure to all radionuclides present in soil above background does not exceed 25 mrem/yr. The SOR approach calculates the ratio of the concentration of each radionuclide versus the radionuclide-specific PRG. The SOR method is based on the principle that a ratio >1 represents unacceptable radiological dose and a ratio less than or equal to (≤)1 represents acceptable radiological dose. If there are multiple radionuclides in the medium being evaluated, the sum of the ratios for all of the radionuclides must also be ≤ 1.

2.1.5.3 Protectiveness of Groundwater

The numerical groundwater flow and transport model updated as part of this FS (as summarized in Section 1.3.2 and detailed in Appendix D) was used to predict future transport of total uranium in the model area for three scenarios, which together represent predicted future groundwater effects from the five FS alternatives for OU-1 soil. All of the transport simulations resulted in similar predictions, whether with continuing leaching source (three different simulations) or without. Model simulations predict minimal transport of or change in this total uranium plume over the 1,000-year period of the FS alternatives. These simulations confirm that all of the FS alternatives for OU-1 soil meet the objective of preventing further degradation of groundwater via total uranium contamination.

For transport simulations representing the groundwater effects for FS alternatives involving soil excavation, it is reasonable to expect no further groundwater degradation, regardless of the total uranium sorption conditions. Excavation of above-criteria soil will remove the most significant potential continuing leaching sources of total uranium, which have been in place for up to 60 to 70 years. If these soil were a significant source of contamination to groundwater in the past, excavation would tremendously diminish this contribution.

Future transport of thorium in OU-1 groundwater was qualitatively evaluated through comparison to model-predicted transport of total uranium in OU-1. As with total uranium, no further degradation of OU-1 groundwater is predicted to occur due to thorium.

Proposed soil PRGs for total uranium, thorium-230, thorium-232, and radium-226 in OU-1 and OU-2 are protective of groundwater. A summary of the modeling updates is presented in this section and the complete Groundwater Flow and Contaminant Transport Modeling report is included in Appendix D.

2.1.5.4 Building PRGs

PRGs for buildings are receptor-specific surface radiological concentrations that are associated with acceptable levels of exposure. Site-specific PRGs were developed for the three building survey measurements (i.e., fixed activity, removable activity, and direct gamma exposure) and assume contributions from all COCs. As discussed in Section 2.1.1, portions of 10 CFR 20 Subpart E were determined to be ARARs for the Former Harshaw Chemical Company Site.

PRGs for buildings are isotope/receptor-specific surface activity limits. These limits are expressed in terms of activity per unit area (e.g., dpm/100 cm^2) for each applicable receptor and each radionuclide. The dose rate limit used in the PRG development (i.e., an annual dose limit of 25 mrem/yr to the average member of the critical group) is based on criteria contained in 10 CFR Part 20, the likely ARAR identified for the site. Herein, the critical group is the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances. For the Former Harshaw Chemical Company Site, the construction worker scenario generally results in limiting PRGs for surface contamination of building materials.

Given that trespasser activity has recently been noted at some of the buildings and that the trespasser scenario was not previously evaluated for building contamination, this receptor has been added in determining the critical receptor for the Former Harshaw Chemical Company Site. The results of the exposure analysis for the building trespasser do not exceed the exposures calculated for the other building scenarios as documented in the RI. Evaluation of the trespasser confirms that construction workers constitute the critical group for the Former Harshaw Chemical Company Site and remediation for this receptor will result in preventing unacceptable radiological dose to other potential receptors, including trespassers.

2.2 GENERAL RESPONSE ACTIONS

The following sections present discussions regarding the contamination extent and volume calculations and GRAs.

2.2.1 Extent and Volume Calculations

The USACE Buffalo District developed an estimate of contaminated soil at the Former Harshaw Chemical Company Site for use in the detailed analysis of alternatives. This estimation was used to

develop conceptual excavation footprints and associated in-situ and ex-situ contaminated soil volumes to support cost estimates used during the detailed analysis of alternatives.

2.2.1.1 Method

The USACE Buffalo District utilized the method developed by ANL to estimate contaminated soil volumes at the Former Harshaw Chemical Company Site. The method, known as the Bayesian Approaches to Adaptive Spatial Sampling (BAASS), utilizes both "soft" and "hard" data to generate a probability that a given area will exceed a targeted cleanup objective or threshold. Soft data includes aerial photographs, non-intrusive geophysics, gamma walkover surveys, anecdotal information, and historical site/process knowledge. This information is used to create an initial conceptual site model (ICSM). The ICSM was entered into the BAASS software, hard data (site characterization results) were applied, and the CSM was updated. The results of the BAASS model were then exported to ArcGIS (geographic information system [GIS] software suite produced by Esri). The ArcGIS spatial analyst was used to convert the BAASS output into confidence contours. Each contour represents a 2-D area with a probability that soil contained within the contour exceeded the cleanup objective. Using 3-D modeling software (EarthVision), the probability contours were converted into volumes. Volumes were generated for confidence levels associated with specific BAASS probability contours:

Confidence Level	BAASS Probability	Description
90%	0.1	90% confidence the area includes all soil that exceeds threshold (largest extent)
80%	0.2	80% confidence the area includes all soil that exceeds threshold
70%	0.3	70% confidence the area includes all soil that exceeds threshold
60%	0.4	60% confidence the area includes all soil that exceeds threshold
50%	0.5	50% confidence the area includes all soil that exceeds threshold (smallest extent)

% = Percent
BAASS = Bayesian Approaches to Adaptive Spatial Sampling

The BAASS software simulation described above addressed only the lateral extent (i.e., the area) of contamination based on the ICSM and site characterization data. To convert these areas to in-situ volumes, estimations of maximum depths of contamination that exceeded the threshold were applied to area results in order to calculate the 3-D volume of soil present within each confidence level area. The depth estimations were derived from site characterization results. The USACE Buffalo District then analyzed the resulting volumes and determined the volume most likely to be excavated (and therefore addressed in the FS).

Based on the selected confidence level volume of 80%, the in-situ soil volume was then modified to represent an ex-situ soil volume (i.e., the volume of soil actually generated during excavation). The ex-situ engineered volume was based on the maximum excavation footprint required to access and remove contaminated material associated with the specified confidence interval. It included necessary safety trenching and step-backs to ensure worker safety and assumed over-excavation and excavated soil expansion.

2.2.1.2 Data Evaluation

Historical sampling for the Former Harshaw Chemical Company Site did not include an analysis for all COCs identified in the RI Report. Additionally, of the samples collected during the RI field work, not all were analyzed for all COCs. Therefore, there was a need to determine the most appropriate method to develop a SOR for volume estimating purposes.

The dataset used to generate the volume estimate was compiled from historical samples and RI samples. The hierarchy of analytical methods presented in Table 8-1 of the RI Report was used to select the results for each sample. An SOR was calculated for each sample using the values presented in Table 2-1. Negative values that might have resulted after background concentrations were subtracted and were not included in the SOR. Each radionuclide is divided by its respective PRG. The fractions are then summed to obtain the final SOR for each sample. An SOR >1 is assumed to "fail" and is included in the estimate of contaminated material.

Because some samples did not undergo full-suite COC analysis, there was a potential to underestimate contaminated volumes (i.e., if all COCs had been included, the SOR might have exceeded 1 and would have been included in the estimate). Therefore, an analysis was performed to best infer which samples might have exceeded an SOR of 1 if all COCs had been included. Using spatial analysis, samples that fell within 15 ft (4.6 m) of a sample which had an SOR >1 were assigned a higher probability of failing. If a sample was farther than 15 ft (4.6 m) from a failing sample and had an initial SOR <0.5, it was assigned a low probability of failing. However, based on the observation that radium-226, thorium-230, and thorium-232 could contribute 0.1, 0.2, and 0.2, respectively, to an SOR, samples with a raw SOR >0.5 were also assigned a higher probability of failing (independent of the spatial analysis).

The existing data were also collapsed into a 2-D representation of the site. Where multiple samples were collected at various depths from a single location, the maximum SOR was retained for the volume estimate. USACE ensured a more conservative approach to volume estimating in this manner. Additionally, in order to access deep contamination that might be covered with non-impacted soil, the non-impacted soil would be excavated as well, making it appropriate to include that material in the estimate. This became the amended dataset used in the BAASS analysis.

2.2.1.3 Initial Conceptual Site Model

A BAASS analysis requires developing ICSMs for each area of interest. ICSMs capture the soft information available for a particular area as probabilities of contamination. They present an understanding, absent of sampling data, of where contamination is likely to be found. The contamination probability is captured by a set of grid points overlain on the area of interest - the probability of contamination in an ICSM can and often does vary from grid point to grid point. In the case of the Former Harshaw Chemical Company Site, a 5-ft (1.5-m) grid spacing was used for each area of interest.

Information available at the Former Harshaw Chemical Company Site for constructing ICSMs included a series of historical aerial photographs dating from 1937 through 2002, gamma walkover data for much of the facility, and maps showing the physical locations of buildings/structures associated with processing activities. The historical aerial photographs were particularly valuable for identifying the extent of historical riverbank fill activities. Based on available soft information, individual grid nodes were assigned one of the following contamination probabilities: 0.06, 0.14, 0.25, 0.40, 0.60, or 0.75. In general, the following rules were followed:

- **0.75:** Soil with evidence of relatively heavy contamination (based on gamma walkover surveys) and soil immediately adjacent to facilities known to have significant amounts of contamination present where no gamma walkover data was available to determine the contamination status of surface soil.

- **0.60:** Soil with evidence of a relatively medium amount of contamination (based on gamma walkover surveys) and soil in areas where historical anecdotal reports indicated contamination was present and had been removed.

- **0.40:** Soil with some evidence of contamination present (based on gamma walkover surveys) and soil beneath building footprints where contamination inside the building was known to have existed.

- **0.25:** Soil where historical fill activities took place that may have made use of contaminated material and soil producing slightly elevated gamma walkover survey results suggesting the possibility of contamination impacts.

- **0.14:** Soil in the area of buildings where contamination was present but with no additional evidence of contamination.

- **0.06:** remaining soil within the site boundary not addressed by the higher probabilities discussed above.

The ICSMs for IA03, IA04 North, IA04 South, IA05, and IA07 are shown in Figure 2-2 though Figure 2-6.

2.2.1.4 Bayesian Approaches to Adaptive Spatial Sampling

BAASS requires three additional key parameters: a variogram function, the range for the variogram selected, and a search neighborhood. (A variogram is a graph that characterizes the spatial continuity or roughness of a dataset.) The variogram functional form combined with its range captures beliefs about the spatial autocorrelation present. The search neighborhood determines which sampling locations can contribute to the updating process at any particular grid node. The variogram functional form and range, in conjunction with the spatial pattern of sampled locations, determines how much "weight" each sampled location has in estimating the probability of contamination at a grid node. Bayesian updating is used to merge the ICSM probabilities with those obtained from the indicator kriging. For the Former Harshaw Chemical Company Site, 100 ft (30.5 m) was used for both the radius of the search neighborhood and for the range of the variogram. The functional form of the variogram was set to exponential.

After updating, areas distant from sampled locations generally have contamination probabilities that reflect the ICSM, while areas where sampled locations are dense have probabilities that reflect the results of sampling.

2.2.1.5 ArcGIS

The output from BAASS (ICSM updated with the hard data) was assembled in a geo-referenced tabular form. The data was turned into a point file and projected onto the basemap. Using Spatial Analyst, a tool available within ArcGIS, the data was kriged and the resulting raster was used to generate contours. The contour intervals were displayed to show the range of confidence in the areas assumed to be contaminated. Generally the 90% confidence interval produced well-bounded contours. In two areas, IA04 South and IA07 North, the model did not produce bounded contours at any confidence interval. This was a result of not having sufficient hard data to bind the ICSM. Initially there was a low probability of contamination in each of these areas. Therefore, neither area was carried forward to the next step of volume estimating.

2.2.1.6 Earth Vision 3-D Modeling

ArcGIS generated area contours related to the probability that an area was contaminated. In order to generate a contamination volume, 3-D modeling was conducted using EarthVision. The selected

confidence level contour identified by USACE (80% confidence level) was used as the basis for the initial in-situ soil volume (i.e., prior to excavation) (Figures 2-7 through 2-10). The in-situ soil volume was further modified by incorporating engineering aspects of soil excavation, including safety trenching/benching (where required), and assumed lateral and vertical over-excavation.

Area-specific excavation footprints were developed to include the in-situ soil volume identified previously and to represent conceptual models for soil excavation design plans. The final excavation footprints represented the maximum extent of excavation around each in-situ soil volume. Because the final excavation footprint areas include engineering aspects of the excavation process, the associated areas (and therefore volumes) are larger than the in-situ volumes. During the development of the ex-situ volumes, the following items were noted:

- Excavations around storm sewers were not sloped based on the assumption that trench boxes would be used during excavation;
- A majority of the excavation areas did not require side slopes/benching because the excavation depths were 5 ft (1.5 m) or less;
- Calculated side slopes were based on a 1.5H:1V slope, as defined in the USACE Safety and Health Requirements Manual (Engineer Manual [EM]-385-1-1, September 15, 2008); and
- A 25% swell factor was applied to the soil volume calculations.

The maximum depth of contamination present within each excavation footprint that exceeded the target cleanup objective was determined for each soil sample location within the footprint. If elevated samples were separated vertically by one or more acceptable samples, the deepest elevated sample was used. Because all soil remedial alternatives developed in the FS include the excavation of contaminated soil, the presence of lower concentrations lying above elevated concentrations would not affect the overall excavation volume (i.e., the shallow soil would be excavated to reach the deeper soil regardless of concentrations).

When the maximum depths of contamination were determined for each excavation footprint, these values were used to generate a 3-D surface within EarthVision to represent the simulated bottom of the soil excavation in its entirety. The volume of the specific area was generated by calculating the difference between the bottom excavation surface and a similar land topographic surface developed previously within EarthVision as part of a 3-D geologic model. In addition to the upper and lower excavation surfaces, the volume modeling also considered the presence of features within the 3-D geologic model (such as the bedrock surface) to ensure the in-situ volumes represented realistic estimations based on known site conditions. The final volume resulting from this process represents the best engineering estimate of the ex-situ volume of soil generated during excavation activities for FS remedial alternatives.

2.2.2 General Response Actions

The GRAs are media-specific remedial actions that can potentially satisfy RAOs for site COCs by: (1) mitigating human and environmental exposure; (2) controlling their migration; and/or (3) limiting their extent. Once screened, these general actions become potential components of remedial alternatives for site remediation. The following GRAs are proposed for soil and buildings at the Former Harshaw Chemical Company Site:

- Land-use controls;

- Containment;
- Removal;
- Treatment; and
- Disposal.

2.2.2.1 Land-Use Controls

The primary goal of land-use controls is to limit exposure by restricting access to contaminated media. No remedial actions would be taken that reduce the volume, mobility, or toxicity of the COCs. Land-use controls are legal and administrative mechanisms that manage access to or use of affected property areas or warn of a hazard. Because USACE does not own the property, some of the following land-use controls may be difficult to implement since they will rely on the cooperation of the land owner. Site security measures can be used in conjunction with land-use controls. These measures include the use of fences, berms, and warning signs around a contaminated site to prevent unauthorized access.

Land use controls include both engineering controls and institutional controls. There are four categories of institutional controls:

1. Proprietary controls, which involve placement of restrictions on land through use of easements, covenants, and reversionary interests;

2. Governmental controls on land use, such as permit programs and planning and zoning limits;

3. Enforcement and permit tools with land-use control components, such as Unilateral Administrative Orders (UAOs), Administrative Order of Consent (AOCs), or Consent Decrees (CDs), which may have components that limit certain site activities; and

4. Informational tools, such as state registries of contaminated properties, deed notices, and advisories, which provide information or notification that contamination exists on-site.

The following is USEPA's overall expectation for the use of land-use controls:

> "The use of institutional controls shall not substitute for active response measures (e.g., treatment and/or containment of source material, restoration of ground waters to their beneficial uses) as the sole remedy unless such active measures are determined not to be practical based on the balancing of trade-offs among alternatives that is conducted during the selection of remedy." [40 CFR § 300.430(a)(iii)(D)]

2.2.2.2 Containment

Containment actions can protect human health and the environment by reducing exposure by creating a physical barrier between the contamination and the receptor or mobility of the COCs. However, containment actions do not reduce contaminant volume or toxicity; therefore, containment actions often require other actions, such as land-use controls or monitoring, to ensure the protectiveness of the containment actions.

For soil, containment options include consolidating contaminated soil and capping that area with a low-permeability material (e.g., native soil, clay, concrete, asphalt, or synthetic liner) to reduce infiltration of water. This reduces potential exposure by reducing contaminant mobility. Such containment actions can be accomplished with the construction of an on-site landfill or disposal cell.

For sewers and drains, containment options may include grouting of inactive subsurface lines in order to stabilize them and prevent the transfer of COCs from the line to the surrounding soil. Injection of grout prevents contaminant seepage from inside the sewer or drain through fittings and joints. In addition, grouting can be used in combination with other response actions, such as removal of a section of sewer or drain followed by grouting the remaining section at its terminal end.

Containment actions related to buildings involve surface sealing or covering contaminated surfaces with appropriate sealants to prevent direct contact and to reduce potential mobility. The applicable options for surface sealing include painting, applying resins or liquid plastic, or using other impermeable materials (e.g., plastic sheeting or wooden structures) to provide a containment effect.

2.2.2.3 Removal

Removal of contaminated media from a site reduces or eliminates the potential for human and environmental exposure. Contaminated soil is excavated to reduce the long-term potential for exposure as well as reduce the ability of the soil to contribute contaminants to other site media, such as surface water, sediment, groundwater, or sewers. Similarly, excavation of subsurface sewers and drains removes them as a potential contributor to contaminant exposure or migration.

Removal actions for buildings can include decontamination and/or partial or complete dismantlement. Partial dismantling of the buildings may involve drilling or cutting appropriate portions or sections of buildings, resulting in less material requiring disposal than complete dismantlement, which is often used when an entire building is contaminated.

Removal can be complete (i.e., all media with COCs above PRGs), or partial (i.e., media with the highest concentrations of a COC). Removal is not a stand-alone remedial action; it must be combined with subsequent treatment and/or disposal of the removed media.

2.2.2.4 Treatment

Treatment technology, in accordance with 40 CFR 300.5, means any unit operation or series of unit operations that alters the composition of a hazardous substance or pollutant or contaminant through chemical, biological, or physical means so as to reduce toxicity, mobility, or volume of the contaminated materials being treated. Treatment technologies are an alternative to land disposal of hazardous wastes without treatment.. In-situ treatment can be appropriate as a stand-alone remedial alternative or may serve as one of several components of a remedial alternative. Ex-situ treatment is not a stand-alone response action; removal of the contaminated media is required prior to treatment. Disposal of treatment residuals also may be required.

For soil, physical processes involve physically binding the contaminants to reduce their mobility or the potential for exposure (e.g., encapsulation, thermoplastic solidification, precipitation, solidification/stabilization [S/S], or vitrification) or extracting the contaminants from soil to reduce contaminated soil volumes (e.g., soil washing or electrokinetic separation). Chemical treatment processes add chemicals (in-situ or ex-situ) to react with contaminants to reduce their toxicity or mobility (e.g., chemical oxidation/reduction, chemical soil washing, hydrolysis, neutralization, or stabilization). Biological treatment involves using microbes to degrade or concentrate contaminants (e.g., phytoremediation, composting, or bioslurry). Thermal treatment, such as incineration, uses high temperatures to volatilize, decompose, or melt certain contaminants.

For buildings and other structural material, treatment options include physical and chemical decontamination procedures. Physical procedures include vacuuming, scrubbing, scraping, sanding, grinding, scabbling using pelletized carbon dioxide, or sandblasting. These methods use physical force to mechanically separate contaminants from the surface of the material. Chemical procedures involve the use of chemicals (water, solvents, complexing agents, acids, or bases) to dissolve or suspend the contaminants in the decontamination fluid to facilitate their removal from the surface of the material.

2.2.2.5 Disposal

Disposal actions involve the transportation and permanent placement of waste materials in a manner that protects human health and the environment. Disposal is not a stand-alone response action. It is used in conjunction with other response actions, such as removal or ex-situ treatment, to form a remedial action alternative.

Options for disposal of contaminated soil or bulk waste (e.g., building materials or other structural media) include placement in an on-site engineered repository or off-site permitted waste facility. Transportation is accomplished using a variety of modes; trucks, railcars, or barges move contaminated soil, sediment, or other material to the applicable permanent repository.

2.3 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS (SOIL AND BUILDINGS)

This section describes the technology types and process options available for remediating the media of interest. As discussed in Section 1.2.5, the RI BRA concluded several MED/AEC-related radiological constituents present in soil and building material posed potential unacceptable radiological dose to human receptors. No unacceptable radiological doses were noted in groundwater, surface water, or sediment. Therefore, only the technology types and process options that address radiological contamination in soil (OU-1 and OU-2) and building materials (OU-1) are identified for initial screening (Figure 1-4).

The physical conditions at the site and types and concentrations of COCs were used to determine which technologies could be effectively implemented. Additionally, technical feasibility was evaluated using the following technology reference guides and screening tools:

- Remediation Technologies Screening Matrix (FRTR 2010);
- Technology Screening Guide for Radioactively Contaminated Sites (USEPA 1996);
- Technology Reference Guide for Radioactively Contaminated Media (USEPA 2007);
- Technology Reference Guide for Radiological Contaminated Surfaces (USEPA 2006); and
- D&D of Radiologically Contaminated Facilities (ITRC 2008).

Available literature on remediation technologies and process options was also researched to identify innovative technologies that may potentially be feasible for implementation at the site. The USEPA RI/FS guidance states that remedial technologies may be eliminated during the screening phase on the basis of technical implementability (USEPA 1988).

In accordance with the NCP requirement [40 CFR §300.430(e)(3)(i)], remedial alternatives developed through the FS process shall include measures that reduce the toxicity, mobility, or volume of the contaminant, as appropriate. Although technologies for radiologically contaminated media can effectively reduce the volume or mobility of contaminated material, none of the treatment technologies will change the radioactivity (i.e., carcinogenicity) of the radiological COCs. Over time, the level of radioactivity emitted from the immobilized radionuclides reduces itself through a process of radioactive

decay. Therefore, the main focus for identification and screening of technologies in this FS is to reduce the volume or mobility of the radiological contaminants or reduce exposures to radiological contaminants in the media of concern.

2.3.1 Identification and Screening of Technologies (Soil)

Soil technologies that can be technically implemented at the site are those that can reduce the contaminant mobility and/or the volume of contaminated media or limit human exposures to the COCs. Technologies with unknown or uncertain technical implementability will be eliminated if known cost-effective options are available. Remediation technologies for soil that are technically implementable will be further evaluated in Section 2.3.2 on the basis of practical and administrative implementability, effectiveness, and cost. The following sections describe the identification and screening of the technical implementability of several soil remediation technologies for radiological COCs in soil. A summary of the screening of technologies for soil is presented in Figure 2-11.

2.3.1.1 Land-Use Controls

Land-use controls limit human exposure to COCs by restricting human access to the property and restricting human exposure to contaminants migrating from the site. Control mechanisms can be administrative, legal and/or physical, and may require cooperation among property owners, regulatory authorities, and the authority of local governments for their implementation. Specific characteristics of the site determine which controls are appropriate. However, since USACE does not own the property, some land-use controls may be difficult to implement.

The NCP has outlined criteria to evaluate when the use of land-use controls would be acceptable as a component of a remedial alternative. The NCP [40 CFR §300.430(a)(1)(iii)(D)] states that "institutional controls shall not substitute for active response measures … as the sole remedy unless active measures are determined not be practicable, based on the balancing of trade-offs among alternatives that is conducted during the selection of [the] remedy."

Approved land-use controls will be monitored through the five-year review process. As stated in 40 CFR 300.430(f)(4)(ii), if a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use/unrestricted exposure, the lead agency shall review such action no less often than every five years after initiation of the selected remedial action. The following sections describe the administrative, legal, and physical mechanisms available under land-use controls.

2.3.1.1.1 Administrative and Legal Mechanisms

Four types of administrative and legal controls are:

- Proprietary controls;
- Governmental controls;
- Enforcement and permit tools; and
- Informational tools.

Proprietary Controls

State property law may include mechanisms that permit application of proprietary controls to a site. These controls, which may be used to restrict or affect the use of a property, may include (but are not

limited to) vehicles such as deed notices, easements, site-use restrictions, and restrictive covenants. These mechanisms can be implemented without intervention from Federal, state, or local regulatory authority. These controls are retained for further consideration.

Governmental Controls

Governmental controls are typically established by state or local governments and may include mechanisms such as zoning, local permits, police ordinances, and groundwater use restrictions. These controls are retained for further consideration.

Enforcement and Permit Tools

Administrative orders or CDs available under CERCLA can be used to restrict land use. Enforcement authority can be used to: (1) prohibit a party from specific land use or on-site operations; or (2) require a settling party to place some other form of control on the property. USACE does not have enforcement authority; therefore, these tools are not implementable at the site. If enforcement actions are applied to the site to address non-FUSRAP materials and can be used as a component providing protectiveness for FUSRAP-related materials, these enforcement actions will be acknowledged and included in a Land-Use Control Plan.

Informational Tools

Notification may be provided alerting the public that residual or capped contamination remains on-site. Signage, advisories, and registries of contaminated properties may be used. Signage can be used in addition to physical mechanisms to identify restricted areas and/or indicate prohibited activities.

A deed notice may also be used. A deed notice is a non-enforceable, purely informational document filed in public land records that alerts anyone searching the records to important information about the property.

These controls are retained for further consideration.

2.3.1.1.2 Physical Mechanisms

Physical controls include the use of fences, berms, and security personnel to minimize unauthorized access, minimizing human contact with contaminated media. These controls must remain in place, regardless of changes in property ownership, to implement the remedy. These controls are retained for further consideration.

2.3.1.2 Containment

Containment actions prevent or minimize contaminant migration and eliminate exposure pathways. The contaminated medium is neither chemically nor physically changed, nor are the volumes of contaminated media reduced. Containment technologies considered for the site include capping, cryogenic barriers, and vertical barriers.

2.3.1.2.1 Capping

Capping is a containment technology that utilizes a barrier between the contaminated media and the surface, thereby reducing the exposure of humans and the environment to the COCs. Capping involves

covering the contaminated media with a cap sufficiently thick and impermeable to minimize water infiltration, subsequent migration of contamination to the surface, and windblown contamination (USEPA 1996). The process options screened included caps constructed of native soil, clay, synthetic liner, multi-layered, asphalt, and concrete.

Native soil can be used in areas of low radioactivity to provide an exposure barrier and, in conjunction with surface controls, reduce migration by wind and water erosion. However, material left in place would not allow for unlimited use/unrestricted exposure. Clay caps also are potentially applicable. Synthetic liners or multi-layered caps of different media are less susceptible to cracking, and therefore, are potentially applicable. Asphalt and concrete caps are susceptible to cracking if not properly maintained. Existing building slabs and paved surfaces can be effective in reducing direct human contact and wind and water erosion.

Since capping is technically implementable, it is retained for further consideration.

2.3.1.2.2 Cryogenic Barriers

A cryogenic barrier is an in-situ containment technology that freezes soil to create an ice barrier around a contaminated zone, thus reducing the mobility of contaminants by confining the materials. Cryogenic barriers do not reduce the volume of the contaminated material, and the contaminated media would remain on-site. Cryogenic barriers are often used when the waste mass is too large for practical treatment and where soluble and mobile constituents pose an imminent threat to a drinking water source.

This technology has been fully demonstrated for geotechnical applications at construction sites and at the Oak Ridge National Laboratory (Oak Ridge, Tennessee) in 1998. However the system would be maintained indefinitely, which would result in a higher cost than other, more effective process options. Therefore, cryogenic barriers are not being retained for further consideration.

2.3.1.2.3 Vertical Barriers

A vertical barrier is a containment technology that is installed around an area of contamination to contain source material and minimize or preclude any potential impacts to groundwater and surface water. The use of vertical barriers would depend on the intrinsic soil permeability (i.e., the ease with which water is transported through a mass). Vertical barriers are primarily used as groundwater remedies or to prevent flow of groundwater to a landfill or capped soil area. Soil containment can be achieved by diverting groundwater flow around the contaminated soil or by capturing contaminated groundwater from soil areas. Vertical barriers are typically combined with other treatment options, including covers, in-situ treatment, or groundwater treatment to produce a complete containment system. Vertical barriers are typically used at sites to confine impacted groundwater, but two types of vertical barriers can also be used to contain contaminated soil: slurry walls and grout curtains. Since groundwater is not a medium of concern at the site, vertical barriers are not retained for further consideration regarding impacted groundwater. However, the technology could be considered for any alternatives involving either capping contaminated soil areas or construction of an on-site disposal cell should those technologies be retained.

Slurry walls are subsurface barriers that consist of a vertically excavated trench filled with slurry (generally a mix of bentonite and water or cement, bentonite, and water). Slurry walls are typically installed at depths of <50 ft (15.2 m). Slurry walls are the most common type of vertical barrier due to their low relative cost. The use of slurry walls can be limited by the topography, geology, and the type of contamination at the site. For example, a soil-bentonite slurry will flow unless the site and confining layer are nearly level (Evanko and Dzombak 1997).

Grout curtains are narrow, vertical grout walls installed in the ground by drilling a borehole and pressure-injecting grout directly into the surrounding soil at closely spaced intervals. The spacing is such that each borehole with grout intersects the next and forms a continuous wall or curtain. The grout solidifies and reduces water flow through the contaminated region (USEPA 1996). Grout curtains may be used upgradient of the contaminated soil area to prevent clean groundwater from migrating through waste or downgradient of the contaminated soil area to limit the migration of contaminants. Grout curtains are generally used at shallow depths (30-40 ft [9.1-12.2 m] maximum depth]. This technique is more expensive than slurry walls; therefore, its use is usually limited to sealing voids in bedrock (Evanko and Dzombak 1997).

2.3.1.3 Removal

The process option evaluated for removal was soil excavation. Removal by excavation protects human health and the environment by reducing exposures to the contaminated material from potential receptors. This technology is often a component of remedial alternatives since soil removal typically requires additional measures such as treatment or disposal.

Removal mechanisms are dependent upon the location and volume of material that must be moved. If significant volumes of soil or debris must be moved, and if the areas are easily accessible, a large mechanical excavator may be required. If operating space is limited and/or quantity of material is moderate to small, use of smaller mechanical devices or hand tools may be more desirable. During excavation or removal activities, it is important to control dust and surface runoff to prevent human health and environmental exposures.

In order to reduce the potential for disposal of below-PRG soil, waste minimization practices and technologies (such as sorting by manual radiation scanning, sampling and laboratory analysis, or the use of an automated soil segregation system) will be considered in the FS and are assumed to result in a 50% reduction in excavated soil requiring disposal. A 50% reduction is a conservative assumption based upon actual contaminated volume reduction experienced at other FUSRAP sites.

Removal options are common and implementable. Soil excavation is retained for further consideration.

2.3.1.4 Treatment

Process options evaluated for soil treatment include biological, physical, chemical, and thermal treatment options.

2.3.1.4.1 Biological

Biological treatment is the use of plants and microorganisms, such as bacteria and fungi, to remediate contaminated soil. Bioremediation may include transforming (biotransformation) or degrading (biodegradation) contaminants to nonhazardous or less hazardous forms. Biotransformation is any alteration of the chemical structure of a compound by organisms. Biodegradation is the breaking down of an organic substance by organisms into smaller organic or inorganic components (NABIR 2003). While radioactive contaminants cannot be biodegraded, biological organisms can alter the oxidation state and solubility of those contaminants, thus increasing mobility, which allows for extraction or removal. In other bioremediation strategies, the opposite will occur, and the transformed metal or radionuclide may precipitate out of solution, leading to immobilization (NABIR 2003).

Phytoremediation is a process by which plants uptake soluble contaminants from soil and water and sequester them for later harvesting and disposal in a properly permitted disposal area. It is an emerging, rather than established, technology for remediation but phytoremediation has been shown to be effective for the treatment of radiological contaminants in shallow soil.

Phytoremediation is a process option considered for the site. Phytoremediation does not address the presence of insoluble COCs, such as thorium; thus, other technologies are required in remediation areas containing relatively soluble radionuclides (e.g., uranium) and radionuclides that are insoluble. Plants would remain contaminated, so this technology must be combined with land-use controls or other technologies (off-site disposal) for phytoremediation to be considered a viable alternative.

Phytoremediation is retained for further evaluation.

2.3.1.4.2 Physical/Chemical

Physical process options are those that physically bind the contaminated soil matrix and thereby attenuate or completely retard the mobility of contaminants. These technologies do not change the radiological or chemical properties of the contamination but may help arrest the movement of soluble compounds within the matrix. Chemical treatments may result in a reduction or oxidation process that chemically converts hazardous contaminants to non-hazardous or less toxic compounds or compounds that are more stable, less mobile, and/or inert.

Physical and chemical treatments may be used independently of each other or may be combined into treatment trains. An example is S/S, which treats contaminants by physically binding or enclosing them within a stabilized mass (solidification) or inducing chemical reactions between the stabilizing agent and contaminants to reduce their mobility (stabilization). The following physical/chemical treatment technologies were evaluated for the site:

- Electrokinetic separation;
- Soil washing;
- Flotation;
- Solvent/chemical extraction; and
- S/S.

Electrokinetic Separation

Electrokinetic separation is an in-situ process that separates and extracts heavy metals, radionuclides, and organic contaminants from saturated or unsaturated soil, using a low intensity direct current across electrode pairs that have been implanted in the ground on each side of the contaminated soil mass. Contaminants are desorbed from the soil surface and are transported in ionic form to respective electrodes, depending on their charge. The contaminants may then be extracted to a groundwater well recovery system or deposited at the electrode and removed. The residuals would likely require further treatment and/or disposal.

Electrokinetic separation has been used with varying degrees of success for uranium in moist clays, but removal has been limited for thorium. In the case of thorium, application of the technology tends to cause precipitation of a hydroxide gel which prevents transport to the cathode once it reaches its hydroxide solubility limit. This could result in thorium remaining in soil at concentrations above PRGs. The problems associated with the inability to successfully remediate all radiological COCs using this

technology indicates an uncertain effectiveness; therefore, electrokinetic separation is not retained for further consideration.

Soil Washing

Soil washing is a process in which contaminated soil and debris are mixed with water (with or without surfactants) to create a slurry. The slurry is then fed into a scrubbing machine to remove contaminated fine soil particles (silts and clay) from granular soil particles. This is an ex-situ process; therefore, it must be combined with another removal technology, such as excavation.

Soil washing works best and is the most cost effective on soil that contains a greater fraction of larger-grained soil particles (at least 50% sand and gravel) and <25% silt and clay. The optimal range of soil particle size is from 0.25 millimeters (mm) to 2 mm in diameter (USEPA 1996). Oversized particles may be removed prior to implementing this technology. Undersized particles reduce the performance, as the small particles are very difficult to separate into contaminated and uncontaminated components.

Geotechnical samples indicate contaminated site soil and fill contain significant silt and clay fractions (50% or greater). This precludes the use of soil washing and it is not retained for consideration.

Flotation

Flotation separates radionuclide-contaminated soil fractions (usually fine soil particles such as silt and clay) from the clean soil fractions (large granular soil particles and gravel) via a slurry treated with a flotation agent in order to reduce the volume of soil requiring treatment or disposal (USEPA 1996). This technology is applied as an ex-situ process; therefore, it would be combined with a removal technology, such as excavation.

Implementation of this technology requires extensive knowledge of the site's soil characteristics, including particle size, organic content, and association of radionuclides with particle size, chemical composition, and mineralogical composition. A flotation agent compatible with site soil is important; otherwise, the flotation process is ineffective. This technology has not been demonstrated beyond the bench scale (USEPA 1996).

Since on-site MED impacts are seen in variably textured soil and heterogeneous fill, floatation is not retained for further consideration.

Solvent/Chemical Extraction

Chemical extraction does not destroy the excavated contaminated material but separates the contaminated material from the native soil. This technique would reduce the amount of contaminated waste that would require additional treatment. Solvent extraction is a form of chemical extraction that mixes soil or sediment using an organic solvent to extract the contaminants from the total soil or sediment mass. After the contaminants have been extracted, the solvent is separated from the soil and distilled in an evaporator or stripped of contaminants in a column.

These techniques are all ex-situ processes, and therefore, would need to be combined with another removal technology, such as excavation.

This technology has been used to extract uranium from mineral ores; however, the technology has not been demonstrated to treat contaminated soil. Therefore, solvent/chemical extraction is not retained for further consideration.

Solidification/Stabilization

S/S technologies reduce the mobility of radioactive contaminants through physical and chemical processes. In the solidification process, contaminants are physically bound or enclosed in an impervious matrix. Stabilization involves the addition of a stabilization agent that induces a chemical reaction between the stabilization agent and the contaminants, which results in reduced contaminant mobility. The resulting solid mass resists leaching and minimizes migration.

S/S may be employed as an in-situ or ex-situ treatment technology. In-situ techniques use auger and injector head systems to apply agents to in-situ soil. However, soil having high clay content and heterogenous fill may impede in-situ immobilization. Environmental conditions may also erode materials used to stabilize contaminants. Furthermore, remaining solidified material may restrict future use of the site. Long-term monitoring of the site would be necessary to ensure the contaminants have not re-mobilized. Therefore, in-situ S/S is not retained for further consideration at the site.

Ex-situ S/S techniques involve excavating contaminated soil material and machine-mixing them with the solidifying agent instead of injecting the agent into the materials in place. Ex-situ S/S may facilitate the disposal of waste in an on-site disposal facility or the transportation of waste to an off-site disposal facility because it reduces the mobility of contaminants. Soil with radiological contamination in excess of PRGs is excavated and treated by stabilization, if appropriate, along with solidification materials, such as cement and fly ash, and the treated materials, as well as the residuals, would be disposed of in an appropriate disposal facility (USACE 1998). According to Federal Remediation Technologies Roundtable (FRTR), larger particles, such as coarse gravel or cobbles are undesirable for chemical extraction processes and also may not be suitable for S/S technology (FRTR 2009). As a result, pre-treating soil for S/S (e.g., crushing) may be required to facilitate the treatment process.

Ex-situ S/S process options that may be feasible for implementation at the site include cement S/S and chemical S/S. Cement S/S processes involve the addition of cement or a cement-based mixture to attenuate the solubility or mobility of the contaminated material by generation of a monolithic mass. Cement S/S is best suited for highly porous, coarse-grained, low-level radioactive contamination in permeable matrices (USEPA 1996). Cement S/S has a long history of usage and is easily implemented. Chemical S/S involves adding chemical reagents to the contaminated material to limit the solubility and mobility. Chemical S/S agents include thermoplastic materials (e.g., asphalt bitumen, paraffin, polyethylene), thermosetting polymers (e.g., vinyl ester monomers, urea formaldehyde, epoxy polymers), and other proprietary additives (USEPA 1996). Chemical S/S is better suited for fine-grained soil with small pores (USEPA 1996). For ex-situ S/S, the volume of the treated material will increase due to the addition of stabilization agent. Detailed characterization of the site and waste matrix is required to determine the suitability of each method.

Ex-situ S/S is retained for further consideration.

2.3.1.4.3 Thermal

Thermal treatment uses high temperatures to volatilize, decompose, or melt the contaminants. The thermal treatment technology considered for the site was vitrification. This process can be in-situ or ex-situ and involves applying extreme temperatures to contaminated medium followed by cooling that

then results in a dense glassified mass. Glassification immobilizes radioactive constituents in the solid mass.

Ex-situ and In-situ Vitrification

Ex-situ vitrification involves application of heat, in excess of 1,100°C, to contaminated soil after excavation. Heating devices include plasma torches and electric arc furnaces. The resulting process generates a dense, glassified mass which limits the mobility of radioactive materials from leaching or wind transport and will trap radon within the stabilized soil mass. Volume reductions may range as high as 65% for ex-situ vitrification, depending on the material type. A pre-treatment step may be required to reduce the moisture content of contaminated soil before processing. Small quantities of organic contaminants may be volatilized during vitrification, and afterburners may be required to treat the off-gases. Additionally, ex-situ vitrification would be combined with a removal technology (e.g., excavation) and a disposal option (e.g., capping or off-site disposal). Implementation of this technology is highly dependent on the physical properties of soil (FRTR 2010); therefore, treatability studies would be required.

In-situ vitrification relies on the application of heat >1,600°C to contaminated soil in place. To accomplish glassification, electrodes are inserted into the soil and electric resistance is used to transform it to a molten state. Once the molten material cools and solidifies, the COCs are immobilized in the glassified mass and the mobility of radiologically contaminated soil is reduced. Verification that the process has completely glassified all the contaminated soil may be difficult if the area of contaminated soil to be treated is large. Additionally, the presence of large inclusions (brick, rock, scrap metal, and highly concentrated contaminant layers) in the areas to be treated limits the use of in-situ vitrification (USEPA 1994). In-situ verification would require post-treatment monitoring to determine effectiveness, and land-use controls would be implemented since material would remain on-site.

Full-scale vitrification processes are currently operational at several sites, but vitrification is not widely practiced because potentially higher costs are involved (Yim and Linga 2000). Because of the uncertainty associated with implementing vitrification, higher costs, and the availability of other technology options, ex-situ and in-situ vitrification are not retained for further evaluation.

2.3.1.5 Disposal

Landfill disposal relocates contaminants from one place to another for long-term containment. Landfill disposal is not a treatment to destroy or detoxify contaminants; although, treatment can be applied prior to disposal to reduce the toxicity, mobility, or volume of contaminated media. The options for disposal following excavation of soil at the site are an on-site constructed landfill and use of an off-site disposal facility.

2.3.1.5.1 On-Site Disposal

On-site disposal would require new construction of an engineered disposal facility. An on-site disposal facility can be designed and constructed to contain all excavated material and post-treatment residue to prevent any exposure to the FUSRAP materials and be protective of human health and the environment. However, for this alternative to be implementable the Federal government would have to acquire some or all of the Former Harshaw Chemical Company Site in fee, or a sufficient interest in the property to allow for the creation of a permanent on-site disposal facility. Acquisition of the site or a suitable interest in the parcel to allow the creation and continued maintenance of an on-site permanent disposal facility is possible but may prove difficult in light of the nature and extent of contamination at the site. Any

acquisition of the site or portions of the site to implement this alternative would result in the Federal Government potentially acquiring property with contamination unrelated to the former MED and AEC activities or any other activity of the Federal Government, and the associated liability and responsibility to remediate that contamination. Expenditure of FUSRAP funds to remediate non-FUSRAP related contamination is not authorized by P.L. 106-60. As such, this option is not considered implementable under FUSRAP and is not retained for further consideration.

2.3.1.5.2 Off-Site Disposal

Off-site disposal would utilize commercial or municipal landfills for disposal of waste or affected soil excavated from a contaminated area. The appropriate landfill would depend on the nature of the material for disposal. Properly licensed low-level radioactive waste (LLRW) disposal facilities exist off-site. For hazardous and other regulated waste, a number of permitted Resource Conservation and Recovery Act (RCRA) Subtitle C Disposal Facility landfills are authorized to accept disposal waste that contain low levels of radioactivity. The waste must not be regulated by the NRC or the agreement state and must meet the waste acceptance criteria established by the individual disposal facility permit. For other waste, non-hazardous municipal landfills could be considered. Municipal landfills are allowed to accept waste that is not classified as hazardous under Federal (RCRA) regulations.

Several options exist for the transportation of waste materials to off-site disposal facilities. These options include, but are not limited to, transportation by truck to a properly licensed or permitted disposal site or to a rail transload site.

The option for off-site disposal is retained for further consideration.

2.3.2 Evaluation of Technologies and Selection of Representative Technologies (Soil)

Potential remedial technologies for soil were initially screened based on technical implementability. The remedial technologies that passed this screen are further evaluated using the criteria of effectiveness, implementability (practical and administrative), and cost (three of the NCP balancing criteria). Each process option is rated low, moderate, or high for each of three criteria. For example, an option rated high for effectiveness, high implementability and low or moderate cost will be retained and developed into a remedial alternative (Section 3). A discussion of the results is presented in the following subsections and summarized in Figure 2-12.

Effectiveness includes the consideration of the ability of the alternative to protect human health and the environment by reducing the mobility or volume of contaminants and the ability to meet the RAOs defined for the site. Process options providing significantly less effectiveness than other more promising options are rated low and eliminated from further consideration.

Implementability considers practical issues such as the ability to construct, reliably operate, and monitor the implementation of the remedial action, as well as administrative issues such as the ability to gain acceptance of the alternative. Process options that are technically or administratively infeasible or require equipment, specialists, or facilities that are not available within a reasonable period of time are rated low and eliminated from further consideration.

The cost evaluation presents the estimated costs associated with capital and operating expenses. The average reported or estimated costs of a process option were rated in the following manner:

- **Low:** <150 dollars ($) per cubic yard ($yd^3$);

- **Moderate:** Between \$150 per yd^3 and \$300 per yd^3; and
- **High:** >\$300 per yd^3.

Costs that are grossly excessive compared to the overall effectiveness of alternatives may be used as a factor to exclude the technology from further consideration.

2.3.2.1 Land-Use Controls

Land-use controls are physical, legal, and administrative mechanisms designed to control the exposure of human and ecological receptors to the on-site contaminants. These options are not generally used as the sole remedy, but are integrated into an engineering remedy that does not achieve PRGs for the most likely land use.

Effectiveness

When properly designed and implemented, land-use controls will increase protection of human health and the environment over the baseline (i.e., no action) conditions by restricting entrance to or limiting the use of the site. Land-use controls will not reduce the mobility or volume of site-related contaminants, but the potential for exposure is reduced; therefore, the effectiveness of the action is rated moderate.

Implementability

Land-use controls are readily available, proven methods for addressing risk. Installation of physical controls (e.g., fences, signs) and monitoring pose no significant technical difficulties but do present an on-going maintenance requirement. The materials and services needed to implement land-use controls are readily available. Therefore, land-use controls are rated high for technical implementability.

Given the Federal government does not own the property, some land-use controls may be administratively difficult to implement. Implementation of land-use controls will require involvement of the local government and land owners. There could be difficulties implementing land-use controls due to multiple land owners. One type of land-use control is a restrictive covenant. Restrictive covenants require the consent of the owner of the property to which a restrictive covenant is applied. USACE has not secured property owner approval or authorization to acquire such interests in the property to establish appropriate land-use controls. USACE will need to secure these agreements prior to the approval of the ROD to establish the types of land-use controls that will be implemented at each property and to identify the parties responsible for securing, maintaining, and enforcing the controls. Uncertainties concerning whether the landowners are willing to accept and comply with the terms of these agreements make the use of land-use controls potentially difficult to implement. Therefore, land-use controls are rated low for administrative implementability.

The overall implementability rating is based on the lower of the technical and administrative implementability ratings. Therefore, the overall implementability of land-use controls is rated low, based on the low administrative implementability.

Cost

The costs incurred for land-use controls include the administrative cost of setting up the land-use controls, as well as the cost of maintaining and monitoring the controls. The costs also may include material costs if signage or fencing is installed. Costs for land-use controls may be found in Appendix C if this FS Report.

The relative costs of land-use controls are moderate.

Summary of Evaluation

The effectiveness and cost of land-use controls are rated moderate. The implementability is rated low. Land-use controls have been retained for further consideration.

2.3.2.2 Containment - Capping

Capping is a containment technology that provides a barrier between the contaminated material and the potential receptors, resulting in reduced exposures. In addition, capping reduces the mobility of the contaminants.

Effectiveness

Capping does not reduce the volume of the contaminated media. However, capping does reduce exposures by physically separating the contaminated materials from any potential receptors. Capping also may reduce the mobility of contaminants because it would reduce rainwater infiltration and vertical contaminant transport if properly maintained. However, horizontal migration is not limited unless the technology is combined with surrounding vertical barriers. The cap, with regular maintenance, would eliminate the potential for direct contact (absorption, ingestion, or inhalation) and minimize potential exposure to external gamma radiation and radon gas.

The effectiveness of capping is rated high.

Implementability

Capping is a proven technology that is relatively easy to physically implement. Materials and equipment are readily available for cap construction, although weather, topography, and subsurface conditions may affect the ease of implementation. No off-site activity is required to treat, store, or otherwise manage the contaminated material because the technology is in-situ. Installation of a gas collection and treatment system may be an option for managing radon emissions, although a properly designed cap will retard transport to the point that radon emissions are essentially eliminated.

The focus of a capping alternative at the site would be to contain any contaminated areas on-site to prevent exposure and minimize infiltration. Consolidation of contaminated soil from the site would need to occur prior to capping. Sections 3734.027 and 3748.10 of the Ohio Revised Code contain exemptions that may allow for on-site disposal. However, an on-site engineered facility would be difficult to implement due to the site requirements set forth in OAC 3745-29-07 for Solid Waste Landfills or OAC 3745-50-38 for a RCRA Subtitle C facility, as both prohibit siting a landfill in a flood hazard area. Portions of the site are located within the 100-year floodplain, and the entire site is adjacent to the Cuyahoga River and Big Creek. Therefore, the implementability of capping is rated low.

Cost

Landfill caps are generally the least expensive way to manage the human health and ecological risks effectively. Rough industry costs are $175,000/acre for RCRA Subtitle D and $225,000/acre for RCRA Subtitle C. The cost is rated moderate.

Summary of Evaluation

The effectiveness of the cap is rated high since the technology reduces the mobility and exposure to contaminated soil. The implementability of capping is rated low due to the difficulty of siting requirements and gaining acceptance from the regulatory agencies, site owner and the community. The cost is rated moderate. As discussed in Section 2.3.1.5.1, on-site disposal is not considered implementable and is not considered for further evaluation. Based on that decision, capping is not retained for further consideration.

2.3.2.3 Removal - Soil Excavation

Removal technologies protect human health and the environment by physically separating the contaminated media from potential receptors. The removal process option retained for further evaluation is soil excavation.

Effectiveness

Soil removal increases protection of human health and the environment over previously outlined technologies, thus reducing future potential exposures. During implementation, there is possible short-term risk from fugitive dust emissions, which would be readily managed by implementing a health and safety plan and an environmental protection plan. Although air quality could be adversely affected by the release of particulates, mitigation measures, such as dust suppression methods and use of proper safety procedures and equipment, would be implemented to minimize any increased risk to on-site workers during remedial activities. Short-term risks, including occupational injuries and a risk of fatalities, increase as the volume of soil being handled increases. Excavation is more effective when used with characterization activities to identify excavation boundaries, which limit under-excavation and over-excavation of soil.

Removing contaminated soil reduces the mobility and exposures of radiological contaminants to humans and the environment at the site; therefore, the effectiveness of soil excavation is rated high.

Implementability

Soil excavation uses readily available resources and conventional earth-moving equipment. Construction of temporary roads and a staging area for loading and unloading, soil erosion control, excavation dewatering, water treatment, dust control, and additional clearing and grubbing may be necessary. Administrative coordination between remediation activities and the current tenant's operations are necessary. Transportation and disposal are technologies that are generally combined with excavation.

The implementability of soil excavation is rated high.

Cost

Costs related to soil excavation are estimated at \$20 per yd^3 to \$70 per yd^3. Costs for removal include the following:

- Equipment;
- Staging;
- Waste minimization techniques and practices;
- Stockpiling;

- Backfilling (overburden, cutback soil, or non-regulated soil passing dry soil sorter); and
- Labor.

The cost of soil excavation is rated low, as it is <$150 per yd^3; however, excavation must be combined with treatment or disposal and those costs may be high. Additional costs associated with treatment and/or disposal are discussed in the subsections below.

Summary of Evaluation

The effectiveness of soil excavation is rated high given that removal of contaminated soil will reduce the mobility of contaminants to the environment and exposures to humans at the site. The implementability of soil excavation is rated high, as the technology uses readily available resources and conventional equipment. The cost of soil excavation is rated low, as it is <$150 per yd^3.

Soil excavation is retained for further consideration.

2.3.2.4 Treatment - Biological

When it can be implemented using in-situ methods, phytoremediation is generally favored over conventional technologies (soil excavation) due to the reduced impacts to the environment. However, at the Former Harshaw Chemical Company Site, treatment using ex-situ phytoremediation would be required because the majority of the contaminated soil is found at depths >2 ft (0.6 m) bgs. Implementation of this process would require contaminated soil to be excavated and relocated to a temporary on-site treatment area. Phytoremediation would be implemented through phytoextraction where radionuclides would be absorbed by plant roots, with subsequent accumulation in the aboveground portions of the plant. Plants would be harvested and then disposed of as radioactive waste. After treatment, the soil could be re-used as backfill on-site.

Effectiveness

There are several possible uses for phytoremediation of radionuclides, but most applications to date have been at the bench or pilot scale (NABIR 1999). Phytoremediation is most appropriate for large areas of relatively thin surface layers of contaminated soil within the root depth of the selected plant. Because phytoextraction occurs in the root zone of plants, remediation of contaminated soil has been shown to be limited to the top 15 cm (USEPA 2001). Deeper soil contamination, high contaminant concentrations, or small soil volumes might be more effectively treated using conventional technologies (USEPA 2001).

As a general rule, readily bioavailable metals for plant uptake include cadmium, nickel, zinc, arsenic, selenium, and copper, while lead, chromium, and uranium are not very bioavailable (Schnoor 1997). Research on phytoremediation methods for heavy metals has focused on identifying plants that uptake a metal from metal-rich soil at a higher degree than other plants. These plants are considered hyperaccumulators. Some hyperaccumulator plants have shown the ability to accumulate other metals (if present) while others will take up only a specific metal (USEPA 2001). Ebbs et al. (2001) states that hyperaccumulators are absent for radionuclides. Radium-226 was shown to be phytoextracted using corn, dwarf sunflower, and tall fescue grass, but the percent removal per year was estimated to be very low (USEPA 2001).

Other recent research has focused on increasing the bioavailability of heavy metals (including radionuclides) to plant biouptake. The effectiveness of phytoextraction is limited by the sorption of heavy metals to soil particles and the low solubility of the metals. However, it has been shown that heavy

metals can be solubilized by the addition of chelating agents to allow for plant uptake (USEPA 2001). Uranium has been shown to be greatly more bioavailable by the addition of citric acid to the soil. Uranium concentrations in soil ranging from 280 to 750 milligrams per kilograms (mg/kg) of total uranium were shown to be effectively phytoextracted when soil is treated or amended with citric acid (USEPA 2001). Huang et al. (1998) observed that organic acids increased uranium accumulation in plant shoots more than 1,000-fold. Uranium concentration in Indian mustard (*Brassica juncea)* increased from 5 mg/kg to more than 5,000 mg/kg in treated soil. The use of soil amendments may also increase contaminant mobility which may leach to groundwater, although it has been shown that citric acid has a rapid degradation in soil (Ebbs et al. 2001). Research regarding the use of soil amendments for biouptake of thorium or radium - other COCs at the site - is very limited.

Although studies indicate that use of soil amendments do effectively reduce the mobility and volume of uranium contaminated soil, the technology would require a pilot demonstration using site soil. Greenhouse or pilot field studies of selected plants would be needed to determine the ability of candidate plant species to survive in the contaminated environment. According to Schnoor (1997), for phytoextraction to be effective, one needs vigorously growing plants (>3 tons dry matter per acre-yr), an easily harvestable aboveground portion, and a plant that accumulates large amounts of metals (~1,000 mg/kg) in aboveground biomass. To achieve cleanup within three to five years, the plant must accumulate about ten times the level in soil (e.g., if the level in soil is 500 mg/kg, the concentration in the plant must be almost 5,000 mg/kg to cleanup the soil in a few years).

The effectiveness of using phytoremediation for the Former Harshaw Chemical Company Site has been shown in some studies for uranium-contaminated soil, but the potential effectiveness in treating other radionuclides (thorium and radium) is unknown. Additionally, the presence of other metals in soil at the site may impact the ability for plants to grow in site soil. Studies have shown that plant growth in soil contaminated with 10,000 mg/kg of nickel impeded plant growth (USEPA 2001). For these reasons, the effectiveness of using phytoremediation is rated low.

Implementability

For phytoremediation to be effective at the site, contaminated soil would be excavated and staged at an on-site treatment area. Growing plants at the site would likely be easy with a minimal amount of maintenance (i.e., irrigation and fertilizing). The planting and harvesting of plants may be repeated to bring soil contaminant levels down to allowable limits. Replanting may also be required due to drought, disease, insects, or animals killing off plants (ITRC 1999).

A longer time period (10-20 years) for phytoremediation is likely required, as this technology is dependent on plant growth rates (USEPA 2001). More recently, research has focused on the use of soil amendments and how multiple harvesting periods per season can reduce remediation efforts (USEPA 2001).

Qualified vendors and equipment are available to perform this treatment option, and the land needed to construct an on-site phytoremediation treatment plot is available. Phytoremediation is also likely to be more acceptable to the local community than other treatment options because it is perceived as an environmentally friendly, low-technology alternative (USEPA 2001). The implementability is rated high.

Cost

Many phytoremediation technologies are still in the field-demonstration stage; therefore, cost data for full-scale implementation of phytoremediation are sparse (USEPA 2001). Phytoremediation costs would

include preliminary treatability studies to select the proper plant and to assess its effectiveness; soil preparation; planting; maintenance such as irrigation and fertilization; monitoring, which may include plant nutrient status, plant contaminant concentrations, as well as soil concentrations; and disposal of contaminated biomass. Based on available cost data for implementing phytoremediation at sites of varying size and complexity, the costs range from $112 to $1,775 per yd^3 of soil (FRTR 2009). Costs are rated high.

Summary of Evaluation

Phytoremediation is not retained based on its low effectiveness and high cost compared to other treatment options that provide greater demonstrated effectiveness and lower cost.

2.3.2.5 Treatment - Physical/Chemical

S/S is the only physical/chemical treatment technology/process option retained for further consideration after the initial screening.

2.3.2.5.1 Solidification/Stabilization

S/S technologies reduce the mobility of radioactive contaminants and metals through physical and chemical processes. In the solidification process, contaminants are physically bound or enclosed in an impervious matrix. Stabilization involves the addition of a stabilization agent that induces a chemical reaction between the stabilization agent and the contaminants, which results in reduced contaminant mobility.

Effectiveness

S/S does not reduce the volume of contaminants; however, the technology has been proven to greatly reduce the mobility of the contaminants, thus protecting human health and the environment by reducing the exposure. The volume of treated material will increase due to the addition of stabilization agent. The increase in volume depends on the amount of stabilization agent required to effect stabilization.

The effectiveness of S/S is rated moderate even though S/S is a proven technology because it does result in an overall increase in volume of contaminated that must be dispositioned.

Implementability

S/S is well demonstrated and easy to implement, as conventional materials and widely available equipment are used in the process. Metals and all classes of radioactive contamination are treatable by this technology. Detailed characterization of the site and treated material matrix would be required to determine the suitability.

The implementability of S/S is rated high.

Cost

Costs can vary based on specific soil conditions, contaminants, and availability of solidification agents. In addition, ex-situ costs for transportation and off-site disposal of the solidified material factor into the overall cost. Low costs may reflect in-situ mixing techniques and high costs may reflect in-drum mixing techniques.

For ex-situ S/S processes, overall costs are $230 per yd^3. Based on this cost estimate, the cost is rated moderate.

Summary of Evaluation

The effectiveness of S/S is rated moderate. The implementability is rated high because the technology is well demonstrated and uses conventional materials and widely available equipment in the process. The cost is rated moderate. Therefore, S/S is retained for further evaluation.

2.3.2.6 Off-Site Disposal

Contaminated soil that is excavated at the site and defined as regulated waste must be disposed of at a properly permitted landfill. Disposal in an off-site landfill would reduce mobility and exposures to radiologically contaminated soil at the site. After soil is excavated and treatment is implemented, sampling and analysis of soil is conducted to develop a waste profile to confirm that the waste achieves applicable Waste Acceptance Criteria (WAC) before disposal. In addition, any off-site transfer of any CERCLA hazardous substance, pollutant, or contaminant will require notification to the appropriate USEPA Off-site Coordinator to determine the acceptability of any selected disposal facility prior to any wastes leaving the site in accordance with 40 CFR 300.440.

Excavated soil requiring off-site disposal could consist of:

- Soil containing RCRA hazardous waste for disposal at a RCRA facility.
- Soil containing RCRA hazardous waste commingled with residual radioactive material consisting of <0.05% source material by weight and with total activity complying with disposal site WAC for disposal at a RCRA facility.
- Soil containing RCRA hazardous waste and source material exceeding 0.05% by weight or total activity in excess of RCRA disposal site WAC for disposal at a facility authorized to dispose of mixed, low-level waste.
- Soil containing residual radioactive material with >0.05% source material by weight or total activity exceeding RCRA disposal site WAC for disposal at an LLRW facility.
- Soil with radioactivity at levels compliant with WAC for a Subtitle D disposal facility.

Soil must be appropriately disposed of at a properly permitted disposal facility. Soil that exhibits RCRA-hazardous characteristics (e.g., toxicity characteristic leaching procedure) must be appropriately treated and disposed of in a properly permitted facility. Similarly, radiologically contaminated materials must be disposed of in a properly permitted RCRA facility or licensed, LLRW or low-level mixed waste facility, consistent with regulations and applicable WAC. Subtitle C landfill facilities are commonly permitted to accept both RCRA and Toxic Substances Control Act (TSCA) hazardous waste, along with material that meets the acceptance criteria of 10 CFR 40.13(a). Based on review of RI soil characterization data, RCRA wastes are not currently anticipated, but confirmatory evaluations will be performed as an integral part of remedial actions. Subtitle C disposal requirements commonly limit total activity of naturally-occurring constituents to a maximum of 2,000 pCi/g. In addition, source materials (i.e., uranium and thorium) are limited to a maximum of 0.05% by weight (i.e., to about 54.5 and 165 pCi/g for thorium-232 and uranium-238, respectively). The stated limits apply to both

volumetrically-contaminated media (e.g., soil) and to surficially-contaminated materials and are applied as a limit on the average concentration per unit mass as averaged over a conveyance or package. As such, based on a review of RI characterization data, it is reasonable to conclude that a high percentage (e.g., >60%) of the soil could be segregated fairly easily for disposal in a Subtitle C facility. Subject to monitoring considerations, uranium and radium are detectable with field radiation measurement instruments such that segregation should generally be implementable.

Because application for alternative disposal pursuant to 10 CFR 20.2002 is not available to USACE, radiological solid waste that exceeds Subtitle C waste acceptance requirements and/or does not meet the definition of an unimportant quantity of source material in 10 CFR 40.13(a) will require disposal in a LLRW facility or equivalent. The Low-Level Radioactive Waste Policy of 1980 (P.L. 96-573) defined LLRW as radioactive material that is not high-level radioactive waste, spent nuclear fuel, or byproduct material and radioactive material that the NRC classifies as LLRW consistent with existing law.

Non-hazardous solid waste (RCRA Subtitle D landfill) includes regular construction and demolition (C&D) wastes that would be recycled or disposed of at a Subtitle D landfill.

Waste generated as a result of a remedial action would be transported to the off-site disposal facility in trucks, railcars, or intermodal containers that can be transported by truck or rail. The transport of wastes to an off-site disposal facility would comply with Department of Transportation (DOT) regulations and directives as well as other applicable Federal regulations. Specific requirements would include waste profiling and a comparison of waste profiles to WAC to determine acceptability of waste at a given facility. Additionally, requirements for manifesting, packaging, marking, and labeling waste packages; placarding transport vehicles; choosing appropriate waste transporters and shipment destinations; and recordkeeping and reporting would be required.

Off-site disposal at a properly permitted disposal facility is retained for further consideration for contaminated soil that is excavated at the site.

Effectiveness

No reduction in the volume of contaminated material is achieved by this option, but future risk to on-site receptors is reduced by removing the contaminated material from the site; risk is transferred to the off-site facility that is regulated and located and designed to manage the associated risk. The effectiveness of off-site disposal is rated high.

Implementability

The United States has properly licensed or permitted disposal facilities that can accept waste from the site. Currently licensed facilities include sites in Clive, Utah and Andrews, Texas, with the latter site being allowed to receive wastes once the facility is fully operational. The volume of radiological soil that requires disposal is not prohibitive for acceptance at these facilities. Facilities also exist for the Subtitle C soil from the site. In addition, regulated or licensed transporters are available to handle the waste. This is a common remedial action on many FUSRAP sites and is readily implementable by USACE. The implementability is rated high.

Cost

The quantity of material for disposal is a major factor that influences the cost. For large volumes of material, it may be desirable to reduce the volume through other treatments prior to disposal. Costs also

depend on the distance the waste must be transported to the disposal facility. Cost estimates for off-site disposal are estimated at $650 per yd^3 for LLRW, excluding transportation to a disposal facility. Overall, the costs associated with off-site disposal are rated high.

Summary of Evaluation

The effectiveness of off-site disposal is rated high, as future exposure to on-site receptors is reduced by removing the contaminated material from the site. The implementability is rated high, as both licensed/permitted disposal facilities and approved transporters exist in the United States. The cost is rated high at $650 per yd^3, excluding transportation costs. Off-site disposal is retained for further consideration.

2.3.3 Identification and Screening of Technologies (Buildings)

Technologies for remediation of contaminated buildings (materials) that can be technically implemented at the site are those that can reduce the contaminant mobility and/or the volume of contaminated media or limit human exposures to the COCs. Technologies with unknown or uncertain technical implementability will be eliminated if cost-effective options are available. Those remediation technologies for buildings that are technically implementable will be further evaluated on the basis of practical and administrative implementability, effectiveness, and cost (Section 2.3.4). The following sections describe the identification and screening of the technical implementability of several soil remediation technologies for radiological COCs on building materials. A summary of the screening of technologies for buildings is presented in Figure 2-13.

2.3.3.1 Land-Use Controls

Land-use controls are classified as a limited-action response and are non-engineering measures designed to limit exposure to hazardous substances remaining in place. 40 CFR §300.430 states that land-use controls should not be used as the sole remedy. Land-use controls were retained for further evaluation of their practicality as compared to action-based remedies and as a supplemental component to any other remedy selected if residual contaminant concentrations for building materials do not meet PRGs.

2.3.3.2 Containment

Containment as a remediation technology for building materials involves applying a sealant or sheeting to the building surface to reduce mobility and prevent direct contact with contaminants. Containment technologies require additional preparation methods for applying sealant or sheeting such as high pressure washing or vacuuming that ultimately serve as physical treatment (decontamination) methods. Additionally, containment requires ongoing maintenance to ensure building surfaces are not exposed as a result of peeling of the sealant due to wear.

Containment is most feasible for cases where controlled reuse of a facility is proposed or for interior surfaces where environmental wear is significantly reduced. Radiological contamination at OU-1 buildings exists on the exteriors of the buildings which would be exposed to the weather, and since other effective options exist, containment technologies were not retained for further consideration.

2.3.3.3 Treatment

Treatment technologies for buildings include chemical and physical decontamination. Chemical decontamination is a technology that uses chemical agents to transform and remove contamination.

Physical decontamination involves the removal of contamination from the building materials by surface cleaning or removal. During surface cleaning, the surface remains intact; however, contamination on the surface is mechanically dislodged. During surface removal, the contamination is removed along with a layer of the building surface.

Remedial technologies and process options are evaluated during the screening phase on the basis of technical implementability (USEPA 1988). The location and type of building materials requiring remediation were used to determine which technologies could be effectively implemented. Technical feasibility was evaluated using the following technology reference guides and screening tools:

- Remediation Technologies Screening Matrix (FRTR 2010);
- Technology Reference Guide for Radiological Contaminated Surfaces (USEPA 2006);
- D&D of Radiologically Contaminated Facilities (ITRC 2008); and
- Available literature on potential innovative technologies that may be feasible for implementation at the site.

Remedial technologies may be eliminated during the screening phase on the basis of technical implementability (USEPA 1988). Technologies that are best suited for the materials and locations are presented here for further evaluation. Chemical decontamination methods are effective on steel surfaces but are limited on porous surfaces such as concrete (ITRC 2008). Chemical decontamination also generates liquid waste streams that require treatment and may generate secondary waste streams. Treatment of the secondary waste streams may significantly increase cost (USEPA 2006). Therefore, chemical decontamination is not retained for further consideration.

The following physical decontamination process options were evaluated for the site:

- Surface cleaning:
  - Brushing;
  - Wiping;
  - Flushing;
  - Vacuuming; and
  - Strippable coatings and gels.
- Surface removal:
  - Blasting; and
  - Scarification.

All surface cleaning techniques evaluated were found to be acceptable; however, only vacuuming is retained for further consideration as the primary means of removing loose building surface contamination due to its ease of use and minimal impact to the environment. Surface cleaning would be combined with a surface removal option to address fixed contamination, where present.

Blasting techniques include high pressure water, dry ice blasting, grit (sand) blasting, and soft media blast cleaning. High pressure water is the only blasting surface removal process option retained for further consideration, as other blasting techniques have undesirable side effects such as escaped shot, significant airborne contamination, or inability to penetrate to deeper contaminated areas. All scarifying removal techniques (grinding, scabbling, and spalling) are retained for further evaluation.

2.3.3.4 Dismantlement

Radiological contamination on building materials can be remediated by dismantlement using conventional methods, such as an excavator with a grappler attachment to remove entire buildings or by removing portions of a building. Dismantlement protects human health and the environment by reducing exposures to the contaminated building material from potential receptors. Dismantlement may be necessary in some cases to access other contaminated media associated with a building, including contaminated soil beneath a foundation. Dust control measures are required to prevent exposures to COCs in the material. Dismantlement is a well proven technology and is retained for further consideration.

2.3.3.5 Disposal

Disposal options for radiologically contaminated building materials are similar to the disposal options for radiologically contaminated soil, as discussed in Section 2.3.1.5. On-site disposal would require new construction of an engineered landfill. An on-site disposal facility can be designed and constructed using state-of-the-art technology to contain all excavated materials and post-treatment residuals. Currently, the Former Harshaw Chemical Company Site is not owned by the USACE; therefore, USACE would need to purchase the property in order to construct an on-site disposal facility for this option to be considered implementable. Purchase of the property would also buy all liabilities associated with all other non-FUSRAP contamination issues located at the Former Harshaw Chemical Company Site, or other unknown liabilities. This additional liability for the Federal government would be beyond that being addressed by FUSRAP and associated funding. FUSRAP funding is to be used to clean up contaminated sites throughout the United States where work was performed as part of the Nation's early atomic energy program. Additional authorization and appropriations separate from FUSRAP might be necessary to address other non-FUSRAP environmental liabilities should the property be purchased. Considering that the purchase of the Former Harshaw Chemical Company Site would increase the overall environmental liabilities for the Federal government which is contrary to Corps policy and that there is uncertainty regarding if and where additional authorization and funding would be available to address these non-FUSRAP contaminants, this option is not considered implementable. Therefore, on-site disposal is not retained for further evaluation. Off-site disposal would utilize commercial or municipal landfills. As indicated in Section 2.3.1.5, only off-site disposal is retained for further consideration.

2.3.4 Evaluation of Technologies and Selection of Representative Technologies (Buildings)

The remedial technologies and process options for building materials that pass the initial screen are further evaluated in this section based on the following criteria:

- Effectiveness;
- Implementability; and
- Cost.

Each technology or process option is rated as low, moderate, or high for each criteria. Effectiveness and implementability are defined in Section 2.3.2. The cost criteria are defined below. A discussion of the results is presented in the following subsections and summarized in Figure 2-14. Technologies and process options that are retained based on these criteria are used to develop the remedial action alternatives presented in Section 3.

The cost evaluation presents the estimated costs associated with capital and operating expenses. The average reported or estimated costs of a process option are rated as follows:

- **Low:** <$10.00 per square foot ($ft^2$);
- **Moderate:** Between $10.00 per ft^2 and $20.00 per ft^2; and
- **High:** >$20.00 per ft^2.

These ranges of costs were based on the high and low costs presented in the Technology Reference Guide for Radiologically Contaminated Surfaces (USEPA 2006). Costs are also compared relative to the overall cost of O&M on a per-year basis. Costs that are grossly excessive compared to the overall effectiveness of alternatives are rated high and may be used as a factor to exclude the technology from further consideration.

2.3.4.1 Land-Use Controls

As described in Section 2.3.2.1, land-use controls are physical, legal, and administrative mechanisms designed to control the exposure of human and ecological receptors to the on-site contaminants. 40 CFR §300.430 states that land-use controls should not be used as the sole remedy. However, land-use controls can be integrated into an engineering remedy that does not achieve PRGs.

Effectiveness

Land-use controls would increase protectiveness over baseline conditions (no action) by limiting direct access to contaminated buildings or building materials. In addition, land-use controls would limit activities and future uses of the buildings if PRGs are not achieved. The use of land-use controls would not reduce the mobility or volume of site-related contaminants; however, the potential for exposure over the long term would be reduced. Therefore, the effectiveness of land-use controls is rated moderate.

Implementability

Land-use controls are readily available and proven methods for addressing risk. Installation of physical controls (e.g., fences, signs) and monitoring pose no significant technical difficulties. The materials and services needed to implement land-use controls are readily available. Therefore, land-use controls are rated high for technical implementability.

Because USACE does not own the property, some of the land-use controls may be administratively difficult to implement. Implementation of land-use controls would require involvement of the local government and land owners. There could be difficulties implementing land-use controls due to multiple land owners. One type of land-use control is a restrictive covenant. Restrictive covenants require the consent of the owner of each property to which a restrictive covenant is applied. USACE has not secured property owner approval or authorization to acquire such interests in the property to establish appropriate land-use controls. USACE may need to secure these agreements prior to the approval of the ROD in order to establish the types of land-use controls that will be implemented at each property and to identify the parties that will be responsible for securing, maintaining, and enforcing the controls. Uncertainties concerning whether the landowners would be willing to accept and comply with the terms of these agreements make the use of land-use controls difficult to implement administratively. Therefore, land-use controls are rated low for administrative implementability.

To be conservative, the overall implementability rating is based on the lower of the technical and administrative implementability ratings. Therefore, the overall implementability of land-use controls is rated low, based on the low administrative implementability.

Cost

The relative cost of land-use controls includes the administrative cost for establishing land-use controls and materials and long-term maintenance costs for signage, fencing, or any other security measures. Costs for land-use controls may be found in Appendix C if this FS Report.

The relative costs of land-use controls are moderate.

Summary of Evaluation

The effectiveness and cost are rated moderate. The implementability is rated low. Land-use controls have been retained for further consideration for building materials.

2.3.4.2 Treatment - Physical Decontamination

All surface cleaning techniques were found to be acceptable; however, only vacuuming was retained as a surface cleaning process option, and all scarifying options were retained for further consideration.

2.3.4.2.1 Surface Cleaning - Vacuuming

High Efficiency Particulate Air (HEPA) vacuuming can be used to remove large amounts of loose dust and debris from surfaces. This method is only practical in areas containing large amounts of dust and debris. HEPA vacuuming only removes loose contamination; therefore, any fixed contamination on surfaces will remain after vacuuming. Typically, this technique is an initial step for decontamination and is followed by more aggressive treatment techniques or building removal.

Effectiveness

Removable contamination (e.g., dust) can be relatively easily removed from many solid (smooth) surfaces. Vacuuming removable contamination protects human health and the environment by reducing the mobility and potentially the volume of contaminated building materials. Therefore, the effectiveness of vacuuming is rated high.

Implementability

Vacuums capable of generating the required system performance are commercially available and require minimal training. The implementability of vacuuming is rated high.

Cost

The cost for vacuuming is estimated at \$2.00 per ft^2 (USEPA 2006) and is considered to be low.

Summary of Evaluation

Vacuuming is effective for removable contamination, easily implemented, and low in cost. For these reasons, decontamination by vacuuming is retained for further consideration.

2.3.4.2.2 Blasting - High-Pressure Water

High-pressure water may be employed to remove contamination from concrete or metal surfaces. Flushing building surfaces with water causes soluble contaminants to be dissolved and unbound particulates to be dislodged. The high-pressure water systems also capture the resulting water and debris and filter the mixture to separate the water from leftover sludge for analysis and treatment or disposal. The filtered water can also be recycled prior to final treatment to reduce both water consumption and the total waste volume (DOE 1994). High-pressure water systems also significantly reduce the potential for airborne contamination that may be encountered using dry decontamination methods and minimize exposure by collecting any floor or wall contamination as it is removed.

Effectiveness

High-pressure water can be used on multiple surfaces including concrete, brick, tile, and metal. High-pressure water is effective on both porous and non-porous materials. Although the contaminant source would be removed from most surfaces, decontamination may not be completely effective on some surfaces. Consequently, some surfaces would be re-evaluated for risk, and further decontamination or replacement solutions may be implemented.

This technique has been used successfully for surface decontamination at many radiologically-contaminated buildings. The effectiveness of high-pressure water decontamination is rated high because the removal of contaminated material or residuals from the structure reduces or eliminates radiation exposure, enables the re-use of structures or equipment, and reduces the amount of material (e.g., equipment, construction, and related debris) requiring further treatment or disposal.

Implementability

High-pressure water methods are implementable. Using high-pressure water for decontamination of buildings and structures requires specialized equipment and trained personnel, which are commercially available. Monitoring would be conducted during implementation to ensure protection of remedial workers. The implementability of high-pressure water is rated high.

Cost

High-pressure water cleaning systems are a primary technology for physical decontamination and are rated low cost at approximately \$3.63 per ft^2 (USEPA 2006). Decontamination and any potential restoration costs are also low in capital and O&M costs compared to similar techniques.

Summary of Evaluation

The effectiveness of this treatment method is rated high because the treatment reduces or eliminates unacceptable risk or radiological dose to the potential receptors. This technique requires specialized equipment and trained personnel, which are commercially available. Therefore, the implementability of high-pressure water is rated high. The cost of high-pressure water is rated low since costs were below \$10 per ft^2. Therefore, high-pressure water is retained for further consideration.

2.3.4.2.3 Scarification - Grinding, Scabbling, and Spalling

Scarification techniques include grinding, scabbling, and spalling. Grinding uses a diamond-grinding wheel to strip concrete or coated surfaces. The grinder removes 1.5 to 3 mm of a surface, leaving it

smooth. This technique is a dry decontamination method; therefore, no water or chemicals are required. The waste stream produced is only the stripped surface debris. A dust collection shroud is attached to a vacuum hose of a HEPA filtration system to control dust and debris.

Scabbling is another scarification process used to remove concrete or coating surfaces. Scabbling tools typically incorporate several pneumatically operated piston heads striking (chipping) a concrete or coating surface. Vacuum attachments and shrouding configurations are incorporated so that scabbling may be done while providing for high efficiency control of dust and debris with no detectable increase in airborne concentrations. This technique is a dry decontamination method; no water, chemicals, or abrasives are required. The waste stream produced is only the removed debris. Scabblers are best suited for removing thin layers (up to 12.7 mm) of contaminated concrete (including concrete block) and cement. Hand scabbling equipment can be used for localized spots of contamination or around tight spaces (e.g., corners, pipe penetrations). Floor scabbling equipment is useful for large areas of floor that only have limited penetration of contamination into the concrete.

Spalling is another physical decontamination method using chippers and jackhammers to remove contamination by mechanical impact. Small electric versions are available for hand-held use on localized spots where contamination has deeply penetrated. Pneumatic versions are available for mounting on construction equipment such as a skid steer for removal of large areas. Similar to scabbling, this process is a dry decontamination technique and can generate large amounts of dust. Vacuum attachments and shrouding configurations are utilized so that chipping may be done with no detectable increase in airborne concentrations. This decontamination technique is best used when contamination has penetrated more deeply into concrete than can be effectively decontaminated by scabbling or grinding.

Effectiveness

Scarification techniques are protective of human health and the environment because contaminated portions of the building materials are removed. Scarification may not be completely effective on some surfaces because contamination may be present deeper within the building material. Additionally, large-scale concrete and masonry contamination (e.g., Building G-1) is problematic in order to decontaminate to release criteria; therefore, scarification would be performed only on debris materials in order to reduce the amount of LLRW waste prior to disposal. Additionally, isolated contaminated building materials, such as roofing material, cannot be easily and effectively remediated using scarification.

The effectiveness of scarification decontamination is rated high because the removal of contaminated material or residuals from the structure reduces or eliminates radiation exposure, enables the re-use of structures or equipment, and reduces the amount of material (e.g., construction, related debris) requiring further treatment or disposal.

Implementability

Scarification decontamination methods are implementable and are a proven technology. Waste management tends to be simpler because the removed surface material can be collected directly and routed to waste disposal. The scarification methods of buildings and structures require specialized equipment and trained personnel, which are commercially available. Monitoring would be conducted during implementation to ensure protection of remedial workers. The implementability of decontamination by scarification is rated high.

Cost

The approximate cost of using a concrete grinder is \$2.92 per ft^2, a pneumatic scabbler is \$10.37 per ft^2, and a concrete spaller is \$18.52 per ft^2 (USEPA 2006). The average decontamination cost for the three methods are rated moderate. Potential costs may be incurred to restore building surfaces after remediation. Since most building surfaces proposed for remediation (except for Building G-1) using scarification are small, isolated areas, the potential restoration requirements and costs would be low. Therefore, the overall cost rating for scarification is moderate.

Summary of Evaluation

The effectiveness of the scarification techniques is rated high because the reduced exposure to the contaminated materials by removal. The implementability is rated high as these methods are proven technology and the equipment and personnel are commercially available. The overall cost is rated moderate as described above. Therefore, scarification is retained for further evaluation.

2.3.4.3 Dismantlement

Risks associated with buildings or their structural materials may be eliminated or reduced by removal of a portion of the structure or the entire structure, usually without the intent of re-use. In addition, dismantlement of a building would allow for access to contaminated soil present beneath the building. With the exception of Building G-1, complete dismantlement is not proposed for any other OU-1 building, as there are no soil areas above PRGs beneath the remaining buildings. For some contaminated building materials at the remaining OU-1 buildings (e.g., roofing materials at the Foundry, Boiler House, and Warehouse), decontamination is not cost effective or implementable; therefore, the roofing materials could be removed, disposed of and replaced.

Resulting debris would be properly disposed of at an off-site landfill. Debris from the removed structures would be segregated into waste streams, size-reduced if necessary, and containerized and staged prior to disposal or direct-loaded onto transport vehicles for off-site disposal. The waste generated by the removal would be characterized to determine the waste type for disposal in an appropriate facility.

Effectiveness

Dismantlement would reduce mobility, volume, and exposure to contaminated building materials and would be protective of human health and the environment because potential risks would be reduced. During implementation, there would be possible short-term risk from fugitive dust emissions, which would be readily managed by implementation of a health and safety plan and an environmental protection plan. Although air quality could be adversely affected by the release of particulates, mitigation measures, such as dust suppression methods and use of proper safety procedures and equipment, would be implemented to minimize any increased risk to on-site workers during remediation. Short-term risks, including occupational injuries and a risk of fatalities, would increase with building dismantlement. Removal of contaminated building materials by dismantlement or partial removal and replacement would permanently reduce the mobility of contaminants at the site; therefore, the effectiveness is rated high.

Implementability

Building dismantlement and removal uses readily available resources and conventional construction equipment. Equipment, personnel, and services are readily available to complete this action. Development of temporary roads, debris storage areas, and staging areas for loading and unloading; soil

erosion control; and additional clearing and grubbing may be necessary. The implementability of building dismantlement (Building G-1) or partial building material dismantlement with replacement (at remaining OU-1 buildings) is rated high.

Cost

Costs related to building dismantlement are estimated at $200 per ft^2. In comparison to the other process options presented in this FS, the cost of dismantlement is rated high. Removal and replacement of roofs at some of the OU-1 buildings would be required, but those costs are estimated at no more than $10 per ft^2 which is rated low. Building materials removed during building dismantlement would require disposal. Additional costs associated with disposal are presented in Section 2.3.4.4.

Summary of Evaluation

Dismantlement using conventional construction equipment is typically used as a remedial alternative for radiologically-contaminated buildings. Additionally, other isolated contaminated building materials can be easily and effectively remediated using removal, with replacement as needed, to allow for re-use of the buildings. The effectiveness and implementability of removal by dismantlement is rated high, although the costs are comparatively high. Removal of contaminated building materials by dismantlement for Building G-1 and removal and replacement of other radiologically-contaminated OU-1 building components are retained for further evaluation.

2.3.4.4 Off-Site Disposal

Contaminated building materials from response actions could be disposed of at an off-site landfill. For these materials, sampling and analysis of building materials would be conducted to develop a waste profile to confirm the waste achieves applicable WAC before disposal. Several types of building debris may be generated as a result of remediation activities at the site: non-hazardous solid waste (RCRA Subtitle D landfill), radioactive waste co-mingled with hazardous solid waste (RCRA Subtitle C landfill), and LLRW disposed of to a properly licensed disposal facility. Some types of C&D wastes may also fall under the category of “clean fill,” including materials such as rock, soil, gravel, concrete, broken glass, and/or clay products. Such materials may be used as fill in a variety of situations, with no solid waste permit or approval required, provided there is no violation of other regulations.

Non-hazardous waste includes regular C&D wastes that are not classified as clean fill and are not being reused or recycled and would be disposed of at a Subtitle D landfill.

Subtitle C landfill facilities are commonly permitted to accept both RCRA hazardous waste and TSCA regulated waste, along with material that meets the acceptance criteria of 10 CFR 40.13(a). Based on review of RI building waste characterization data, RCRA wastes are not currently anticipated, but confirmatory evaluations will be performed as an integral part of remedial actions. Subtitle C disposal requirements commonly limit total activity of naturally-occurring constituents to a maximum of 2,000 pCi/g. In addition, source materials (i.e., uranium and thorium) are limited to a maximum of 0.05% by weight (i.e., to about 54.5 and 165 pCi/g for thorium-232 and uranium-238, respectively). The stated limits apply to both volumetrically-contaminated media (e.g., soil) and to surficially-contaminated materials and are applied as a limit on the average concentration per unit mass, as averaged over a conveyance or package. As such, based on a review of RI characterization data, it is reasonable to conclude that as much as 90% of the material could be segregated fairly easily for disposal in a Subtitle C facility. Subject to monitoring considerations, uranium and radium are detectable with field radiation measurement instruments, and segregation should generally be implementable.

Barring application for exemption pursuant to 10 CFR 20.2002, radiological waste that contains source material as defined in 10 CFR 40.13(a) requires disposal in a LLRW facility. The Low-Level Radioactive Waste Policy of 1980 (P.L. 96-573) defined "low-level radioactive waste" as radioactive material that is not high-level radioactive waste, spent nuclear fuel, or byproduct material and radioactive material that the NRC classifies as LLRW consistent with existing law.

Waste generated as a result of a remedial action would be transported to the off-site disposal facility in trucks, railcars, or containers that will be transported by truck or rail. The transport of wastes to an off-site disposal facility would comply with DOT regulations and directives, as well as other applicable Federal regulations. Specific requirements may include waste profiling, manifesting, packaging, marking and labeling waste packages; placarding transport vehicles; choosing appropriate waste transporters and shipment destinations; and recordkeeping and reporting.

Effectiveness

Disposal of building debris in an off-site disposal facility is designed to be a long-term solution to waste disposal. However, without some treatment prior to disposal, it does not reduce the volume or concentration of the contaminants. To mitigate this, engineering design features of the disposal facility, such as liner integrity, monitoring, and mitigation procedures, are necessary to ensure effectiveness. Disposal facilities are designed to be reliable for 100 to 1,000 years with the appropriate maintenance activities and are considered highly effective.

Environmental and human health risks are of principal concern when hazardous or radioactive materials are being removed and handled. Potential health impacts to site workers also include exposure to fugitive dust emissions. Appropriate mitigation measures would be implemented during waste handling activities to reduce worker exposures, airborne emissions, and surface water runoff. Potential short-term risks are associated with the transport of these materials to an off-site disposal facility. Worker and public exposure is minimized during transport by choosing rail transportation over truck and strict enforcement of applicable Federal and state safety provisions. Transportation risks increase with distance and volume, although the potential for any spillage and resultant public exposure would be low.

Because the use of an engineering disposal facility would reduce the exposure and mobility of contaminants, the effectiveness of off-site disposal is rated high.

Implementability

Off-site disposal of debris from contaminated structures is a relatively simple process, with proven procedures and widespread use. About 20 hazardous waste landfills exist in the United States that currently engage in commercial disposal of RCRA Subtitle C hazardous waste. Disposal facilities in the region are in Ohio, Indiana, Michigan, and Pennsylvania. Additionally, four non-hazardous landfills for uncontaminated, non-hazardous C&D debris are located within Cuyahoga County, Ohio (Ohio EPA 2010).

Currently, there are two NRC-licensed commercial LLRW disposal facilities which are authorized for receipt of waste from the site. These facilities are located in Clive, Utah and Andrews, Texas. Although there are only two LLRW facilities available, the volume of radiological material from the site that requires disposal is not prohibitive for acceptance at these facilities. Each of these facilities is authorized to receive Class A LLRW and 11e (2) byproduct material. In addition, the Clive, Utah facility is authorized to receive mixed waste (i.e., waste containing both Atomic Energy Act [AEA]-regulated LLRW and hazardous waste). The facilities accept waste via rail, truck, and containerized shipments.

Facilities also exist for non-radiologically-contaminated debris. Transportation and disposal of contaminated debris would use specially lined dump trucks, rail cars, or intermodal containers which can be transported by truck or rail. Transportation is readily available for use.

Because off-site disposal facilities exist that can receive waste from the site and because transportation is readily available to these facilities, the implementability of off-site disposal is rated high.

Cost

Off-site treatment and disposal capacity is available; however, the type and quantity of material for disposal has the most impact on the cost. For large volumes of material, it may be desirable to reduce the volume through decontamination and/or segregation prior to disposal. Costs also depend on the distance the waste must be transported to the disposal facility.

Cost estimates for off-site disposal are approximately \$30 per yd^3 for non-radiological C&D debris, \$110 per yd^3 for Subtitle C waste, \$650 per yd^3 for LLRW, and \$1,200 per yd^3 for mixed LLRW debris. These estimates do not include transportation to an off-site facility. Additional costs may also include debris characterization and/or decontamination to meet disposal facility WAC. Overall, the costs associated with off-site disposal are rated high.

Summary of Evaluation

Disposal of building materials at off-site licensed or permitted facilities is retained because the effectiveness and implementability of its use as a remediation alternative are high. Although the costs associated with off-site disposal are rated high, other alternatives for remediation are limited. There is potential for reduction of the volume of wastes that would require off-site disposal through decontamination, which could potentially reduce disposal costs.

2.3.5 Representative Technologies

The following summarizes the process options that have been retained through the screening process. These options are assembled, as appropriate, into alternatives in Section 3 to address contaminated soil and buildings at the site.

2.3.5.1 Soil

The following process options for soil have been retained for individual use or in combination in the development of alternatives:

- Land-use controls
  - Legal and administrative mechanisms
    - Governmental controls
    - Proprietary controls
    - Informational tools
  - Physical mechanisms

- Removal
  - Soil excavation

- Treatment

- Physical/Chemical
  - S/S

- Disposal
  - Off-site disposal

2.3.5.2 Buildings

The following process options for buildings have been retained for individual use or in combination in the development of alternatives:

- Land-use controls
  - Legal and administrative mechanisms
    - Governmental controls
    - Proprietary controls
    - Informational tools
  - Physical mechanisms

- Treatment by physical decontamination
  - Surface Cleaning - Vacuuming
  - Surface Removal - Blasting High Pressure Water
  - Surface Removal - Scarification (Grinding, Scabbling, Spalling)

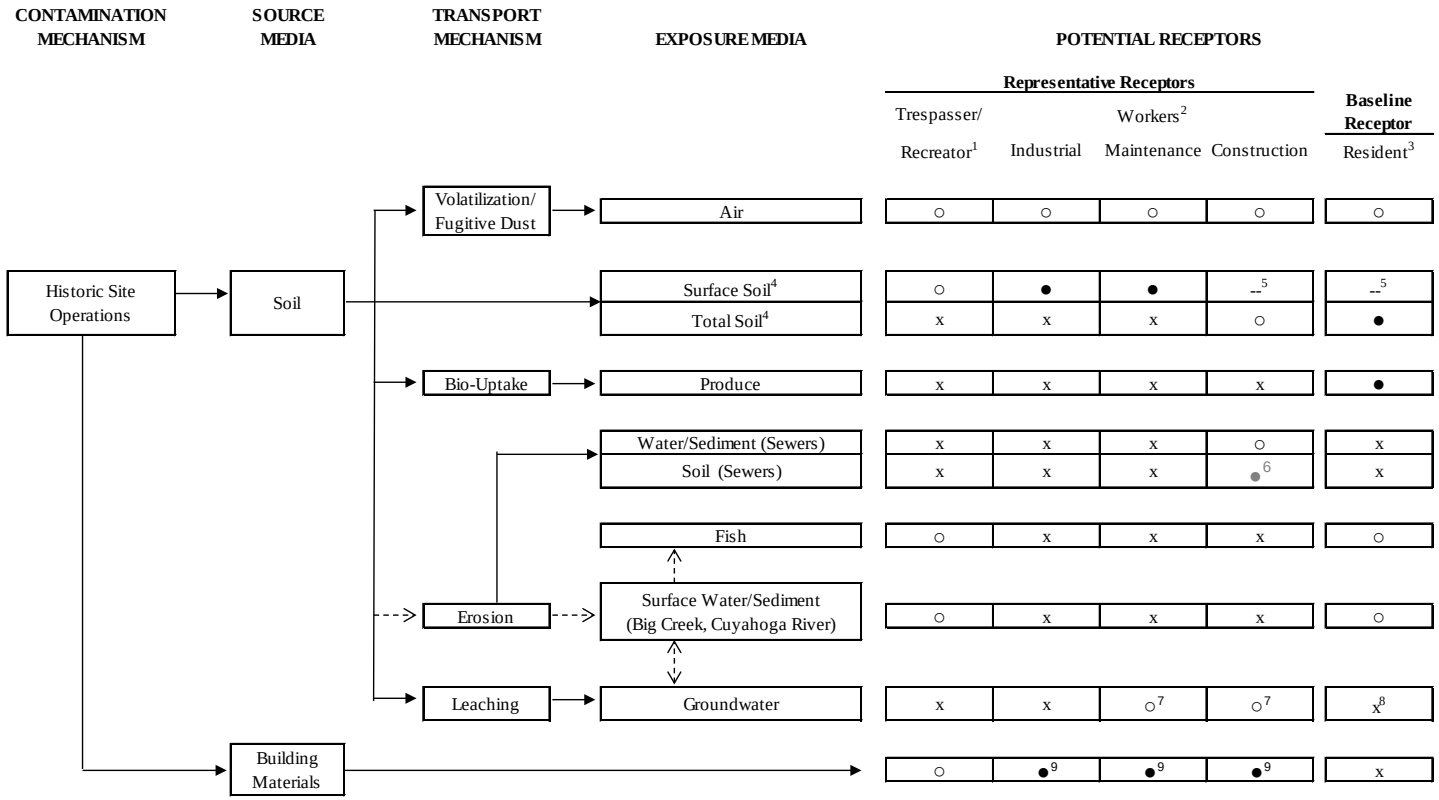
- Dismantlement
  - Partial Removal with Replacement
  - Complete Removal

- Disposal
  - Off-site disposal

Table 2-1. Values Used in SOR Calculation (pCi/g)

	Ra-226	Th-230	Th-232	U-238
Background Value*	0.941	0.878	0.981	1.27
OU-1 PRG±	9.1	35	6	190
OU-2 PRG±	3.6	16	3.6	150

*Mean background values were obtained from Table 8-7 "Background Statistical Report" of the RI Report. The values selected are associated with the 0-13 inches Natural Background Soil dataset.
±PRG are presented in Section 2.1.5
pCi/g = PicoCuries Per Gram
PRG = Preliminary Remediation Goal
SOR = Sum of Ratios



[1] Adult and adolescent trespassers are potential current receptors.
Adult and adolescent recreational users are potential future receptors.
[2] Adult Maintenance Worker represents potential current exposure.
Adult Industrial and Construction Workers represent potential future exposures.
[3] Future Adult and child Residents included as baseline for evaluating the no-action alternative.
[4] Surface soil includes samples collected from 0-2 ft bgs.
Total Soil includes samples collected from 0-13 ft bgs.
[5] Surface Soil is included in the Total Soil interval.
[6] Cs-137 is the only contributor to dose > 25 mrem/year.
[7] Maintenance Worker incidental ingestion while maintaining groundwater treatment system.
Construction Worker incidental ingestion of groundwater within an excavation.
[8] Residential use of groundwater is not a complete pathway because groundwater is not useable and the area is supplied by the municipal water system.
[9] Pathway is only a major contributor at Building G-1.

Figure 2-1. Conceptual Site Model for Development of Remedial Action Objectives at the Former Harshaw Chemical Company Site

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Figure 2-2. Initial Conceptual Site Model - IA03

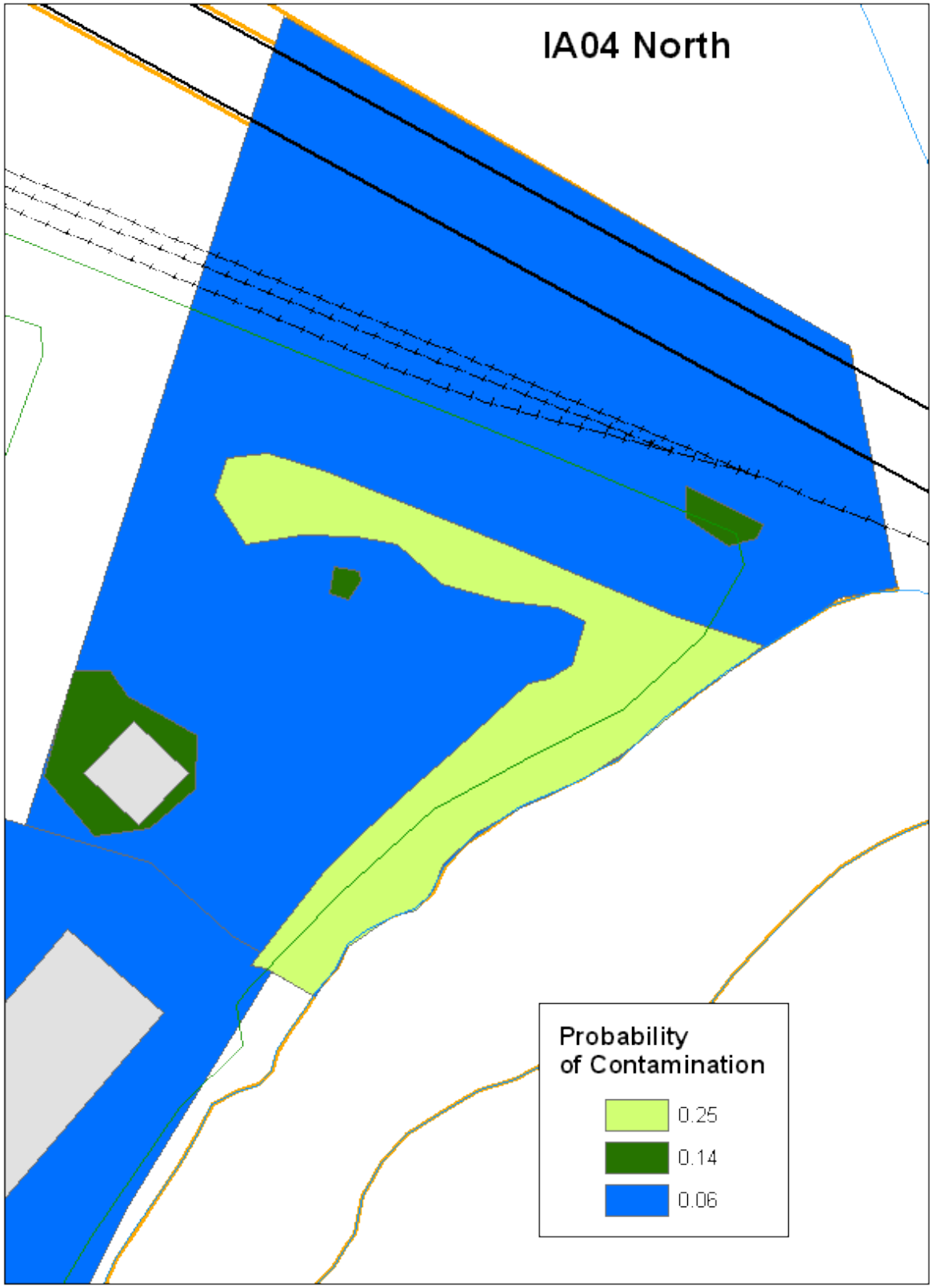

Figure 2-3. Initial Conceptual Site Model - IA04 North

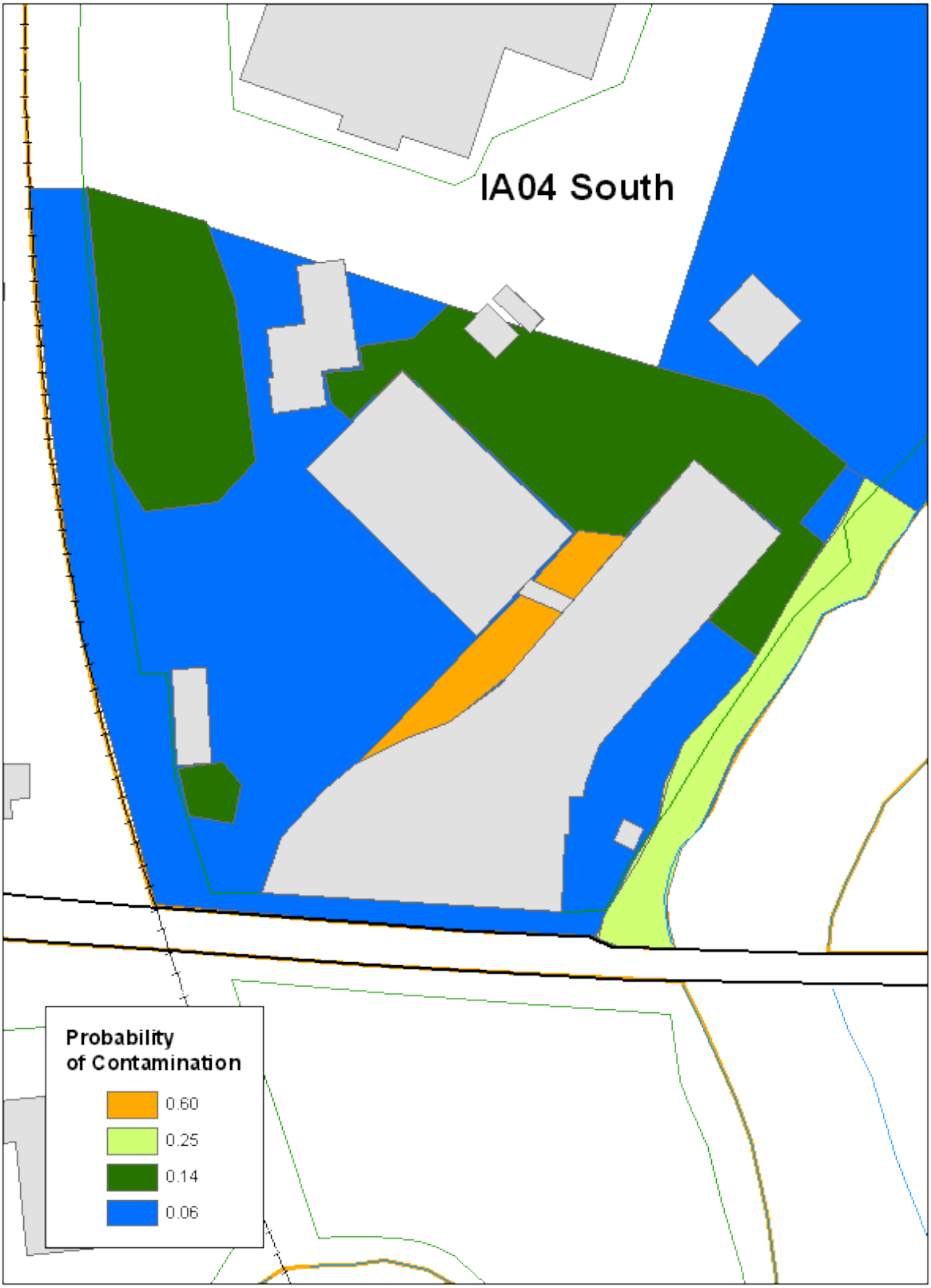

Figure 2-4. Initial Conceptual Site Model - IA04 South

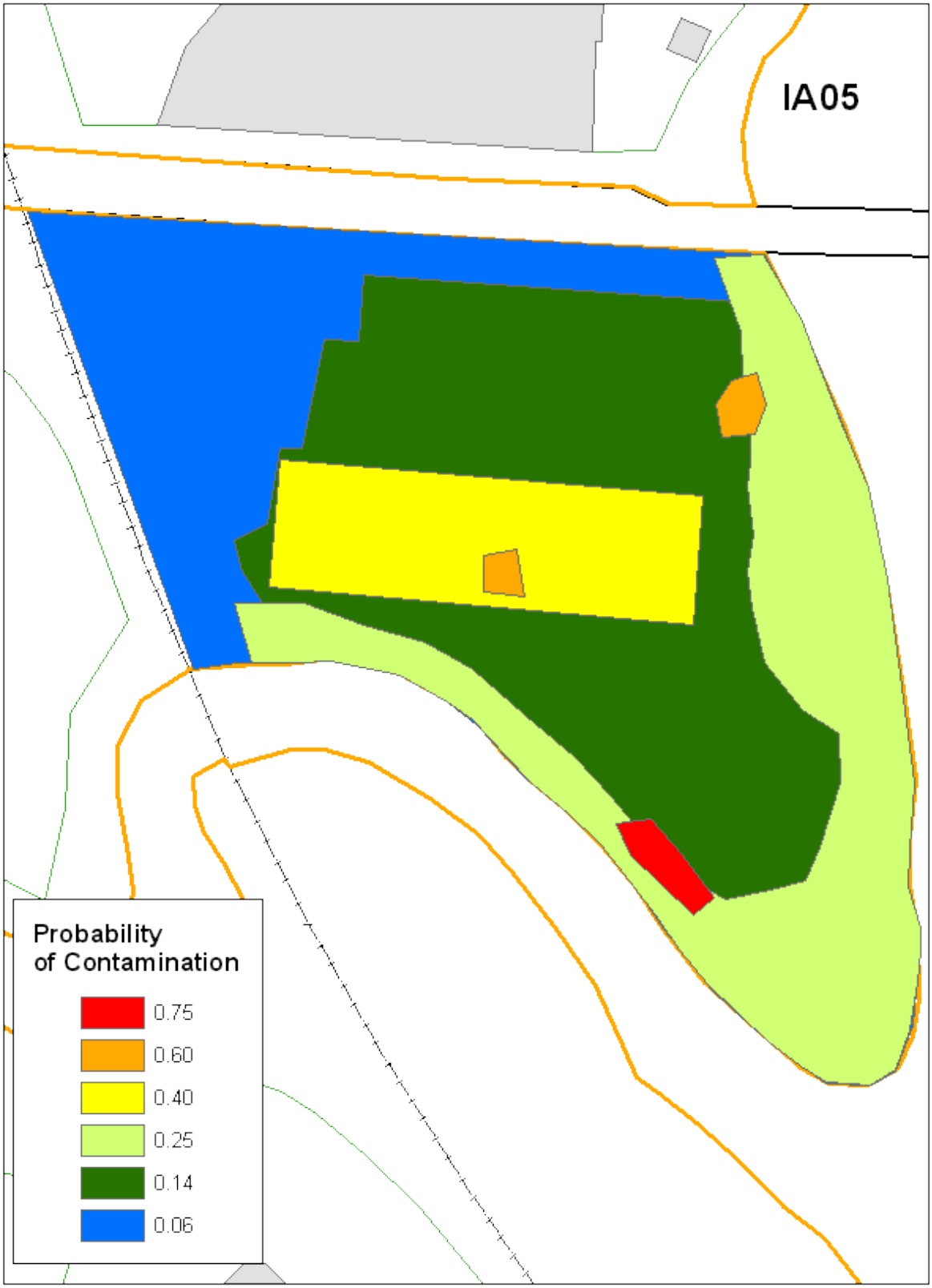

Figure 2-5. Initial Conceptual Site Model - IA05

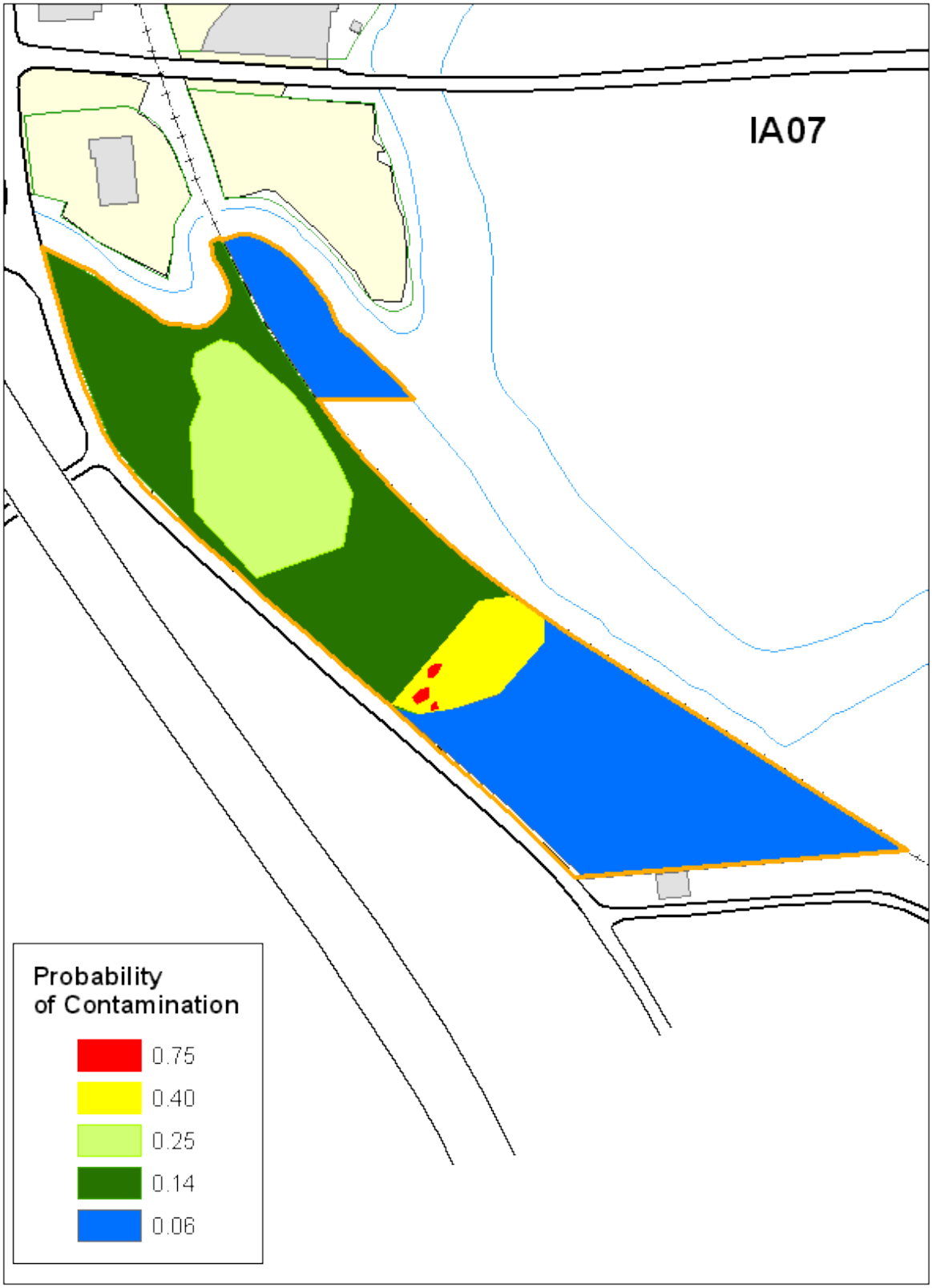

Figure 2-6. Initial Conceptual Site Model - IA07

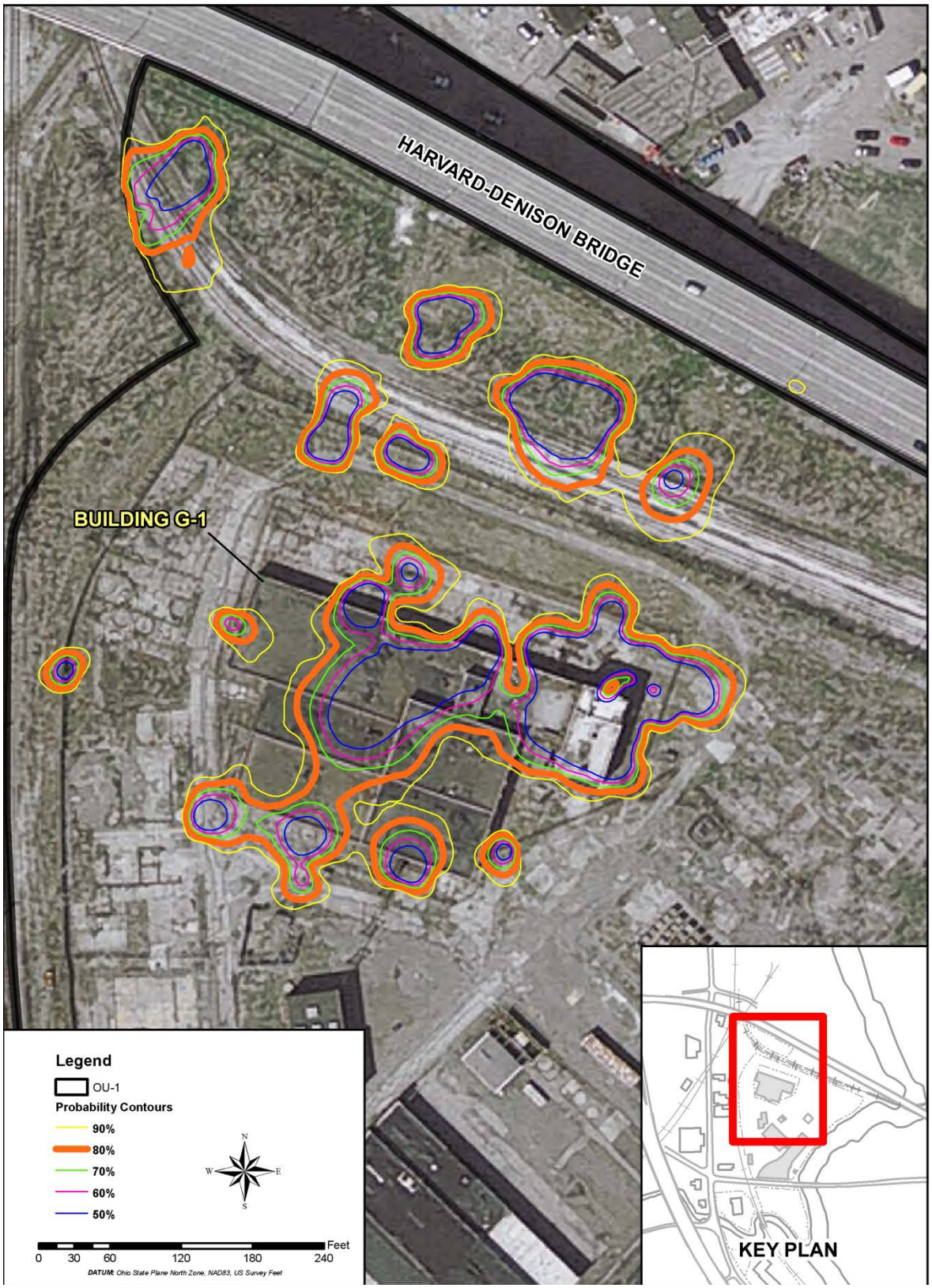

Figure 2-7. In-Situ Soil Volume Contours for Various Probabilities Near Building G-1 (OU-1)

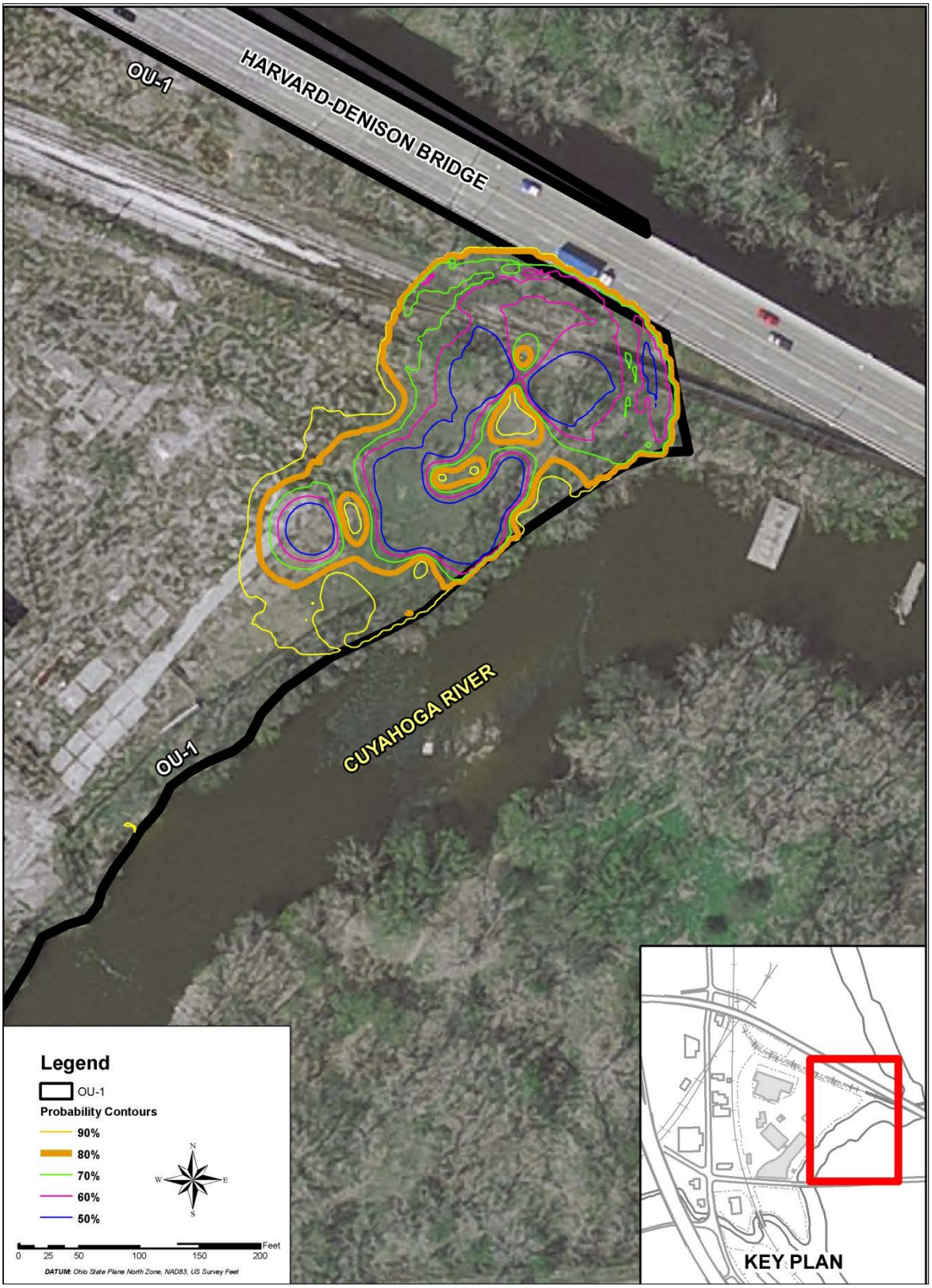

Figure 2-8. In-Situ Soil Volume Contours for Various Probabilities OU-1 East

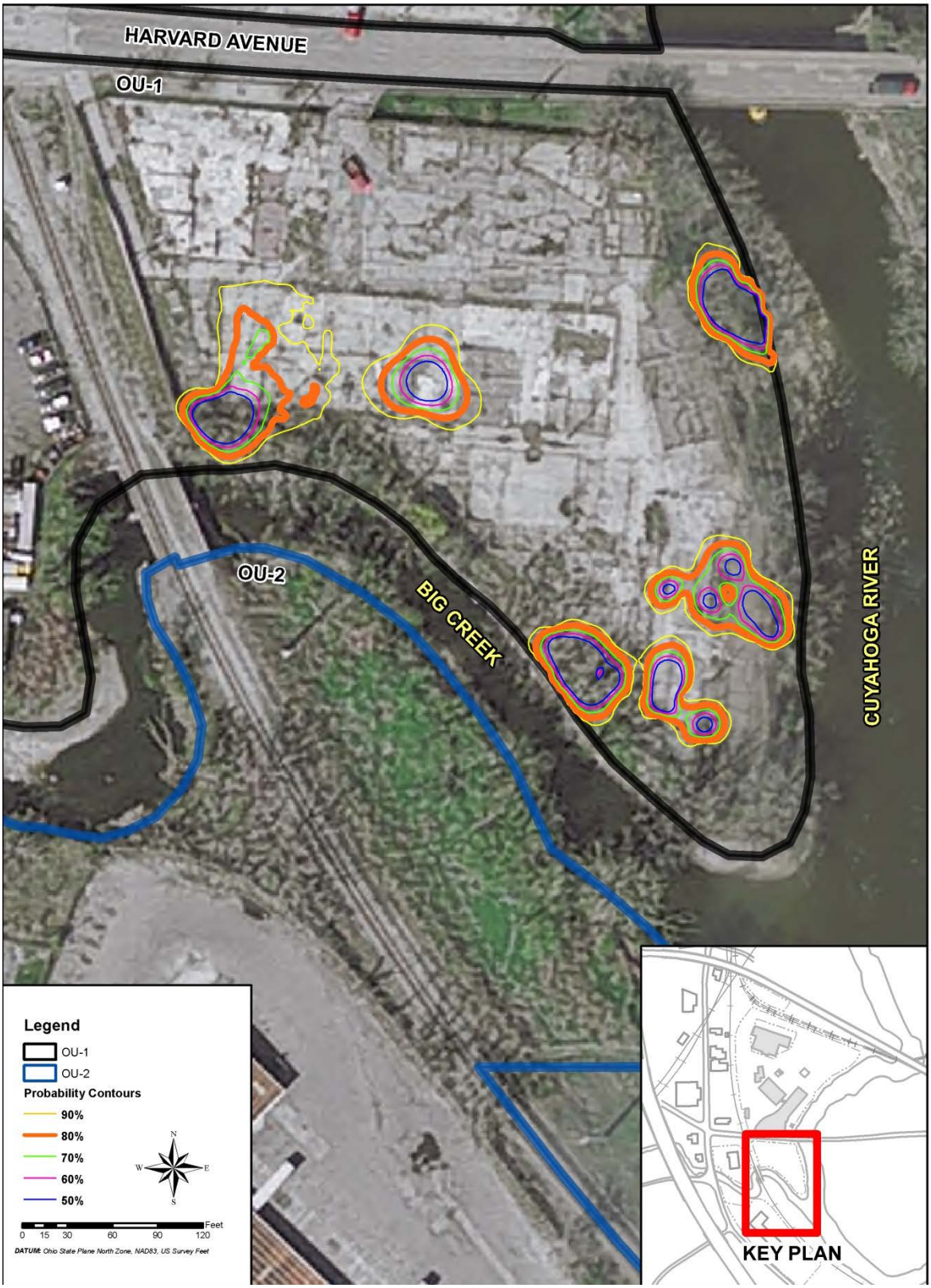

Figure 2-9. In-Situ Soil Volume Contours for Various Probabilities OU-1 (South)

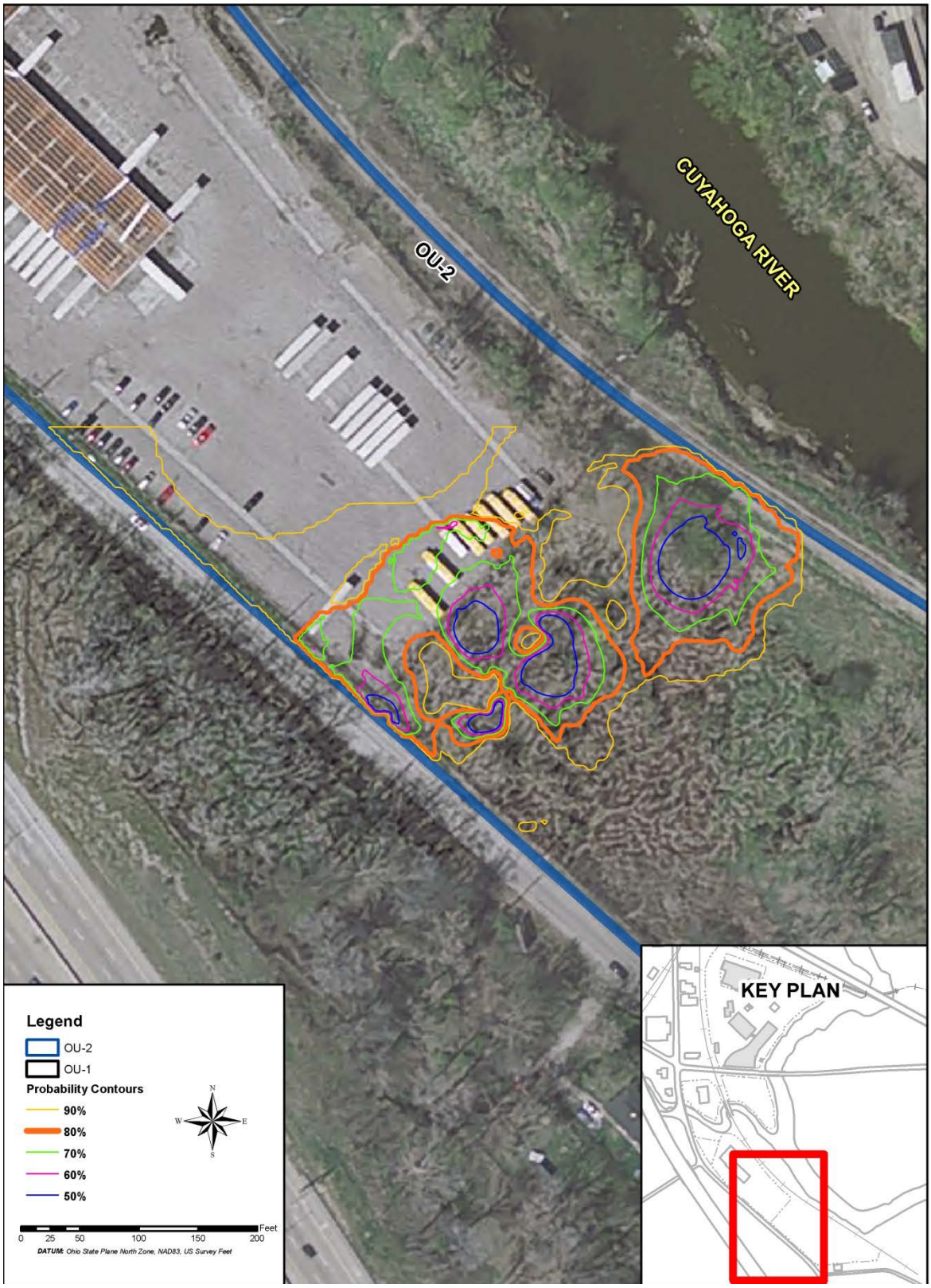

Figure 2-10. In-Situ Soil Volume Contours for Various Probabilities OU-2

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comment
Land-use Controls	Administrative and Legal Mechanisms	Government Controls	Land-use controls may be placed on the site by a government entity to control the types of land use allowed. Zoning restrictions can be used to prohibit development or rezoning to residential use.	Potentially applicable. May be used to limit the future land-use options, depending on the alternative chosen and the amount of contamination left in place.
		Enforcement and Permit Tools	Administrative orders or consent decrees that can be used to restrict the use of land.	Not applicable because USACE does not have enforcement authority.
		Informational Tools	Registries, deed notices, and/or advisories may be used to notify future land owners of residual or capped contamination.	Potentially applicable. May be used to limit the future land-use options, depending on the alternative chosen and the amount of contamination left in place.
		Proprietary Controls	Contractual mechanisms based on private property law (e.g. deed covenants, easements) may be placed on the site to prevent a landowner from disturbing contaminated soil, sediment, or groundwater.	Potentially applicable. May be used to limit the future land-use options, depending on the alternative chosen and the amount of contamination left in place.
	Physical Mechanisms	Physical barriers, permanent markers, and/or security personnel	Access to an area can be restricted through the use of fences, security surveillance, or other engineering controls.	Potentially applicable. Will be used in conjunction with all alternatives during implementation to prevent incidental exposure to contaminated soil.
Containment	Capping	Native soil	Area of contamination is covered with a layer of clean soil.	Potentially applicable for minimizing exposure to radionuclides.
		Clay	Compacted clay cover with soil over areas of contamination.	Potentially applicable for minimizing exposure to radionuclides.
		Synthetic liner	Area of contamination is covered with a geosynthetic clay liner (GCL).	Potentially applicable for minimizing exposure to radionuclides.
		Multi-layered Cap	Multiple layers of different media over areas of contamination. Generally composed of an upper vegetative layer, a drainage layer, and an underlying low-permeability layer.	Potentially applicable for minimizing exposure to radionuclides. Much more costly than other caps.
		Asphalt	A layer of asphalt is applied over areas of contamination.	Potentially applicable for minimizing exposure to radionuclides.
		Concrete	A layer of concrete is applied over areas of contamination.	Potentially applicable for minimizing exposure to radionuclides.

Figure 2-11. Initial Technology Screening for Soil at the Former Harshaw Chemical Company Site

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comment
Containment (continued)	Cryogenic Barriers	N/A	Containment technology that freezes soil to create an ice barrier around a contaminated zone and reduces mobility of the radionuclide contaminants.	Not applicable. Full scale demonstration of technology is limited.
	Vertical Barriers	Slurry Walls	Slurry walls are subsurface barriers that consist of vertically excavated trench filled with a slurry, generally bentonite and water.	Not applicable. Process option typically used to confine impacted groundwater.
		Grout curtains	Narrow, vertical grout walls installed by pressure-injected grout directly into the soil at closely space intervals to form a continuous wall or curtain.	Not applicable. Process option typically used to confine impacted groundwater.
Removal	Soil Excavation	Earth moving equipment	Mechanically or hydraulically operated units such as excavators, front-end loaders, bulldozers, and/or hand tools are used for trenching or other surface and subsurface excavation.	Potentially applicable for excavating, loading, and moving contaminated soil. May be combined with other alternatives.
Treatment	Biological	Phytoremediation	Process by which plants uptake soluble contaminants from soil and water and sequester them for later harvesting and disposal in a properly permitted disposal area.	Potentially applicable. Technology would be combined with excavation to remediate soil impacted at depths >2 ft (0.6 m) bgs.
	Physical/Chemical	Electrokinetic Separation	In-situ treatment by which electrochemical and electrokinetic processes are used to remove metals and polar contaminants from soil.	Not applicable. Full scale has not been demonstrated for radionuclides.
		Soil washing	Ex-situ treatment; contaminants are removed from soil using washing fluid (usually water) with appropriate surfactants.	Not applicable. Geotechnical samples indicate that contaminated site soil contains significant silt and clay fractions.
		Flotation	Ex-situ treatment; chemical treatment technology where a flotation agent is added to a slurry of contaminated soil and water. Air bubbles are injected to float the fine particles for removal.	Not applicable. This technology has not been demonstrated beyond the bench scale.
		Solvent/Chemical Extraction	Ex-situ treatment by contaminated soil is mixed with a solvent to chemically extract the contaminants from the total soil.	Not applicable. This technology has not been demonstrated to treat contaminated soil.

Figure 2-11. Initial Technology Screening for Soil at the Former Harshaw Chemical Company Site (continued)

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comment
Treatment (continued)	Physical/Chemical (continued)	Solidification/ Stabilization (In-Situ)	Soil is mixed with stabilizing agents to immobilize contaminants within soil matrix.	Not applicable. Difficulties with uniform mixing of impacted soil and high clay content of soil.
		Solidification/ Stabilization (Ex-Situ)	Soil is mixed with stabilizing agents to immobilize contaminants within soil matrix.	Potentially applicable.
	Thermal	Vitrification (In-Situ)	In-situ treatment by which heat is applied at >1,600^{o}C using electrodes inserted into the waste mass transforming the waste to a molten state; thus, immobilizing the contaminants.	Not applicable. High level of uncertainty associated with implementation.
		Vitrification (Ex-Situ)	Ex-situ treatment by which heat in excess of 1,100^{o}C is applied to contaminated soil after excavation and containerization. The resulting process generates a dense, glassified mass.	Not applicable. High level of uncertainty associated with implementation.
Disposal	On-site	On-site engineered structure	Design and construct a disposal facility on site.	Not implementable. FUSRAP funds cannot be used to purchase the land necessary for constructing an on-site disposal facility.
	Off-site	Permitted Disposal Facility	Transport treated and/or untreated soil meeting waste acceptance criteria to an off-site disposal facility.	Potentially applicable if contaminants are within acceptance criteria.

Potentially Applicable	Not Applicable

Figure 2-11. Initial Technology Screening for Soil at the Former Harshaw Chemical Company Site (continued)

General Response Action	Remedial Technology Type	Process Option	Description: Effectiveness	Description: Implementability	Description: Cost	Retained
Land-Use Controls	Administrative and Legal Mechanisms	Government Controls	Moderate	Low	Moderate	Yes
		Informational Tools	Moderate	Low	Moderate	Yes
		Proprietary Controls	Moderate	Low	Moderate	Yes
	Physical Mechanism	Physical barriers, permanent markers, and/or security personnel	Moderate	High	Moderate	Yes
Containment	Capping	Native Soil	High	Low	Moderate	No
		Clay	High	Low	Moderate	No
		Synthetic Liner	High	Low	Moderate	No
		Multi-layered Cap	High	Low	Moderate	No
		Asphalt	High	Low	Moderate	No
		Concrete	High	Low	Moderate	No
Removal	Soil Excavation	Earth-moving Equipment	High	High	Low	Yes
Treatment	Physical/Chemical	Solidification/ Stabilization (ex-situ)	Moderate	High	Moderate	Yes
	Biological	Phytoremediation	Low	High	High	No
Disposal	On-site	On-site engineered structure	High	Not Possible	High	No
	Off-site	Permitted Disposal Facility	High	High	High	Yes

Retained	Eliminated from Further Consideration

Figure 2-12. Detailed Technology Screening for Soil at the Former Harshaw Chemical Company Site

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comment
Land-use Controls	Administrative and Legal Mechanisms	Government Controls	Land-use controls may be placed on the site by a government entity to control the types of land use allowed. Zoning restrictions can be used to prohibit development or rezoning to residential use.	Potentially applicable. May be used to limit the future land-use options, depending on the alternative chosen and the amount of contamination left in place.
		Enforcement and Permit Tools	Administrative orders or consent decrees that can be used to restrict the use of land.	Not applicable because USACE does not have enforcement authority.
		Informational Tools	Registries, deed notices, and/or advisories may be used to notify future land owners of residual or capped contamination.	Potentially applicable. May be used to limit the future land-use options, depending on the alternative chosen and the amount of contamination left in place.
		Proprietary Controls	Contractual mechanisms based on private property law (e.g. deed covenants, easements) may be placed on the site to prevent a landowner from disturbing contaminated soil, sediment, or groundwater.	Potentially applicable. May be used to limit the future land-use options, depending on the alternative chosen and the amount of contamination left in place.
	Physical Mechanisms	Physical barriers, permanent markers, and/or security personnel	Access to an area can be restricted through the use of fences, or security surveillance.	Potentially applicable. Will be used in conjunction with all alternatives during implementation to prevent incidental exposure to contaminated soil.
Containment	Surface Barriers	Sealants	Spray on chemicals or applied sheeting that provides a surface barrier to reduce exposure to contaminated surfaces.	Not effective for externally-contaminated building materials.
		Impermeable Sheeting	Spray on chemicals or applied sheeting that provides a surface barrier to reduce exposure to contaminated surfaces.	Not effective for externally-contaminated building materials.
Treatment	Decontamination	Surface Cleaning	Surface cleaning includes brushing, wiping, flushing, vacuuming, and strippable coatings. Contamination is mechanically dislodged.	Potentially applicable.
		Surface Removal	Surface removal includes blasting and/or scarifying techniques to remove the contamination along with a layer of the building surface.	Potentially applicable.

Figure 2-13. Initial Technology Screening for Buildings at the Former Harshaw Chemical Company Site

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comment
Treatment (continued)	Chemical	Chemical Agents	Solvents, complexing agents, acids, or bases which dissolve or suspend the contaminants in a fluid to facilitate their removal from the surface of the material.	Eliminated due to health and safety aspects during use of the chemicals, generation of mixed waste, and other more effective options.
Dismantlement	Partial Removal of Building Materials with Replacement	Conventional	Removal of isolated, contaminated building materials such as roofing through conventional methods.	Potentially applicable. Roofs and other building materials that cannot be easily decontaminated would be removed and replaced.
	Complete Removal	Conventional	Dismantlement of contaminated building structures and disposal of the debris to an on-site disposal landfill.	Potentially applicable for Building G-1 only.
Disposal	On-site	On-site engineered structure	Design and construct a disposal facility on site.	Not implementable. FUSRAP funds cannot be used to purchase the land necessary for constructing an on-site disposal facility.
	Off-site	Permitted Disposal Facility	Transport treated and/or untreated soil meeting waste acceptance criteria to an off-site disposal facility.	Potentially applicable if contaminants are within acceptance criteria.

Potentially Applicable	Not Applicable

Figure 2-13. Initial Technology Screening for Buildings at the Former Harshaw Chemical Company Site (continued)

General Response Action	Remedial Technology Type	Process Option	Description: Effectiveness	Description: Implementability	Description: Cost	Retained
Land-Use Controls	Administrative and Legal Mechanisms	Government Controls	Moderate	Low	Moderate	Yes
		Informational Tools	Moderate	Low	Moderate	Yes
		Proprietary Controls	Moderate	Low	Moderate	Yes
	Physical Mechanisms	Physical barriers, permanent markers, and/or security personnel	Moderate	High	Moderate	Yes
Treatment	Physical Decontamination	Surface Cleaning Vacuum	High	High	Low	Yes
		Surface Removal High Pressure Water	High	High	Low	Yes
		Surface Removal Scarification	High	High	Moderate	Yes
Dismantlement	Partial Removal of Building Materials with Replacement	Conventional	High	High	High	Yes
	Complete Removal	Conventional	High	High	Low	Yes
Disposal	On-site	On-site engineered structure	High	Not Possible	High	No
	Off-site	Permitted Disposal Facility	High	High	Moderate	Yes

Retained	Eliminated from Further Consideration

Figure 2-14. Detailed Technology Screening for Buildings at the Former Harshaw Chemical Company Site

3. DEVELOPMENT AND SCREENING OF ALTERNATIVES

This section describes the remedial alternatives assembled for the Former Harshaw Chemical Company Site.

3.1 DEVELOPMENT OF ALTERNATIVES

Media-specific alternatives for soil and buildings were identified by combining GRAs, technology types, and process options retained from the screening processes described in Section 2. A remedial action decision is required for soil and buildings at OU-1 and for soil at OU-2. The development of alternatives was based on expected future land use, where industrial use is likely for the OU-1 area, and residential redevelopment is a plausible future land use at the OU-2 area. The following media-specific alternatives were identified for soil in OU-1 and OU-2:

- Alternative S1 - No Action (OU-1);
- Alternative S2 - Land-Use Controls (OU-1);
- Alternative S3 - Complete Removal and Off-Site Disposal (OU-1);
- Alternative S4 - Complete Removal, Ex-Situ Treatment, and Off-Site Disposal (OU-1);
- Alternative S5 - No Action (OU-2);
- Alternative S6 - Land-Use Controls (OU-2);
- Alternative S7 - Complete Removal and Off-Site Disposal (OU-2); and
- Alternative S8 - Complete Removal, Ex-Situ Treatment, and Off-Site Disposal (OU-2).

The following media-specific alternatives were identified for buildings in OU-1:

- Alternative B1 - No Action;
- Alternative B2 - Land-Use Controls;
- Alternative B3 - Dismantlement and Off-Site Disposal (Building G-1 only); and
- Alternative B4 - Decontamination (all buildings except G-1).

Media-specific alternatives retained for detailed analysis are summarized in Table 3-1. These media-specific alternatives were further combined to assemble alternatives for each OU. The following alternatives were constructed from the media-specific alternatives:

- Alternative 1 - No Action (OU-1);
- Alternative 2 - Limited Action and Land-Use Controls (OU-1);
- Alternative 3 - Complete Removal and Off-Site Disposal (OU-1);
- Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1);
- Alternative 5 - No Action (OU-2);
- Alternative 6 - Limited Action and Land-Use Controls (OU-2);
- Alternative 7 - Complete Removal and Off-Site Disposal (OU-2); and
- Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2).

The assembled alternatives are described in the following section. Table 3-2 summarizes the assembly of alternatives.

3.1.1 Alternative 1 - No Action (OU-1)

Alternative 1 leaves the site "as is," with no actions taken regarding access or land-use controls beyond those already in place. This alternative provides no additional protection to human health and the environment over current conditions. This alternative also assumes existing controls and monitoring would not be maintained. The No Action alternative is required under the NCP [40 CFR §300.430(e)(6)] as a baseline against which other alternatives can be compared.

Under this alternative, impacted soil would remain at the current locations. No dismantlement or decontamination would occur at any of the buildings in OU-1. Existing physical mechanisms (site security fence) would be left in place but not maintained. Environmental monitoring would not be performed. In addition, no restrictions on land-use would be pursued. However, the site is assumed to operate in compliance with existing regulations that impose limitations on occupational exposures, and the existing land owners would be responsible for this compliance.

3.1.2 Alternative 2 - Limited Action and Land-Use Controls (OU-1)

Alternative 2 is a limited action alternative consisting of the dismantlement of Building G-1 and the off-site disposal of the building debris, bank stabilization, land-use controls, site monitoring, and five-year reviews. Dismantlement of Building G-1 is included in this alternative in order to meet the ARAR standards contained in 10 CFR 20, Subpart E, Section 20.1403 regarding dose limits of 100 mrem/yr and 500 mrem/yr should institutional controls fail. As stated in Section 1.2.5.1.2, the maximum dose to the Reasonable Maximum Exposure (RME) receptor in this building is estimated to be 7,500 mrem/year. Contamination in the other buildings and soil are at levels such that the ARAR dose limits are met. Under this alternative, the remaining impacted media at OU-1 after Building G-1 dismantlement and removal would remain in place, with no other active remedial measures involving removal implemented. The estimated building volume that would be disposed of is 4,800 yd^3 (3,670 cubic meters [m^3]).

Components of this alternative include:

- Remedial Design Plan;
- Building dismantlement;
- Transportation;
- Off-site disposal;
- Bank stabilization;
- Land-use controls; and
- Five-year reviews.

All appropriate substantive requirements relating to the implementation of this alternative will be considered and addressed in the remedial design.

3.1.2.1 Remedial Design Plan

A Remedial Design Plan would be developed prior to the initiation of remedial actions. This plan would detail site preparation activities, the methodology to be used in dismantling Building G-1, implementation and sequence of remedial action activities, decontamination, and transportation and disposal of contaminated building debris.

Short-term land-use controls would be necessary during the active construction period to ensure a safe remediation. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

3.1.2.2 Building Dismantlement

Alternative 2 includes the dismantlement of Building G-1 and removal of its associated material to the slab or foundation. Dismantlement of Building G-1 would remove the potential exposures to radiological contamination from building materials and would allow remediation of the contaminated soil beneath the building. The building is currently in poor condition and the removal would also ensure worker safety during remedial activities.

Mechanical equipment such as excavators or loaders would be used to dismantle the building to the slab/foundation. This approach would require standard dismantlement practices with dust suppression to contain any potential airborne radioactivity. Water from dust suppression activities would be collected, managed, and treated on-site and discharged or disposed of at an off-site disposal facility permitted to accept the waste stream. Dismantlement areas would be maintained as potentially contaminated areas until radiological release surveys could be performed.

Asbestos-containing material (ACM) was previously remediated and the waste is currently stored in Building G-1. The property owner would be required to remove and dispose of the ACM prior to any dismantlement activities.

Building material or debris would be segregated to reduce the amount of waste requiring disposal at an off-site disposal facility. Segregation of waste can provide increased disposal options and cost savings given that radioactivity levels may allow for disposal of up to 90% of building debris to a Subtitle C facility rather than an LLRW facility. Additionally, uncontaminated debris would be cleared for free release for salvage or non-radiological disposal. Bulk building debris may be segregated using waste minimization techniques. The estimated building volume that would be disposed of is 4,800 yd^3 (3,670 m^3).

3.1.2.3 Transportation

Building materials/debris would be hauled to a licensed or permitted disposal facility by direct load to a railcar, trucking to a rail-loading facility, or direct trucking to the disposal facility. For direct loading to a railcar, a rail spur would be constructed at the site. This may allow for increased shipment loadings resulting in potential transportation cost savings. In addition, a rail spur would increase the overall safety and reduce overall transportation risks since the material would only be handled once. The appropriate shipping documentation would accompany the waste shipment. Regulated and licensed transportation would travel along pre-designated routes, and an emergency response plan would be developed.

3.1.2.4 Off-Site Disposal

Building materials/debris would be disposed of at a facility licensed or permitted to accept the characterized waste stream. The selection of an appropriate facility would consider the types of wastes, location, transportation options, and cost. Building materials and debris may require size reduction if specified in the disposal facility's WAC. This can be achieved using the dismantlement equipment (e.g., crushing with an excavator bucket). Materials such as pipes could be cut to conform to this requirement. Debris that does not meet this size criterion would be categorized as oversized debris.

3.1.2.5 Bank Stabilization

Under this alternative, the river and creek banks where impacted media remains would be stabilized to minimize the potential for bank erosion and subsequent release of contaminated materials into the creek or river. The areas that would be stabilized would be those where MED/AEC-related constituents are present within the bank. Due to the bank slopes, the stabilization would involve the installation of Gabion baskets, geotextile, rip rap, and crushed stone.

3.1.2.6 Land-Use Controls

Under this alternative, several forms of land-use controls, access controls, and informational tools are needed to restrict or limit future uses and activities at the site. Land-use controls would include environmental covenants applied to the land to restrict future uses of the site and buildings where concentrations of radionuclides remain above PRGs. Access control measures would be aimed at limiting access to reduce the potential for human exposure for the critical group (construction worker) to soil, buildings, or areas within buildings located at the site. Access control (fencing) is already in place at the site. Additional access controls, such as additional fencing, would be implemented under this alternative. Although the land-use controls would be in-place to preclude exposures to the critical group, under this alternative the land could be used for passive recreation (e.g., concreted bike or walking paths), and no full-time maintenance or commercial workers would be at the recreational facility. Informational tools would include posting signs and placing placards to indicate the presence of hazardous substances and warn against intruding the site.

The implementation of land-use controls would eliminate the exposure pathway for potential future workers, including the construction worker, and thus reduce exposures to contaminants. However, controls would not reduce the toxicity or mobility of the contaminants, and the exposure pathway to soil, air, groundwater, or surface water would not be reduced. Site monitoring would be required to document the effectiveness of this remedial action. Monitoring would involve periodic inspections of the interior and exterior of the buildings conducted during the five-year reviews to evaluate and document any changes to site or material conditions. Specific action items and frequencies associated with the land-use controls would be detailed in the Land-Use Control Plan prepared after the ROD. Five-year reviews would be conducted in accordance with CERCLA 121(c) for areas where contaminants are left above levels acceptable for unlimited use/unrestricted exposure and would involve periodic inspections of the interior and exterior of the buildings conducted during the five-year reviews to evaluate and document any changes to site or material conditions.. Alternative 2 is considered to be protective.

3.1.2.7 Five-Year Reviews

When hazardous substances, pollutants, or contaminants remain on-site at levels that do not achieve unlimited use/unrestricted exposure, CERCLA requires that reviews be conducted at least every five years to ensure the remedy remains protective. Monitoring the site for any changes in land use can be part of the long-term management for the site. The five-year review process is a requirement that analyzes the implementation and effectiveness of the remedy, including any land-use controls where the controls are relied upon.

3.1.3 Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)

Alternative 3 consists of excavation of impacted soil exceeding the PRGs in OU-1 and subsequent off-site disposal. Building G-1 would be dismantled in order to access impacted soil beneath the building slab/foundation. Contaminated building material above PRGs at the remaining buildings would be

removed and the buildings would be returned to a safe condition. These remaining buildings would not be dismantled, as there is not impacted soil above PRGs under them. This alternative would require close coordination of remediation and monitoring activities with the land owner(s) and/or tenants. This coordination aims to minimize health and safety risks to on-site personnel and the disruption to activities consistent with a safe and effective remediation.

Components of this alternative include:

- Remedial Design Plan;
- Building decontamination;
- Building dismantlement;
- Excavation;
- Transportation;
- Off-site disposal;
- Confirmatory sampling;
- Site restoration; and
- Five-year reviews.

All appropriate substantive requirements relating to the implementation of this alternative will be considered and addressed in the remedial design.

3.1.3.1 Remedial Design Plan

A Remedial Design Plan would be developed prior to the initiation of remedial actions. This plan would detail site preparation activities, the extent of excavation, implementation and sequence of remedial action activities, decontamination, and transportation and disposal of contaminated soil. The plan would include provisions for excavating along the river bank (e.g., sheet piling). In addition, excavations >5 ft (1.5 m) bgs would require benching or sloping to ensure worker safety.

Short-term land-use controls would be necessary during the active construction period to ensure a safe remediation. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

3.1.3.2 Building Decontamination

Under Alternative 3, contaminated building materials above PRGs at OU-1 buildings would be decontaminated to remove radiological contamination. Several exterior portions (e.g., windowsills, wall areas, concrete caps, and roofing) of the Boiler House, Warehouse, Foundry, and Garage were found to be above PRGs and would be decontaminated using physical methods. The following summarizes the estimated extent of the radiological contamination that would need to be addressed for each of these buildings based on the results presented in Section 6.3.3 of the RI (USACE 2009):

Building	Impacted Area and Extent			
	Exterior Walls (ft^2)	Windowsills (ft^2)	Roofing/Caps (ft^2)	Roof Vent (ft^2)
Boiler House	224	102	-	-
Warehouse	-	4,410	4,410	25
Foundry	258	60	13,770	-
Garage	2	-	-	-

The primary method for decontamination of building materials would be vacuuming. HEPA vacuuming would be used to clean removable contamination from the building surfaces. HEPA vacuuming only removes loose contamination; therefore, any fixed contamination on surfaces would remain after vacuuming. Both the HEPA filters and the dust and debris would be radiologically surveyed and sampled for RCRA constituents prior to disposal. Radiological contamination surveys would be conducted after treatment to determine if building surfaces meet PRGs or if additional decontamination is necessary. Some building materials (e.g., windowsills) may be further decontaminated using scarification techniques such as grinding, scabbling, and spalling. This technique is a dry decontamination method; therefore, no water or chemicals are required. A dust collection shroud attached to the scarification device would be used to control dust and debris.

For contaminated building materials, such as the roofing material on the Foundry and Warehouse, decontamination is not cost effective or implementable; therefore, the building material would be removed using conventional methods.

Building materials or debris resulting from decontamination or removal would be radiologically surveyed sampled for RCRA wastes and segregated as appropriate to provide increased disposal options and cost savings. Radioactivity levels may allow for disposal of up to 90% of building debris to a Subtitle C facility rather than a LLRW facility. Additionally, uncontaminated debris would be cleared for free release for salvage or non-radiological disposal. Bulk building debris may be segregated using waste minimization techniques similar those used for excavated soil. The inclusion of this component would further support waste minimization associated with the potential re-use or off-site disposal of radiologically impacted materials.

3.1.3.3 Building Dismantlement

Alternative 3 includes the dismantlement of Building G-1 and removal of its associated material to the slab or foundation. Dismantlement of Building G-1 would remove the potential exposures to radiological contamination from building materials and would allow remediation of the contaminated soil beneath the building. The building is currently in poor condition, and the removal would also ensure worker safety during remedial activities. Except for Building G-1, complete dismantlement is not proposed for any other OU-1 building because the radiological contamination of building material is limited to a few small areas, and there are no known soil areas above PRGs beneath the buildings.

Mechanical equipment, such as excavators or loaders, would be used to dismantle the building to the slab/foundation. This approach would require standard dismantlement practices with dust suppression to contain any potential airborne radioactivity. Water from dust suppression activities would be collected, managed, and treated on-site and discharged or disposed of at an off-site disposal facility permitted to accept the waste stream. Dismantlement areas would be maintained as potentially contaminated until radiological release surveys could be performed.

ACM was previously remediated and the waste is currently stored in Building G-1. The property owner would be required to remove and dispose of the ACM prior to any dismantlement activities. Additionally, there is a possibility of contaminated materials being present within piping and/or beneath the floor/foundations of Building G-1. Any material within or beneath the Building G-1 foundation would be handled as part of the soil removal action.

Building material or debris would be segregated to reduce the amount of waste requiring disposal at an off-site disposal facility. Segregation of waste can provide increased disposal options and cost savings given that radioactivity levels may allow for disposal of up to 90% of building debris to a Subtitle C

facility rather than an LLRW facility. Additionally, uncontaminated debris would be cleared for free release for salvage or non-radiological disposal. Bulk building debris may be segregated using waste minimization techniques similar to those used for excavated soil. The inclusion of this component would further support waste minimization associated with the potential re-use or off-site disposal of radiologically impacted materials. The estimated volume associated with the buildings is 4,540 yd^3 (3,471 m^3).

3.1.3.4 Excavation

Impacted soil above PRGs would be excavated and disposed of at a permitted off-site disposal facility. This FS assumes approximately 25% of this material would be considered characteristically hazardous. Waste minimization practices and technologies (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system) would be used to reduce the potential for disposal of below-PRG soil and are assumed to result in a 50% reduction in excavated soil requiring disposal. A 50% reduction is a conservative assumption based on actual contaminated volume reduction experienced at other FUSRAP sites. Soil below PRGs would be sampled to determine if it could be used as backfill. The material below PRGs would also be sampled to determine if it is characteristically hazardous. This FS assumes approximately 25% of the material below PRGs would be considered characteristically hazardous. This material would be segregated and coordination with the property owner would occur. Soil may require staging to sample the material for WAC prior to shipment. This would be dependent on the disposal facility. Impacted areas for OU-1, details regarding the associated excavation areas and depths, and estimated volumes are depicted in Figures 3-1 through 3-3. The total soil disposal volume (i.e., ex-situ) is estimated at 20,829 yd^3 (15,925 m^3). Standard construction equipment, such as excavators, bulldozers, and front-end loaders, would be used to remove contaminated material. In addition, special provisions, such as sheet piling, would be installed prior to excavating along the banks of the Cuyahoga River and/or Big Creek. Site preparation would include removing the existing fence if the fence is located within areas to be excavated. Fence materials would be handled in a manner similar to that for building materials.

Limited clearing and grubbing activities would be necessary to access excavation locations along the river banks. Erosion control materials, such as silt fences and straw bales, would be installed to minimize erosion. Impacted soil would be kept moist or covered with tarps to minimize dust generation. Existing pavement areas would be utilized as long as practical during excavation activities to minimize erosion and dust generation. Access/haul roads would be constructed to provide access to remote excavation. Excavation activities would be guided by various methods to detect radionuclides, including handheld radiation meters, in-situ gamma spectroscopy, and a limited quantity of analytical samples. If an active utility is encountered, an evaluation would be made to determine the potential methods for removing contaminated soil from around the utility (e.g., hand digging), and the utility would be surveyed and decontaminated to meet release criteria. If inactive, the utility would be removed and managed as waste debris. Oversized debris would be crushed or otherwise processed to meet disposal facility requirements.

Excavations may induce infiltration of groundwater/river water into the excavations. This water would be collected and analyzed for potential sanitary discharge (if permitted by the Publicly Owned Treatment Works [POTW]), treated on-site, or sent off-site for disposal at a licensed facility permitted to accept the waste stream. Provisions would be made to cover and protect the excavation areas until confirmatory sampling has been conducted and the areas have been released.

3.1.3.5 Transportation

Impacted soil and building materials/debris would be hauled to a licensed or permitted disposal facility by direct load to a railcar, trucking to a rail-loading facility, or direct trucking to the disposal facility. For direct loading to a railcar, a rail spur would be constructed at the site. This may allow for increased shipment loadings resulting in potential transportation cost savings. In addition, a rail spur would increase the overall safety and reduce overall transportation risks since the material would only be handled once. The appropriate shipping documentation would accompany the waste shipment. Regulated and licensed transportation would travel along pre-designated routes, and an emergency response plan would be developed.

3.1.3.6 Off-Site Disposal

Impacted soil and building materials/debris would be disposed of at a facility licensed or permitted to accept the characterized waste stream. The selection of an appropriate facility would consider the types of wastes, location, transportation options, and cost. Building materials and debris may require size reduction if specified in the disposal facility's WAC. This can be achieved using the dismantlement equipment (e.g., crushing with an excavator bucket). Materials, such as pipes, could be cut to conform to this requirement. Debris that does not meet this size criterion would be categorized as oversized debris.

3.1.3.7 Confirmatory Sampling

Confirmatory sampling would be conducted after the excavation of each area. This sampling would confirm PRGs have been achieved. Final status surveys would be performed for surface soil, subsurface soil, and any buildings remaining at the site after remediation, using the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) statistical sampling approach to address radiological constituents. Release surveys of building materials that are identified for reuse, recycling, or disposal in Subtitle D landfills would be evaluated using methods described in the MARSSIM.

3.1.3.8 Site Restoration

After confirmatory sampling has cleared an area, the excavation area would be in accordance with the approved Remedial Design Plan. Prior to placement, backfill would be tested to ensure design criteria are met. Confirmatory sampling and site restoration would progress area by area to minimize erosion, dust generation, and excavation water.

3.1.3.9 Five-Year Reviews

When impacted material remains on-site at levels that do not achieve unlimited use/unrestricted exposure, CERCLA requires that reviews be conducted at least every five years to ensure the remedy remains protective. Monitoring the site for any changes in land use can be part of the long-term management for the site. The five-year review process is a requirement that analyzes the implementation and effectiveness of the remedy, including any land-use controls where the controls are relied upon. In addition, the five-year reviews will evaluate whether a completed pathway exists for site groundwater to cause an exceedance of maximum contaminant levels in a current or potential source of drinking water.

3.1.4 Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)

Alternative 4 consists of excavation of impacted soil exceeding the PRGs in OU-1, ex-situ treatment by S/S, and subsequent off-site disposal. Although there are no chemical COCs associated with MED/AEC-related activities at the site, MED/AEC-related COCs may be collocated with non-MED/AEC-related chemical constituents. This may result in the waste being classified as mixed waste. The purpose of the treatment would be to render any mixed waste to a non-mixed waste state for disposal at an LLRW facility.

Building G-1 would be dismantled in order to access impacted soil beneath the building slab/foundation. Contaminated building materials above PRGs at the remaining buildings would be removed and the buildings would be returned to a safe condition. These buildings would not be dismantled, as there is not impacted soil above PRGs under the remaining buildings. This alternative would require close coordination of remediation and monitoring activities with the land owner(s) and/or tenants. This coordination aims to minimize health and safety risks to on-site personnel and disruption to activities consistent with a safe and effective remediation.

Components of this alternative include:

- Remedial Design Plan;
- Building decontamination;
- Building dismantlement;
- Excavation;
- Treatment;
- Transportation;
- Off-site disposal;
- Confirmatory sampling;
- Site restoration; and
- Five-year reviews.

All appropriate substantive requirements relating to the implementation of this alternative will be considered and addressed in the remedial design.

3.1.4.1 Remedial Design Plan

A Remedial Design Plan would be developed prior to the initiation of remedial actions. This plan would detail site preparation activities, the extent of excavation, treatment of impacted soil, implementation and sequence of remedial action activities, decontamination, and transportation and disposal of contaminated soil and restoration of the site as necessary. The plan would include provisions for excavating along the river bank (e.g., sheet piling). In addition, excavations >5 ft (1.5 m) bgs would require benching or sloping to ensure worker safety. A treatability study would be conducted to determine a suitable S/S agent for the type of soil at the site.

Short-term land-use controls would be necessary during the active construction period to ensure a safe remediation. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

3.1.4.2 Building Decontamination

Under Alternative 4, contaminated building materials above PRGs at OU-1 buildings would be decontaminated to remove radiological contamination. Several exterior portions (e.g., windowsills, wall areas, concrete caps, and roofing) of the Boiler House, Warehouse, Foundry, and Garage were found to be above PRGs and would be decontaminated using physical methods. The following summarizes the estimated extent of the radiological contamination that would need to be addressed for each of these buildings based on the results presented in Section 6.3.3 of the RI (USACE 2009):

Building	Impacted Area and Extent			
	Exterior Walls (ft^2)	Windowsills (ft^2)	Roofing/Caps (ft^2)	Roof Vent (ft^2)
Boiler House	224	102	-	-
Warehouse	-	4,410	4,410	25
Foundry	258	60	13,770	-
Garage	2	-	-	-

The primary method for decontamination of building materials would be vacuuming. HEPA vacuuming would be used to clean removable contamination from the building surfaces. HEPA vacuuming only removes loose contamination; therefore, any fixed contamination on surfaces would remain after vacuuming. Both the HEPA filters and the dust and debris would be radiologically surveyed and sampled for RCRA constituents prior to disposal. Radiological contamination surveys would be conducted after treatment to determine if building surfaces meet PRGs or if additional decontamination is necessary. Some building materials (e.g., windowsills) may be further decontaminated using scarification techniques such as grinding, scabbling, and spalling. This technique is a dry decontamination method; therefore, no water or chemicals are required. A dust collection shroud attached to the scarification device would be used to control dust and debris.

For contaminated building materials, such as the roofing materials on the Foundry and Warehouse, decontamination is not cost effective or implementable; therefore, the building material would be removed and replaced using conventional methods.

Building materials or debris resulting from decontamination or removal would be radiologically surveyed or sampled for RCRA wastes and segregated to provide increased disposal options and cost savings. Radioactivity levels may allow for diversion of up to 90% of building debris to a Subtitle C facility rather than a LLRW facility. Additionally, uncontaminated debris would be cleared for free release for salvage or non-radiological disposal. Bulk building debris may be segregated using waste minimization techniques similar to those used for excavated soil. The inclusion of this component would further support waste minimization associated with the potential re-use or off-site disposal of radiologically impacted material.

3.1.4.3 Building Dismantlement

Alternative 4 includes the dismantlement of Building G-1 and removal of its associated material to the slab or foundation. Dismantlement of Building G-1 would remove the potential exposures to radiological contamination from building materials and would allow remediation of the contaminated soil beneath the building. The building is currently in poor condition and the removal would also ensure worker safety during remedial activities. Except for Building G-1, complete dismantlement is not proposed for any other OU-1 buildings because the radiological contamination of building materials is limited to a few small areas, and there are no known soil areas above PRGs beneath the buildings.

Mechanical equipment such as excavators or loaders would be used to dismantle the building to the slab/foundation. This approach would require standard dismantlement practices with dust suppression to contain any potential airborne radioactivity. Water would be collected from dust suppression activities, managed, and treated on-site and discharged or disposed of at an off-site disposal facility permitted to accept the waste stream. Dismantlement areas would be maintained as potentially contaminated until radiological release surveys could be performed.

ACM was previously remediated and the waste is currently stored in Building G-1. The ACM would be removed and disposed of by the property owner prior to any dismantlement activities. Additionally, there is a possibility of contaminated materials being present within piping and/or beneath the floor/foundations of Building G-1. Any material within or beneath the Building G-1 foundation would be handled as part of the soil removal action.

Building material or debris would be segregated to reduce the amount of waste requiring disposal at an off-site disposal facility. For example, segregation of waste can provide increased disposal options and cost savings given radioactivity levels may allow for disposal of up to 90% of building debris to a Subtitle C facility rather than a LLRW facility. Additionally, uncontaminated debris would be cleared for free release for salvage or non-radiological disposal. Bulk building debris may be segregated using waste minimization techniques similar to those used for excavated soil. The inclusion of this component would further support waste minimization associated with the potential re-use or off-site disposal of radiologically impacted materials. The estimated volume associated with the buildings is the same as that for Alternative 3, except that the waste would be treated, thus having a larger volume. The estimated disposal volume is 5,675 yd^3 (4,339 m^3).

3.1.4.4 Excavation

Impacted soil would be excavated using conventional earth-moving equipment. This FS assumes approximately 25% of this material would be considered characteristically hazardous. Waste minimization practices and technologies (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system) would be used to reduce the potential for disposal of below-PRG soil and are assumed to result in a 50% reduction in excavated soil requiring disposal. A 50% reduction is a conservative assumption based on actual contaminated volume reduction experienced at other FUSRAP sites. Soil that has been segregated would be stockpiled in manageable segments for treatment with an S/S agent at a staging area. Treated soil would be sampled to ensure the impacted soil has been properly stabilized. Soil below PRGs would be sampled to determine if it could be used as backfill. The material below PRGs would also be sampled to determine if it is characteristically hazardous. This FS assumes approximately 25% of this material below PRGs would be considered characteristically hazardous. This material would be segregated and coordination with the property owner would occur. Stockpiles would be covered with tarps or plastic sheeting while stabilization confirmation samples are analyzed.

Impacted areas for OU-1, details regarding the associated excavation areas and depths, and estimated volumes are depicted in Figures 3-1 through 3-3. The volume of soil to be removed would be the same as that for Alternative 3; however, this soil would be treated and thus have a larger disposal volume. The total soil disposal volume (i.e., ex-situ) after treatment is estimated at 26,037 yd^3 (19,907 m^3). Standard construction equipment, such as excavators, bulldozers, and front-end loaders, would be used to excavate and treat contaminated materials. In addition, special provisions, such as sheet piling, would be installed prior to excavating along the banks of the Cuyahoga River. Site preparation would include removing the existing fence at Building G-1 since the fence is located within areas to be excavated. The fence materials would be handled in a similar manner to the building materials in the section above.

Limited clearing and grubbing activities would be necessary to access excavation locations along the river banks. Erosion control materials such as silt fences and straw bales would be installed to minimize erosion. Impacted soil would be kept moist or covered with tarps to minimize dust generation. Existing pavement areas would be utilized as long as practical during excavation activities to minimize erosion and dust generation. Access/haul roads would be constructed to provide access to remote excavation areas. Asphalt and the underlying sub-base would be removed to access impacted soil areas. Excavation activities would be guided by various methods to detect radionuclides, including handheld radiation meters, in-situ gamma spectroscopy, and a limited quantity of analytical samples. If an active utility is encountered, an evaluation would be made to determine the potential methods for removing contaminated soil from around the utility (e.g., hand digging), and the utility would be surveyed and decontaminated to meet release criteria. If inactive, the utility would be removed and managed as waste debris. Oversized debris would be crushed or otherwise processed to meet disposal facility requirements.

Excavations may induce infiltration of groundwater/river water into the excavations. This water would be collected and analyzed for potential sanitary discharge (if permitted by the POTW), treated on-site, or sent off-site for disposal at a licensed facility permitted to accept the waste stream. Provisions would be made to cover and protect the excavation areas until confirmatory sampling has been conducted and the areas have been released.

3.1.4.5 Treatment

As described above, excavated soil would be segregated using waste minimization techniques (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system) and placed in a staging area to mix and stabilize impacted soil. The staging and S/S treatment area would be equipped with berms and a sump area to manage any accumulated water. Mixing would occur with standard construction equipment (e.g., excavator). Samples would be collected to confirm stabilization was successful. Stockpiles would receive an additional stabilization agent and mixing if sample results indicate stabilization was not successful.

3.1.4.6 Transportation

Impacted soil and building materials/debris would be hauled to a licensed or permitted disposal facility by direct load to a railcar, trucking to a rail-loading facility, or direct trucking to the disposal facility. For direct loading to a railcar, a rail spur would be constructed at the site. This may allow for increased shipment loadings resulting in potential transportation cost savings. In addition, a rail spur would increase the overall safety and reduce overall transportation risks since the material would only be handled once. The appropriate shipping documentation would accompany the waste shipment. Regulated and licensed transportation would travel along pre-designated routes and an emergency response plan would be developed.

3.1.4.7 Off-Site Disposal

Impacted soil and building material/debris would be disposed of at a facility licensed or permitted to accept the characterized waste stream. The facility would be selected based on the types of wastes, location, transportation options, and cost. Building materials and debris may require size reduction if specified in the disposal facility's WAC. This can be achieved using the dismantlement equipment (e.g., crushing with an excavator bucket). Materials such as pipes could be cut to conform to this requirement. Debris that does not meet this size criterion would be categorized as oversized debris.

3.1.4.8 Confirmatory Sampling

Confirmatory sampling would be conducted after excavation of each area. This sampling would confirm PRGs have been achieved. Final status surveys would be performed for surface soil, subsurface soil, and buildings that would remain at the site after remediation, using the MARSSIM statistical sampling approach to address radiological constituents. Release surveys of building material that is identified for reuse, recycling, or disposal in Subtitle D landfills would be evaluated using methods described in the MARSSIM.

3.1.4.9 Site Restoration

After confirmatory sampling has cleared an area, the excavation area would be restored in accordance with the approved Remedial Design Plan. Prior to placement, the backfill would be tested to ensure the design criteria are met. Confirmatory sampling and site restoration can progress area by area to minimize erosion, dust generation, and excavation water.

3.1.4.10 Five-Year Reviews

When impacted material remains on-site at levels that do not achieve unlimited use/unrestricted exposure, CERCLA requires that reviews be conducted at least every five years to ensure the remedy remains protective. Monitoring the site for any changes in land use can be part of the long-term management for the site. The five-year review process is a requirement that analyzes the implementation and effectiveness of the remedy, including any land-use controls where the controls are relied upon. In addition, the five-year reviews will evaluate whether a completed pathway exists for site groundwater to cause an exceedance of maximum contaminant levels in a current or potential source of drinking water.

3.1.5 Alternative 5 - No Action (OU-2)

Alternative 5 leaves the site “as is,” with no actions taken regarding access or land-use controls beyond those already in place. This alternative provides no additional protection to human health and the environment over current conditions. This alternative also assumes existing controls and monitoring would not be maintained. The No Action alternative is required under the NCP [40 CFR §300.430(e)(6)] as a baseline against which other alternatives can be compared.

Under this alternative, impacted soil would remain at the current locations. Environmental monitoring would not be performed. In addition, no restrictions on land-use would be pursued. However, the site is assumed to operate in compliance with existing regulations that impose limitations on occupational exposures, and the existing land owners would be responsible for this compliance.

3.1.6 Alternative 6 - Limited Action and Land-Use Controls (OU-2)

Under this alternative, several forms of land-use controls, access controls, and informational tools would be used to restrict or limit future uses and activities at the site. Land-use controls would include environmental covenants applied to the land to restrict future uses of the site where concentrations of radionuclides remain above PRGs. Access control measures would be aimed at limiting access to reduce the potential for human exposure for the critical group (resident) to soil located at the site. Access controls, such as fencing, would be implemented under this alternative. Although the land-use controls would be in-place to preclude exposures to the critical group, under this alternative the land could be passive recreation (e.g., concreted bike or walking paths), and no full-time maintenance or commercial

workers would be at the recreational facility. Informational tools would include posting signs and placing placards to indicate the presence of hazardous substances and warn against intruding onto the site.

The implementation of land-use controls would eliminate the exposure pathway for potential future workers, including the construction worker, and thus reduce exposures to contaminants. However, controls would not reduce the toxicity or mobility of the contaminants, and the exposure pathway to soil, air, groundwater, or surface water would not be reduced. Site monitoring would be required to document the effectiveness of this remedial action.

Specific action items and frequencies associated with the land-use controls would be detailed in the Land-Use Control Plan prepared after the ROD. Five-year reviews would be conducted in accordance with CERCLA 121(c) for areas where contaminants are left above levels acceptable for unlimited use/unrestricted exposure. Alternative 6 is considered to be protective.

3.1.7 Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)

Alternative 7 consists of excavation of impacted soil exceeding the PRGs in OU-2 and subsequent off-site disposal. This alternative would require close coordination of remediation with the land owner(s) and/or tenants in an effort to minimize health and safety risks to any on-site personnel.

Components of this alternative include:

- Remedial Design Plan;
- Excavation;
- Transportation;
- Off-site disposal;
- Confirmatory sampling; and
- Site restoration.

All appropriate substantive requirements relating to the implementation of this alternative will be considered and addressed in the remedial design.

3.1.7.1 Remedial Design Plan

A Remedial Design Plan would be developed prior to the initiation of remedial actions. This plan would detail site preparation activities, the extent of excavation, implementation and sequence of construction activities, decontamination, transportation, and disposal of contaminated soil and site restoration. The plan would include provisions, such as benching or sloping, for excavations >5 ft (1.5 m) bgs to ensure worker safety.

Short-term land-use controls would be necessary during the active construction period to ensure a safe remediation. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

3.1.7.2 Excavation

Impacted soil above PRGs would be excavated and disposed of at a permitted off-site disposal facility. Waste minimization practices and technologies (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system) in order

to reduce the potential for disposal of below-PRG soil would be used and are assumed to result in a 50% reduction in excavated soil requiring disposal. A 50% reduction is a conservative assumption based on actual contaminated volume reduction experienced at other FUSRAP sites. Soil below PRGs would be sampled to determine if it could be used as backfill. The material below PRGs would also be sampled to determine if it is characteristically hazardous. This FS assumes approximately 10% of this material would be considered characteristically hazardous. The material that is determined to be hazardous would be segregated and coordination with the property owner would occur. Soil may require staging to sample the material for WAC prior to shipment. This would be dependent on the disposal facility. Impacted areas for OU-2, details regarding the associated excavation areas and depths, and estimated volumes are depicted in Figures 3-1 through 3-3. The total soil disposal volume (i.e., ex-situ) is estimated at 2,945 yd^3 (2,252 m^3). Standard construction equipment, such as excavators, bulldozers, and front-end loaders, would be used to remove contaminated material. Site preparation would include clearing and grubbing of the trees and vegetation to allow access to the excavation areas.

Erosion control materials, such as silt fences and straw bales, would be installed to minimize erosion. Impacted soil would be kept moist or covered with tarps to minimize dust generation. Access/haul roads would be constructed to provide access to the excavation areas and minimize erosion. Excavation activities would be guided by various methods to detect radionuclides, including the use of handheld radiation meters, in-situ gamma spectroscopy, and a limited quantity of analytical samples. If an active utility is encountered, an evaluation would determine the potential methods for removing contaminated soil from around the utility (e.g., hand digging), and the utility would be surveyed and decontaminated to meet release criteria. If inactive, the utility would be removed and managed as waste debris. Oversized debris would be crushed or otherwise processed to meet disposal facility requirements.

Excavations may induce infiltration of groundwater/river water into the excavations. This water would be collected and analyzed for potential sanitary discharge (if permitted by the POTW) and treated on-site or sent off-site for disposal at a licensed facility permitted to accept the waste stream. Provisions would be made to cover and protect the excavation areas until confirmatory sampling has been conducted and the areas have been released.

3.1.7.3 Transportation

Impacted soil would be hauled to a licensed or permitted disposal facility by direct load to a railcar, trucking to a rail-loading facility, or direct trucking to the disposal facility. For direct loading to a railcar, a rail spur would be constructed at the site. This may allow for increased shipment loadings resulting in potential transportation cost savings. In addition, a rail spur would increase the overall safety and reduce overall transportation risks since the material would only be handled once. The appropriate shipping documentation would accompany the waste shipment. Regulated and licensed transportation would travel along pre-designated routes, and an emergency response plan would be developed.

3.1.7.4 Off-Site Disposal

Impacted soil would be disposed of at a facility licensed or permitted to accept the characterized waste stream. The selection of an appropriate facility would consider the types of wastes, location, transportation options, and cost.

3.1.7.5 Confirmatory Sampling

Confirmatory sampling would be conducted after the excavation of each area. This sampling would confirm PRGs have been achieved. Final status surveys would be performed for surface and subsurface

soil that would remain at the site after remediation, using the MARSSIM statistical sampling approach to address radiological constituents.

3.1.7.6 Site Restoration

After confirmatory sampling has cleared an area, the excavation area would be restored in accordance with the approved Remedial Design Plan. Prior to placement, the backfill would be tested to ensure the design criteria are met. Confirmatory sampling and site restoration can progress area by area to minimize erosion, dust generation, and excavation water.

3.1.8 Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)

Alternative 8 consists of excavation of impacted soil exceeding the PRGs in OU-2, ex-situ treatment by S/S, and subsequent off-site disposal. Although there are no chemical COCs associated with MED/AEC-related activities at the site, MED/AEC-related COCs may be collocated with non-MED/AEC-related chemical constituents. This may result in the waste being classified as mixed waste. The purpose of the treatment would be to render any mixed waste to a non-mixed waste state for disposal at an LLRW facility.

This alternative would require close coordination of remediation and monitoring activities with the land owner(s) and/or tenants. This coordination aims to minimize health and safety risks to any on-site personnel and disruption to activities consistent with a safe and effective remediation.

Components of this alternative include:

- Remedial Design Plan;
- Excavation;
- Treatment;
- Transportation;
- Off-site disposal;
- Confirmatory sampling; and
- Site restoration.

All appropriate substantive requirements relating to the implementation of this alternative will be considered and addressed in the remedial design.

3.1.8.1 Remedial Design Plan

A Remedial Design Plan would be developed prior to the initiation of remedial actions. This plan would detail site preparation activities, the extent of excavation, treatment of impacted soil, implementation and sequence of construction activities, decontamination, and transportation and disposal of contaminated soil. In addition, excavations >5 ft (1.5 m) bgs would require benching or sloping to ensure worker safety. A treatability study would be conducted to determine a suitable S/S agent for the type of soil at the site.

Short-term land-use controls would be necessary during the active construction period to ensure a safe remediation. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

3.1.8.2 Excavation

Impacted soil would be excavated using conventional earth-moving equipment. Waste minimization practices and technologies (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system) would be used to reduce the potential for disposal of below-PRG soil and are assumed to result in a 50% reduction in excavated soil requiring disposal. A 50% reduction is a conservative assumption based on actual contaminated volume reduction experienced at other FUSRAP sites. Soil below PRGs would be sampled to determine if it could be used as backfill. The material below PRGs would also be sampled to determine if it is characteristically hazardous. This FS assumes approximately 10% of this material would be considered characteristically hazardous. This material would be segregated and coordination with the property owner would occur. After waste minimization practices, soil that has been segregated would be stockpiled in manageable segments for treatment with an S/S agent at a staging area. Treated soil would be sampled to ensure the impacted soil has been properly stabilized. Stockpiles would be covered with tarps or plastic sheeting while stabilization confirmation samples are analyzed.

Impacted areas for OU-2, details regarding the associated excavation areas and depths, and estimated volumes are depicted in Figures 3-1 through 3-3. The volume of soil to be removed would be the same as that for Alternative 7; however, this would be treated and thus have a larger disposal volume. The total soil disposal volume (i.e., ex-situ) after treatment is estimated to be 3,927 yd^3 (3,002 m^3). Standard construction equipment, such as excavators, bulldozers, and front-end loaders, would be used to excavate and treat contaminated material. Erosion control materials, such as silt fences and straw bales, would be installed to minimize erosion. Impacted soil would be kept moist or covered with tarps to minimize dust generation. Access/haul roads would be constructed to provide access to excavation areas. Excavation activities would be guided by various methods to detect radionuclides, including the use of handheld radiation meters, in-situ gamma spectroscopy, and a limited quantity of analytical samples. If an active utility is encountered, an evaluation would be made to determine the potential methods for removing contaminated soil from around the utility (e.g., hand digging), and the utility would be surveyed and decontaminated to meet release criteria. If inactive, the utility would be removed and managed as waste debris. Oversized debris would be crushed or otherwise processed to meet disposal facility requirements.

Excavations may induce infiltration of groundwater/river water into the excavations. This water would be collected and analyzed for potential sanitary discharge (if permitted by the POTW) and treated on-site or sent off-site for disposal at a licensed facility permitted to accept the waste stream. Provisions would be made to cover and protect the excavation areas until confirmatory sampling has been conducted and the areas have been released.

3.1.8.3 Treatment

As described above, excavated soil would be segregated using waste minimization practices and techniques and placed in a staging area prior to treatment by S/S. The staging and S/S treatment area would be constructed to mix and stabilize the impacted soil. This treatment area would be equipped with berms and a sump area to manage any accumulated water. Mixing would occur with standard construction equipment (e.g., excavator). Samples would be collected to confirm stabilization was successful. Stockpiles would receive an additional stabilization agent and mixing if sample results indicated stabilization was not successful.

3.1.8.4 Transportation

Impacted soil would be hauled to a licensed or permitted disposal facility by direct load to a railcar, trucking to a rail-loading facility, or direct trucking to the disposal facility. For direct loading to a railcar, a rail spur would be constructed at the site. This may allow for increased shipment loadings resulting in potential transportation cost savings. In addition, a rail spur would increase the overall safety and reduce overall transportation risks since the material would only be handled once. The appropriate shipping documentation would accompany the waste shipment. Regulated and licensed transportation would travel along pre-designated routes and an emergency response plan would be developed.

3.1.8.5 Off-Site Disposal

Impacted soil would be disposed of at a facility licensed or permitted to accept the characterized waste stream. The selection of an appropriate facility would consider the types of wastes, location, transportation options, and cost.

3.1.8.6 Confirmatory Sampling

Confirmatory sampling would be conducted after the excavation of each area. This sampling would confirm PRGs have been achieved. Final status surveys would be performed for surface and subsurface soil that would remain at the site after remediation, using the MARSSIM statistical sampling approach to address radiological constituents.

3.1.8.7 Site Restoration

After confirmatory sampling has cleared an area, the excavation area would be restored in accordance with the approved Remedial Design Plan. Prior to placement, the backfill would be tested to ensure the design criteria are met. Confirmatory sampling and site restoration can progress area by area to minimize erosion, dust generation, and excavation water.

Table 3-1. Summary of Selected Alternatives for Each Medium at the Former Harshaw Chemical Company Site

Medium-Specific Alternative	Description	Applicable OU
Soil		
Alternative S1	No Action	OU-1
Alternative S2	Land-Use Controls	OU-1
Alternative S3	Complete Removal and Off-Site Disposal	OU-1
Alternative S4	Complete Removal, Ex-Situ Treatment, and Off-Site Disposal	OU-1
Alternative S5	No Action	OU-2
Alternative S6	Land-use Controls	OU-2
Alternative S7	Complete Removal and Off-Site Disposal	OU-2
Alternative S8	Complete Removal, Ex-Situ Treatment, and Off-Site Disposal	OU-2
Buildings		
Alternative B1	No Action	OU-1
Alternative B2	Land-Use Controls	OU-1
Alternative B3	Dismantlement and Off-Site Disposal (Building G-1 only)	OU-1
Alternative B4	Decontamination (all buildings except G-1)	OU-1

OU = Operable Unit

Table 3-2. Assembly of Remedial Alternatives

Remedial Alternatives	Media Alternative Elements	OU
Alternative 1	S1 + B1	OU-1
Alternative 2	S2 + B3	OU-1
Alternative 3	S3 + B3 + B4	OU-1
Alternative 4	S4 + B3 + B4	OU-1
Alternative 5	S5	OU-2
Alternative 6	S6	OU-2
Alternative 7	S7	OU-2
Alternative 8	S8	OU-2

OU = Operable Unit

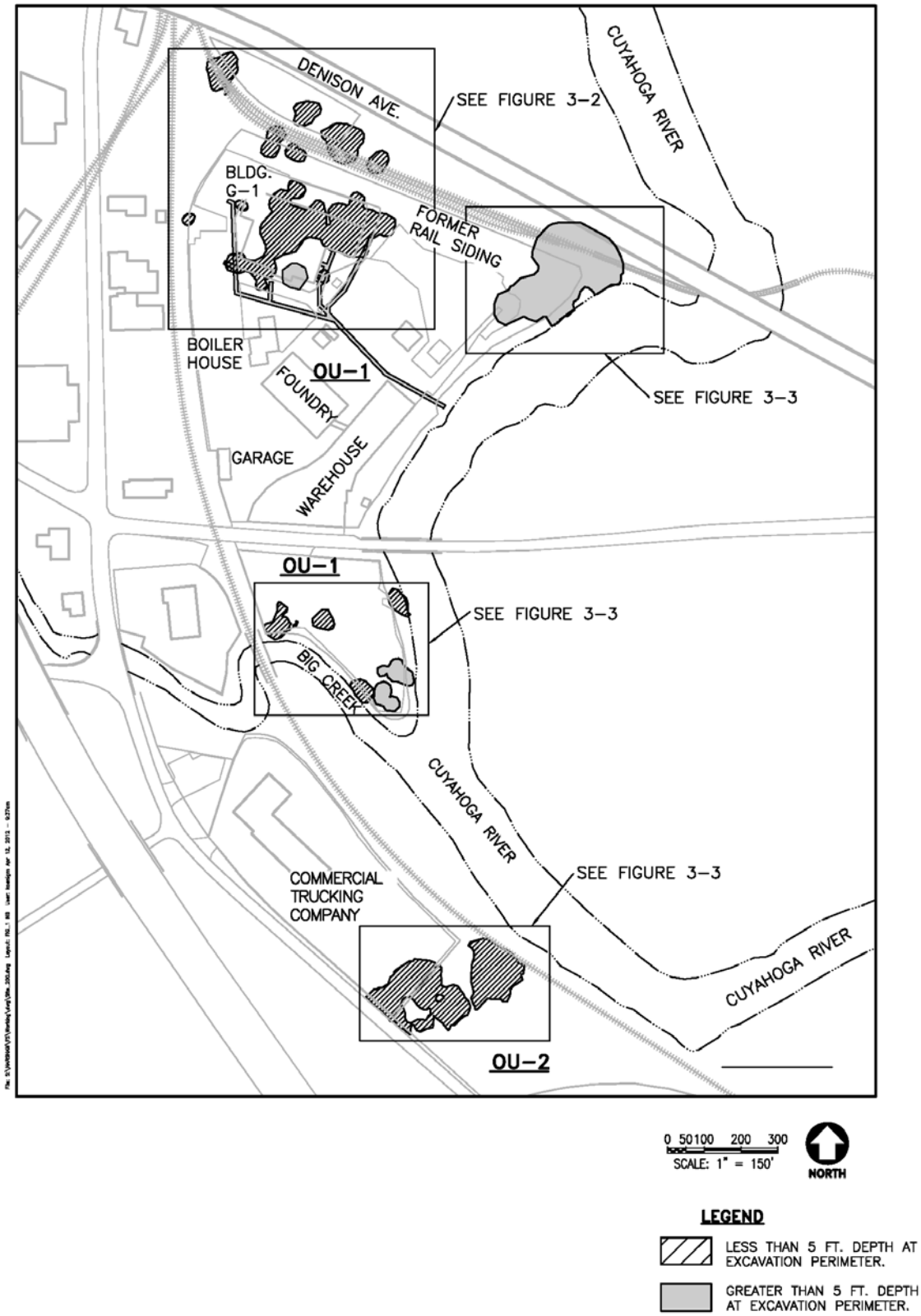

Figure 3-1. Overview of Excavation Boundaries

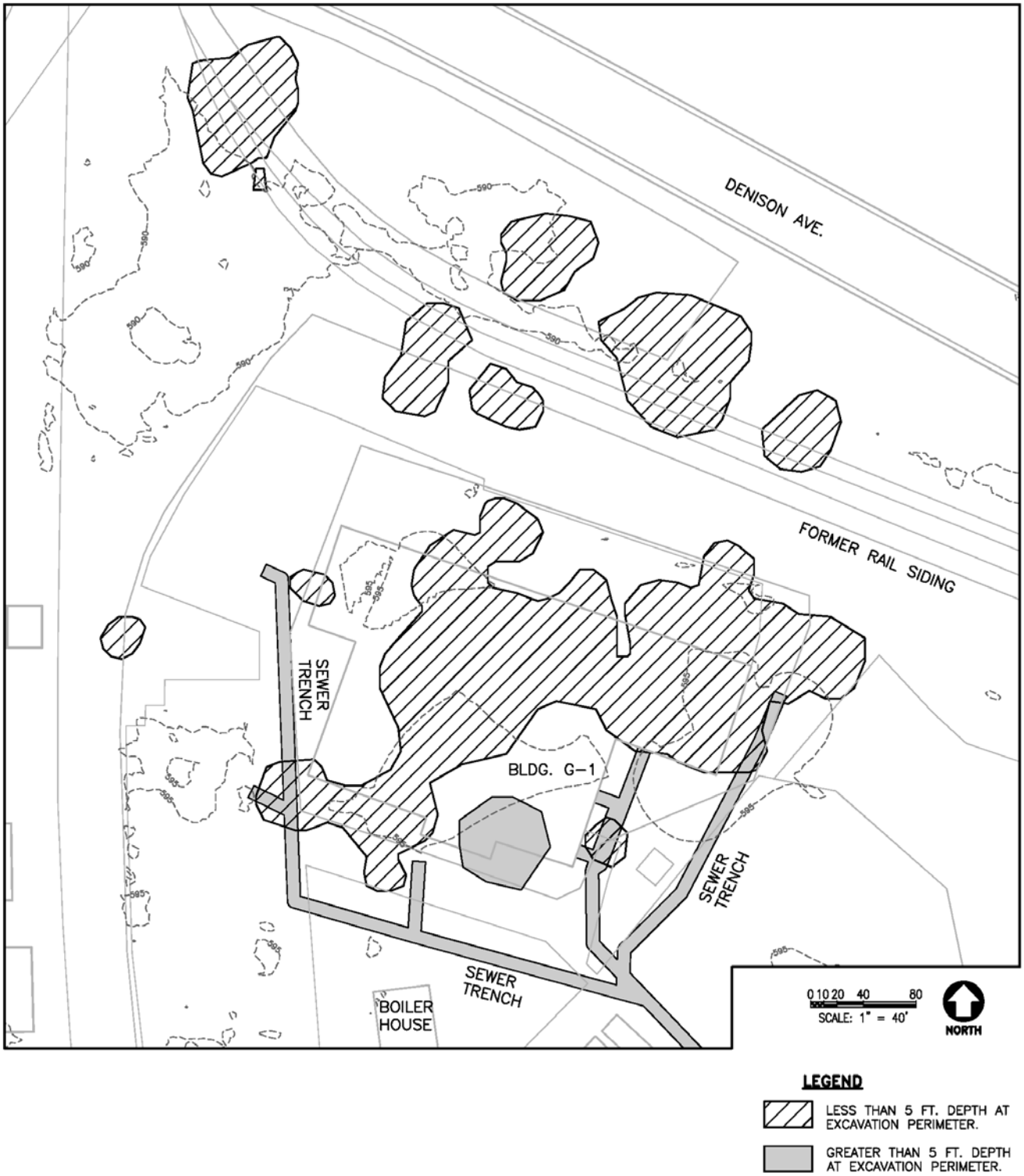

Figure 3-2. Excavation Boundary Details, OU-1 Near Building G-1

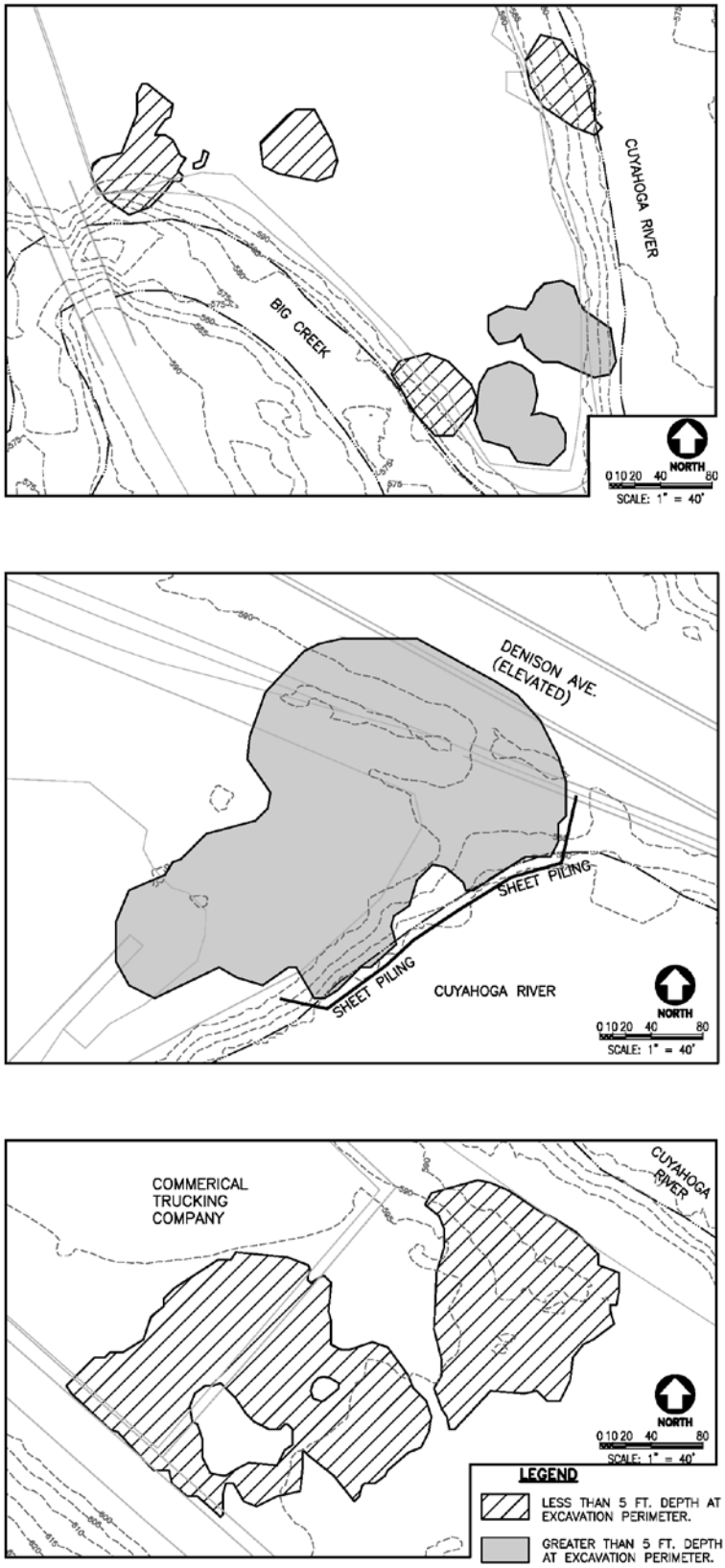

Figure 3-3. Excavation Boundaries OU-1 and OU-2

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4. DETAILED ANALYSIS OF ALTERNATIVES

4.1 INTRODUCTION

This section presents the detailed analysis of alternatives using the nine evaluation criteria from the NCP. The alternatives are analyzed individually against each criterion and then compared against one another to determine their relative strengths and weaknesses. The statutory requirements and considerations are listed below.

The statutory requirements include:

- Be protective of human health and the environment;
- Attain ARARs or provide grounds for justifying a waiver;
- Be cost-effective;
- Use permanent solutions and alternative treatment technologies to the maximum extent practicable; and
- Satisfy the preference for treatment that reduces volume, toxicity, or mobility as a principal element [40 CFR §300.430(f)(1)(c)].

In addition, long-term effectiveness and other considerations must be taken into account in evaluating each of the alternative remedial actions. These considerations include:

- Long-term uncertainties associated with land disposal;
- Goals, objectives, and requirements of the Solid Waste Disposal Act;
- Persistence, toxicity, and mobility of radionuclides and other hazardous substances and their propensity to bioaccumulate;
- Long- and short-term potential for adverse health effects from human exposure;
- Potential threat to human health and the environment associated with excavation, transportation, and disposal;
- Long-term maintenance costs; and
- Potential for future remedial action costs if the alternative being discussed were to fail [40 CFR §300.430(e)(9)].

These statutory requirements are implemented through the use of evaluation criteria presented in the NCP (40 CFR Part 300.430).

The evaluation criteria are grouped into three categories: threshold criteria, balancing criteria, and modifying criteria.

Following the descriptions of the criteria presented below is a detailed analysis of each alternative (Section 4.2), a comparative analysis to assess how the alternatives compare to each other relative to each criterion (Section 4.3), and a description of activities common to most of the alternatives (Section 4.4). Section 4.5 qualitatively assesses the potential cost benefits that could result from implementing select alternatives for OU-1 and OU-2 concurrently. Section 4.6 describes agency coordination and public involvement in the CERCLA process for the Former Harshaw Chemical Company Site. The results of the detailed evaluation of alternatives are summarized in Section 4.7.

4.1.1 Threshold Criteria

The two threshold criteria that NCP [40 CFR §300.430(f)(i)(A)] lists are overall protection of human health and the environment and compliance with ARARs. Assessments against these two criteria relate directly to statutory findings that must ultimately be made in the ROD. Threshold criteria must be met by any remedy in order to be selected.

Overall Protection of Human Health and the Environment

The assessment against this criterion describes how the alternative, as a whole, achieves and maintains protection of human health and the environment. Overall protectiveness is based largely on the degree of confidence that a remedy can achieve and maintain media-specific PRGs or reduce the potential for human and ecological exposure. The media-specific PRG that would eliminate unacceptable risk to human health and the environment for the radiological COCs is a dose of 25 mrem/yr above background. The fact that this PRG is an above-background value is implied throughout this document.

Compliance with ARARs

The assessment against this criterion describes how the alternative complies with ARARs or, if a waiver is required, provides grounds for invoking a waiver under 40 CFR 300.430(f)(1)(ii)(C). Each alternative is evaluated with respect to compliance with the ARARs established for the Former Harshaw Chemical Company Site. The ARARs identified include relevant and appropriate requirements in 10 CFR 20, Subpart E: Sections 20.1402 and 20.1403 (b), and (e). 10 CFR 20.1402 contains the radiological criteria for unrestricted use and is the ARAR for no action and removal alternatives, and 10 CFR 20.1403 contains the criteria for license termination under restricted conditions and is the ARAR for no action and limited action alternatives. 10 CFR 20.1402 requires the annual dose to an average member of the critical group to not exceed 25 mrem/yr and the residual radioactivity to be reduced to levels that are ALARA.

Requirements under 10 CFR 20.1403 (b) require provisions for legally enforceable institutional controls that provide reasonable assurance the TEDE to the average member of the critical group would not exceed 25 mrem/yr above background. The provisions of 10 CFR 20.1403(e) limit the annual dose to an average member of the critical group to 100 mrem/yr (or 500 mrem/yr, as applicable) if land-use controls are no longer in effect. The critical groups for OU-1 and OU-2 are identified in Section 4.2.

The Ohio EPA provided a list of potential ARARs to USACE on February 11, 2010 that consists of 110 citations from the Ohio Revised Code and the OAC. The list is provided in Appendix A. As indicated in Appendix A, none of these potential ARARs were identified as ARARs for this site. A more detailed discussion of the ARARs for the Former Harshaw Chemical Company Site was presented in Section 2.1.1. The final determination of ARARs will be made in the ROD.

4.1.2 Balancing Criteria

Long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost are referred to as "balancing criteria." These represent the primary selection criteria for alternatives determined to be protective of human health and the environment and in compliance with ARARs.

Long-Term Effectiveness and Permanence

The evaluation of alternatives under this criterion addresses the results of a remedial action in terms of the risk remaining at the site after RAOs have been met. The following components of this criterion are addressed for each alternative: (1) magnitude of residual risk; and (2) adequacy and reliability of controls. Alternatives that provide the highest degree of long-term effectiveness and permanence leave little or no untreated waste at the site, make long-term maintenance and monitoring unnecessary, and minimize the need for land-use controls.

Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element. This preference is satisfied when treatment is used to reduce the principal threat at a site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media.

Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until RAOs are met. Under this criterion, alternatives are evaluated with respect to their effects on human health and the environment during implementation of the remedial action. The following factors are addressed as appropriate for each alternative: (1) protection of the community during remedial actions; (2) protection of workers during remedial actions; (3) environmental impacts; and (4) time-frame until RAOs are achieved. The evaluation of short-term effectiveness includes consideration of the effectiveness and reliability of available worker protection and mitigation measures to prevent or reduce potential impacts to the community, workers, and the environment.

Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative. This criterion involves analysis of the following factors: (1) technical feasibility (construction and operation, reliability of technology, ease of undertaking additional remedial action, and monitoring considerations); (2) administrative feasibility (activities needed to coordinate with other offices and agencies); and (3) availability of services and materials during implementation of the alternative.

Cost

This assessment evaluates the capital and O&M costs of each alternative. Capital costs consist of design and construction costs. The O&M costs consist of the post-construction costs necessary to ensure the continued effectiveness of the remedy. These costs include remedial action operating costs, costs associated with maintenance, and the cost of performance evaluations, including monitoring. For

alternatives requiring monitoring and land-use controls, an O&M period of 1,000 years was used for cost estimation purposes. All costs are calculated on a present worth basis. Appendix C contains the detailed cost estimates.

4.1.3 Modifying Criteria

The two modifying criteria are state and community acceptance. Because final comments will not be received until after the FS and PP have been issued for public comment, the modifying criteria will be addressed in the responsiveness summary of the ROD.

State Acceptance

This criterion considers comments received from agencies of the state of Ohio. The primary state agencies supporting this investigation are the Ohio EPA and the Ohio Department of Health (ODH). Comments received from state agencies on the preferred remedy presented in the PP are considered in the final selection of a remedy. The responses to comments are provided in the responsiveness summary of the subsequent ROD.

Community Acceptance

This criterion addresses the comments made by the community on the alternatives being considered. Community input will be encouraged during the comment period for the PP.

4.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES

This section presents a detailed analysis of the remedial alternatives. Eight media-specific remedial alternatives were developed for the Former Harshaw Chemical Company Site. In accordance with the NCP [40 CFR §300.430(e)(9)(iii)], each alternative is assessed against seven of the nine CERCLA evaluation criteria described in Section 4.1. The eighth and ninth criteria, state and community acceptance, cannot be fully addressed until after the public comment period on the PP and will be evaluated as part of the ROD development process. The results of the detailed evaluation of the eight remedial alternatives are summarized in Table 4-1 (OU-1) and Table 4-2 (OU-2).

The concept of the “Critical Group” is used to assess if a remedial alternative can achieve compliance with ARARs. The critical group is defined in 10 CFR 20 as the “group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.” The critical groups for the OU-1 and OU-2 are the construction worker and the resident, respectively. These critical groups were selected because future land use at OU-1 is anticipated to be a combination of uses, including industrial, commercial, and recreational. Anticipated land use at OU-2 is expected to remain undeveloped; however, future planning by the city of Cleveland indicates a portion of the OU may be zoned residential. Therefore, it is assumed that OU-2 would be available for residential development.

The detailed analysis consists of a brief description of each alternative followed by an assessment relative to each of the seven evaluation criterion. The results of the detailed analysis are then used in Section 4.3 to perform a comparative analysis of alternatives relative to each of the evaluation criteria.

4.2.1 Alternative 1 - No Action (OU-1)

The No Action alternative is required by the NCP [40 CFR §300.430(e)(6)] and CERCLA guidance (USEPA 1988) to provide a baseline to which all other remedial alternatives are compared.

4.2.1.1 Description

Alternative 1 assumes no remedial actions would be implemented to address the radiological contamination in soil and building material at OU-1. Impacted soil and buildings would remain at current locations. In addition, any access controls currently in place, such as the site security fence, would not be maintained, and annual groundwater monitoring would no longer be performed. The No Action alternative provides no additional protection to human health and the environment over current conditions.

4.2.1.2 Assessment

Overall Protection of Human Health and the Environment

Alternative 1 is not protective of human health. Results of the BRA indicate several MED/AEC-related radiological constituents present in soil and building material at OU-1 pose potential unacceptable radiological dose to human receptors. Under Alternative 1, the exposure from direct contact, ingestion, and inhalation would continue and could increase since current access control measures (such as the existing site security fence) would not be maintained and no additional land-use controls would be implemented. The potential for human exposure to COCs and the potential for off-site migration could increase over time as a result of disturbances by humans and natural processes. Based on the results of the SLERA, unacceptable exposure to ecological receptors from FUSRAP constituents is negligible. Therefore, Alternative 1 is considered protective of the environment (i.e., ecological receptors).

Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 1 does not comply with the ARARs. Because no remedial action would be implemented, current conditions would not change. The current concentrations of radionuclides in the soil and buildings at OU-1 exceed the ARAR-based PRGs. 10 CFR Part 20 Subpart E is the potential chemical-specific ARAR at the site. The relevant and appropriate requirements in 10 CFR 20, Subpart E are Sections 20.1402 and 20.1403 (b) and (e). Alternative 1 would not comply with the unrestricted release provisions of Sections 20.1402, which require that the annual dose to an average member of the critical group does not exceed 25 mrem/yr and that the residual radioactivity be reduced to levels that are ALARA. Alternative 1 also would not comply with the restricted release provisions of 10 CFR 20.1403(b), which mandate enforceable institutional controls that provide reasonable assurance that the annual dose to an average member of the critical group does not exceed 25 mrem/yr. Implementation of such controls cannot be accomplished under the No Action alternative. For the soil and building materials at OU-1, the critical group, based on assumed industrial future land use, is the construction worker. The release conditions in 10 CFR 20.1403(e) limit the annual dose to an average member of the critical group to 100 mrem/yr (or 500 mrem/yr, as applicable) if land-use controls are no longer in effect. The dose to the average member of the critical group (7,473 mrem/yr for the construction worker at Building G-1) exceeds this dose limit. Alternative 1 does not comply with the ARAR.

Long-Term Effectiveness and Permanence

Alternative 1 would allow contamination to remain on-site. Potential future exposures would remain at unacceptable levels because potential exposures currently exceed target levels and none of the contaminated soil or buildings would be remediated. In addition, Alternative 1 includes no long-term measures to prevent exposures to or spread of contamination. Although the existing site security fence could limit exposure to site contaminants, this alternative assumes that controls would not be maintained and provides no additional controls to prevent or reduce exposure to contaminants. Over a period of time, natural processes (such as radioactive decay and wind or surface water erosion) would result in some contaminant mass reduction on-site; however, this process would be slow and would not be monitored. Under the current and expected future land-use scenarios, there are potential exposures to human health if contamination remains in place. Therefore, Alternative 1 would not be effective in the long term and would not achieve any level of permanence.

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

No reduction in contaminant toxicity, mobility, or volume through treatment is achieved because no treatment process is proposed under Alternative 1.

Short-Term Effectiveness

There are no short-term risks associated with Alternative 1 beyond baseline conditions. There would be no additional short-term health risks to the community, site workers, or the environment because no remedial actions would be implemented.

Implementability

No actions are required for this alternative.

Cost

This alternative is the baseline scenario and requires no action. Therefore, the present value cost of this alternative is $0.

4.2.2 Alternative 2 - Limited Action and Land-Use Controls (OU-1)

4.2.2.1 Description

Alternative 2 is a limited action alternative consisting of the dismantlement of Building G-1, the off-site disposal of the Building G-1 debris, bank stabilization, land-use controls, site monitoring, and five-year reviews. Under this alternative, Building G-1 would be removed, but the remaining impacted media at OU-1 would be left in place, with no other active remedial measures implemented involving removal. The estimated ex-situ building volume that would be disposed of is 4,800 yd^3 (3,670 m^3). A detailed description of Alternative 2 was provided in Section 3.1.2.

The BRA concluded the exposure of certain potential receptors (residential adult, industrial worker, maintenance worker, construction worker, and subsistence farmer) to contaminated soil, buildings, or groundwater at the site could result in radiological doses above acceptable dose limits. Under this alternative, several forms of land-use controls, including institutional controls and physical controls (such as fences), would be implemented to eliminate or reduce potential exposure pathways. The only land uses

allowed under this alternative would be passive recreation (e.g., concreted bike or walking paths) and no full-time maintenance or commercial workers would be at the recreational facility.

Under Alternative 2, access to impacted soil would be controlled through appropriate land-use controls, consisting of both engineering and institutional controls. The existing engineering controls include fencing and signs. Existing institutional controls include property zoning which excludes residential use of the OU-1 properties, state restrictions on the installation of wells for drinking water purposes, and site access procedures that prevent unauthorized entry in hazardous areas. Under Alternative 2, these existing controls would be maintained. If necessary, an additional aluminized steel chain link fence would be installed to restrict access to areas not included in any developed passive recreational areas (e.g., planned canal bike path/walking path corridor).

Signs and placards warning of the presence of hazardous substances would be installed to further reduce the potential for human exposure. Additional institutional controls would be implemented for those areas where hazardous substances, pollutants, or contaminants remain above levels needed to meet PRGs. The objectives of the additional institutional controls and examples of the implemented controls controls that could achieve these objectives include the following:

- To prevent or reduce potential exposures to current and future maintenance, industrial, and construction workers, the land-use controls could also include restrictive covenants that would prevent construction or maintenance activities, such as drilling, boring, trenching, digging, or earth moving in areas with contaminated soil, or manage these activities such that the exposures would be minimal.

- To ensure controls are adequately maintained, property easements could be negotiated with landowners to provide for the property access necessary for site inspections and the maintenance of engineering controls.

- To ensure continued protectiveness in the event of a change in property ownership, the controls would require landowners to notify the government prior to any change in ownership of the property. Proprietary land-use controls would be designed to be binding for subsequent landowners and transferable ("run with the land").

- To provide information concerning the presence and location of contaminated soil, a variety of informational tools could be used, including deed notices, state registries, land-use control tracking systems, or advisories.

These land-use controls, if properly maintained and enforced, minimize exposure risks due to contaminated soil, buildings, and groundwater at OU-1. A Land-Use Control Plan would be developed after the ROD approval to describe the controls, including environmental covenants, and would include notification requirements for changes in land use.

Site monitoring would be conducted to document the effectiveness of this remedial action. Monitoring would involve periodic inspections of the interior and exterior of the buildings and the properties conducted during the five-year reviews to evaluate and document any changes to site conditions. Five-year reviews would be required under Alternative 2. Consistent with the NCP [40 CFR §300.430(f)(4)(ii)], five-year reviews must be conducted at sites where the remedy does not allow for unlimited use/unrestricted exposure. The five-year reviews would help ensure controls are maintained and the remedy remains protective of human health and the environment.

4.2.2.2 Assessment

Overall Protection of Human Health and the Environment

Alternative 2 is protective of human health with the use of land-use controls to preclude use by the critical receptor (construction worker receptor for industrial land-use) so as to meet the ARARs, which are presumed to be protective, for the restricted use of the operable unit. As discussed below regarding compliance with ARARs, should these land-use controls fail, the ARAR standards are met and thus considered to be protective. Land-use controls would ensure human health protectiveness by limiting direct access to contaminated soil and buildings for the critical group (construction worker). The controls would be used to prevent or reduce potential exposures to current and future maintenance, industrial, and construction workers by preventing construction or maintenance activities, such as drilling, boring, trenching, digging, or earth moving in areas with contaminated soil, or managing these activities such that the exposures would be minimal. The environmental covenants would ensure the public is not exposed to unacceptable health risks, and future land owners would be aware of the environmental conditions of the property prior to purchase. Although the land-use controls would be in-place to preclude exposures to the critical group, passive recreational use of the OU would be acceptable and protective and could be allowed by the land-use controls. The overall protection of human health is maintained even if the land-use controls are lost since the exposure to the critical group under those conditions would meet the ARAR criteria as discussed below. Therefore, Alternative 2 is protective of human health.

Based on the results of the SLERA, no remedial action involving removal is required to address ecological exposures. Because no active remediation is conducted under Alternative 2, there would be no loss of vegetation, disruption of soil, or increased erosion resulting from remedial action. Alternative 2 includes bank stabilization for the purpose of minimizing the potential for bank erosion and subsequent release of MED/AEC-related constituents into the creek or river which might result in ecological exposures, thus impacting the environment. Alternative 2 does not prevent the leaching of contaminants to groundwater from contaminated soil. The groundwater modeling results demonstrate groundwater conditions do not further degrade over the 1,000-year period, and therefore, would not significantly impact the environment (Appendix D). No unacceptable risk or radiological dose to ecological receptors from groundwater contamination were identified during the RI or in the Groundwater Flow and Contaminant Transport Modeling report (Appendix D). Therefore, Alternative 2 is protective of the environment.

Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 2 would comply with ARARs identified for limited action alternatives. Alternative 2, which includes the removal of Building G-1, would achieve the restricted release standard under 10 CFR 20.1403, which requires that residual radioactivity results in a TEDE to an average member of the critical group that does not exceed 25 mrem/yr. This assumes land-use controls, including access restrictions and digging/drilling restrictions, are maintained in order to limit exposures to contaminated soil. 10 CFR 20.1403 also requires residual radioactivity at the site to be reduced so that if the institutional controls are lost, there is reasonable assurance that the TEDE would not exceed 100 mrem/yr. Building G-1 dismantlement and shipment off-site is a necessary component of this alternative to meet this ARAR. Without removal of the building, the potential dose, should institutional controls be lost, would be in excess of 7,000 mrem/yr. If controls are lost under Alternative 2 after removal of Building G-1, the dose to the average member of the critical group at OU-1 (39 mrem/yr for the construction worker) would not exceed this dose limit. Therefore, Alternative 2 would be compliant with this ARAR.

Long-Term Effectiveness and Permanence

Alternative 2 relies on building dismantlement, land-use controls, site monitoring, and five-year reviews to eliminate or reduce exposures to contaminants. Alternative 2 would reduce the amount of contaminated material remaining on-site through the dismantlement of Building G-1 and the off-site disposal of the building debris. Future exposure to the contaminated soil remaining on-site would be maintained at acceptable levels through the implementation and maintenance of land-use controls. It is reasonably expected that land-use controls can be implemented and would be effective in protecting human health but would not result in a permanent reduction in site exposure unless the controls are maintained perpetually. However, the NCP [40 CFR §300.430(a)(1)(iii)(D)] states that "institutional controls shall not substitute for active response measures…as the sole remedy unless active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during the section of [the] remedy."

There are uncertainties regarding the ability of land-use controls to ensure protectiveness over the long term. Due to the slow rate of radioactive decay, land-use controls would have to be maintained and enforced over a long time period. For purposes of this document, it is assumed the land-use controls would be required for a period of 1,000 years. Over the 1,000-year period, erosion and undermining of the river bank during flooding episodes could result in disturbance and migration of contamination and possible subsequent release. Under this alternative, there would be engineering controls put into place to preclude/minimize river bank erosion. In addition, it is expected that land ownership would change over this time period, making maintenance and enforcement of the controls more uncertain.

Mitigative measures would be taken to reduce the uncertainties regarding land-use controls. The proprietary land-use controls would be structured to be binding and transferable for subsequent landowners. In addition, Alternative 2 includes requirements to verify the maintenance of the land-use controls through continued site monitoring (surveillance) to identify any changes in site conditions that affect protectiveness. The long-term roles and responsibilities for monitoring, maintaining, and enforcing the land-use controls would be specified in the Land-Use Control Plan. Five-year reviews would be conducted to evaluate the effectiveness of land-use controls and to ensure any land-use changes are identified. The long term effectiveness and permanence of Alternative 2 is rated moderate.

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

No reduction in contaminant toxicity, mobility, or volume through treatment is achieved because no treatment process is proposed under Alternative 2.

Short-Term Effectiveness

Alternative 2 is highly effective in the short term. There could be short-term risks to remediation workers due to potential exposures during remediation activities associated with the dismantlement of Building G-1, but the risks would be mitigated through the use of good safety practices and personal protective equipment (PPE). Air monitoring at the work site and at the perimeter of the site would be used to identify potential off-site risks to workers and the neighboring community during building dismantlement activities. Some minimal short-term risks to the surrounding community would result from the transport of building wastes off-site through nearby residential areas. The transportation of approximately 4,800 yd^3 (3,670 m^3) of contaminated building materials to an off-site disposal location is required as part of this alternative, which presents transportation-related risks. Dispersal and subsequent exposures to contaminated materials would be mitigated by packaging them in accordance with DOT regulations to ensure the contents remain safely enclosed in the event of an accident. A site-specific health and safety

plan would address potential exposures and monitoring requirements to ensure protection of the workers and community. Because Alternative 2 would make use of land-use controls rather than active soil remediation to minimize exposures to contaminated soil, potential adverse short-term impacts to the community, workers, or the environment due to excavation activities are avoided. There may be potential short-term risks to workers during the periodic monitoring activities and the installation/maintenance of fences and signage; however, the risk is considered minimal. Alternative 2 would require less than one year to implement, but would include a 1,000-year O&M period during which periodic site monitoring and five-year reviews would be conducted. However, the NCP [40 CFR §300.430(a)(1)(iii)(D)] states that "institutional controls shall not substitute for active response measures…as the sole remedy unless active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during the section of [the] remedy."

Implementability

The materials and services needed to implement Alternative 2 are readily available. Building dismantlement and off-site disposal can be accomplished using conventional equipment and would be easily implemented. Bank stabilization techniques are common practice. Land-use controls are readily available and proven methods of addressing exposures. Installation of physical controls (e.g., fences, signs) and monitoring pose no significant technical difficulties. Therefore, Alternative 2 is rated high in technical implementability.

Given that the Federal government does not own the property, some of the land-use controls may be administratively difficult to implement. Implementation of land-use controls would require involvement of the local government and the land owners. There could be difficulties implementing land-use controls due to multiple land owners. One type of land-use control that would be implemented under Alternative 2 is a restrictive covenant. Restrictive covenants require the consent of the owner of each property to which a restrictive covenant is applied. USACE has not secured property owner approval or authorization to acquire such interests in the property to establish appropriate land-use controls; these agreements would be required prior to the approval of the ROD in order to establish the types of land-use controls that would be implemented at each property and to identify the parties that would be responsible for securing, maintaining, and enforcing the controls. Uncertainties concerning whether the landowners would be willing to accept and comply with the terms of these agreements make this alternative difficult to implement administratively. Therefore, Alternative 2 is rated low for administrative implementability.

The overall implementability rating is based on the lower of the technical and administrative implementability ratings. Therefore, the overall implementability of Alternative 2 is rated low, based on the low administrative implementability.

Cost

The estimated total cost (present worth) for Alternative 2 over the 1,000-year period is $12,406,557. The total cost would include the dismantlement of Building G-1 and the off-site disposal of the building debris, bank stabilization using riprap, implementation and maintenance of land-use controls, preparation of a site monitoring plan, site monitoring and the performance of five-year reviews. Estimated capital costs of $11,320,378 include the costs associated with the dismantlement of Building G-1 and the off-site disposal of the building debris, bank stabilization using riprap, as well as administrative costs associated with planning, implementing, monitoring and enforcing land-use controls for the first year, preparation of a site monitoring plan, and installation of physical land-use controls (i.e., fence, signs, gate). O&M costs of $1,086,179 are estimated for a 1,000-year period. The estimated total non-discounted cost for Alternative 2 over a 1,000-year period is $56,604,601 which includes capital costs of $11,320,378 and

O&M costs of $45,284,223. Additional detailed cost information may be found in Table C-3 in Appendix C of this FS Report.

4.2.3 Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)

4.2.3.1 Description

Alternative 3 consists of excavation of impacted soil exceeding the PRGs in OU-1 and subsequent off-site disposal to a properly permitted off-site disposal facility, consistent with disposal site WAC. Approximately 25,636 yd^3 (19,600 m^3) of impacted soil (in-situ) would be excavated from OU-1. Special precautions, including the installation of sheet piling, would be taken prior to excavating along the banks of the Cuyahoga River to reduce the environmental impacts to the river. The soil would be staged at an on-site staging area and processed through a waste minimization practice and technology. The estimated ex-situ soil and building volumes (after waste minimization practices) are 20,829 yd^3 (15,925 m^3) and 4,540 yd^3 (3,471 m^3), respectively. A detailed description of Alternative 3 was provided in Section 3.1.3.

Based upon previous volume reduction experience at other FUSRAP sites, the cost estimate for this alternative assumes 50% of the material processed through the waste minimization practices and technologies (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system) would be above PRGs. The material that is above PRGs would be sampled in accordance with the disposal facility's WAC. For the purposes of this FS, it is assumed that approximately 25% of the material above the PRGs would also be considered characteristically hazardous waste and would require disposal as mixed LLRW. This assumption is based on the history of operations at the site when metals were used extensively as part of the commercial process. The material below PRGs would also be sampled to determine if it is characteristically hazardous. This FS assumes that approximately 25% of this material would be considered characteristically hazardous. This material would be segregated and coordination with the property owner would occur. Non-hazardous material below PRGs would be used as backfill at the site. The material to be shipped to an off-site disposal facility would be placed in intermodal containers and sent by truck to a transfer facility (an off-site railcar loading facility) for shipment to the disposal facility. Additional information concerning intermodal transport is provided in Appendix C. There is a potential for cost savings should the material being shipped off-site meet the WAC for Subtitle C facilities, as discussed in Sections 2.3.1.5.2 and 2.3.2.6. There are uncertainties associated with what volume, if any, could be shipped to such facilities; therefore, the cost estimates assume the total volume would be shipped to a radioactive-licensed facility for disposal.

In addition, Building G-1 would be dismantled to allow for removal of contaminated building materials and to access impacted soil beneath the building slab/foundation. Building materials that exceed the PRGs at the remaining buildings at OU-1 would be removed. Building material, such as brick and concrete, would be crushed on-site and processed through the waste minimization practices. All remediated areas would be restored at the completion of the project. Cleanup levels would achieve the unrestricted release standards in 10 CFR 20.1402. Alternative 3 would also include five-year reviews to verify continued protectiveness. Additional details and assumptions regarding this alternative are presented in the Key Parameters and Assumptions Table in Appendix C.

4.2.3.2 Assessment

Overall Protection of Human Health and the Environment

Alternative 3 is protective of human health and the environment. Removal of radiologically contaminated soil would achieve the PRGs at OU-1 and would limit risks from exposure to contaminated soil to within acceptable levels. Contaminated building materials above PRGs at OU-1 buildings would be decontaminated to remove radiological contamination. The primary methods for decontamination of building materials would be vacuuming and scabbling. Radiological contamination surveys would be conducted after treatment to determine if building surfaces meet PRGs or if additional decontamination is necessary. Where decontamination is not cost effective or implementable, the building materials would be removed using conventional methods. Soil and building materials exceeding the PRGs would be placed in a properly permitted off-site disposal facility that would provide for protective management and appropriate monitoring of potential releases of any residual contaminants. Environmental protection at the site would be enhanced by removal of the contaminated material off-site.

Groundwater contamination is present in the shallow aquifer beneath OU-1. However, groundwater is not an exposure pathway based on the critical group selected for OU-1. Additionally, the removal of the soil contamination beneath and in the vicinity of Building G-1, as well as removal of the soil contamination located in other areas of OU-1, would remove potential sources of groundwater contamination and is expected to have a beneficial effect on contaminant levels in groundwater over time. The update to the groundwater flow and contaminant transport modeling contained in Appendix D concluded that (1) the proposed soil PRGs for total uranium, thorium-230, thorium-232, and radium-226 in OU-1 are protective of groundwater in that the residual soil concentrations will not result in any further degradation of the groundwater; and (2) model simulations predict minimal transport of or change in the total uranium plume over the 1,000-year period of the FS alternatives. Groundwater is currently not used at the site for drinking water or industrial purposes. Future use of groundwater as a drinking water source is unlikely because the water-bearing zone below the site generally has poor quality and low well yields and sufficient municipal water supplies are available. In addition, existing governmental restrictions would make current or future exposures to the existing groundwater contamination unlikely. Under Ohio's VAP, because the Former Harshaw Chemical Company Site is situated within the buffer zone of two USDs for Cleveland, Ohio, no new groundwater wells are permitted at the site for drinking water purposes.

Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 3 would comply with ARARs identified for complete removal alternatives. It would achieve the unrestricted release conditions of 10 CFR 20.1402, which require residual radioactivity that is distinguishable from background radiation to result in a TEDE that does not exceed 25 mrem/yr for an average member of the critical group. Alternative 3 would ensure that the maximum dose to the average member of the critical group at OU-1 (the construction worker) would not exceed the 25 mrem/yr dose limit through the removal and off-site disposal of contaminated media exceeding the PRGs. An ALARA analysis would be performed as part of the remedial design to ensure the remedy achieves residual levels of contamination that are ALARA. Therefore, Alternative 3 would be compliant with this ARAR.

Long-Term Effectiveness and Permanence

Under Alternative 3, the excavation and removal of contaminated soil and building material would be effective in the long term and result in a permanent reduction in site exposure. The magnitude of residual exposure to MED/AEC-related constituents would be low because this alternative would leave only

acceptable concentrations of MED/AEC-related constituents (below the PRGs) at OU-1. Industrial land use would continue at OU-1 to prevent inappropriate use of the property and would be verified through the five-year review process. This alternative is rated high for long-term effectiveness and permanence.

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Waste minimization practices proposed under Alternative 3, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal.

Short-Term Effectiveness

The excavation, transport, and disposal activities under Alternative 3 could pose short-term risks to site workers and surrounding community. There could also be short-term risks due to potential exposures to remediation workers during the decontamination and building dismantlement activities. Air quality could be affected by release of particulates during soil excavation. To minimize dust generation during excavation activities, impacted soil would be kept moist or covered with tarps. If dry building decontamination methods are used, a dust collection shroud would be used to control dust and debris. The short-term risks to workers resulting from remediation activities would be mitigated through the use of good safety practices and PPE. There is a slight potential for an increase in short-term risks to the surrounding community from excavation and dismantlement activities due to fugitive dust generation, but risks would be controlled by mitigative measures. In addition, air monitoring would be conducted at the work site and the site perimeter to ensure the health of workers and the surrounding community. Some minimal short-term risks to the surrounding community would result from the transport of wastes off-site through nearby residential areas. The transportation of approximately 20,829 yd^3 (15,925 m^3) of contaminated soil and 4,540 yd^3 (3,471 m^3) of contaminated building materials to an off-site disposal location is required as part of this alternative, which presents transportation-related risks. Dispersal and subsequent exposures to contaminated material would be mitigated by packaging them in accordance with DOT regulations to ensure the contents remain safely enclosed in the event of an accident. A site-specific health and safety plan would address potential exposures and monitoring requirements to ensure protection of the workers and community.

Short-term environmental impacts (such as loss of vegetation, disturbance of soil, and increased erosion) could result from Alternative 3. Excavation would potentially negatively impact animals and plants at the excavated locations and disturb existing features of the environment that may provide habitat or food to plants and animals. If needed, erosion control materials such as silt fences and straw bales would be installed to minimize erosion and reduce surface water runoff during excavation activities. Special precautions, including the installation of sheet piling, would be taken prior to excavating along the banks of the Cuyahoga River to reduce environmental impacts to the river.

The amount of time to achieve RAOs is relatively short (approximately 2 to 3 years, assuming funding is available) but the remediation timeframe also includes an O&M period of 1,000 years for performance of five-year reviews. Because remediation activities would involve short-term risks to the community and workers, but mitigative measures would be taken to minimize exposure, this alternative is rated moderately effective in the short term.

Implementability

Alternative 3 would be technically easy to implement. No specialized equipment, personnel, or services are required. Soil excavation, transport, and disposal activities use readily available resources and conventional earthmoving equipment. Decontamination is a conventional method of remediating

radiologically contaminated structures and would be easily implemented. Decontamination equipment and trained personnel are readily available. Therefore, the technical implementability of Alternative 3 is rated high.

No administrative problems are anticipated that would limit the implementability of Alternative 3. This alternative would require some coordination of remediation activities with the land owner(s) and/or tenants to minimize health and safety risks to on-site personnel, but it is expected this would be successfully accomplished. In addition, no problems related to obtaining approvals from other agencies are expected for this alternative. Therefore, Alternative 3 is rated high for administrative implementability.

Cost

The estimated total cost (present worth) for Alternative 3 over a 1,000-year period is $55,185,927. This includes capital costs of $55,034,232 and O&M costs of $151,694. The capital costs include preparation of a remedial design plan, building decontamination, building dismantlement, excavation, confirmatory sampling, transport, off-site disposal, site restoration, and preparation of a remedial action completion report. The O&M costs include the cost for performance of five-year reviews. The estimated total non-discounted cost for Alternative 3 over a 1,000-year period is $61,829,592, which includes capital costs of $55,034,232 and O&M costs of $6,795,360. Detailed information concerning the costs is provided in Appendix C.

4.2.4 Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)

4.2.4.1 Description

Alternative 4 consists of excavation of impacted soil exceeding the PRGs in OU-1, ex-situ treatment by S/S, and subsequent transport to a properly permitted off-site disposal facility consistent with disposal site WAC. Similar to Alternative 3, approximately 25,636 yd^3 (19,600 m^3) of impacted soil (in-situ) would be excavated from OU-1 and transported to an on-site staging area and processed using waste minimization practices and technologies (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system). Based on previous volume reduction experiences at other FUSRAP sites, the cost estimate for this alternative assumes 50% of the material processed through the waste minimization practices and technologies would be above PRGs. The estimated ex-situ soil and building volumes (after waste minimization and soil stabilization practices) are 26,037 yd^3 (19,907 m^3) and 5,675 yd^3 (4,339 m^3), respectively. A detailed description of Alternative 4 was provided in Section 3.1.4.

The material that is above PRGs would be sampled in accordance with the disposal facility's WAC. For the purposes of this FS, it is assumed approximately 25% of the material above the PRGs would also be considered characteristically hazardous waste and would require disposal as mixed LLRW. This assumption is based on the history of operations at the site during which metals were used extensively as part of the commercial process. The material below PRGs would also be sampled to determine if it is characteristically hazardous. This FS assumes approximately 25% of this material would be considered characteristically hazardous. This material would be segregated and coordination with the property owner would occur. Non-hazardous material below PRGs would be used as backfill at the site.

S/S has been proven to greatly reduce the mobility of the contaminants by binding them in a concrete-like, leach-resistant matrix; however, it does increase the overall volume of waste material that must be dispositioned. Contaminated waste materials are collected, screened to remove oversized

material, and introduced to a batch mixer where the wastes are mixed with water, chemical additives, and fly ash, kiln dust, or cement. Samples of the treated materials would be collected and analyzed to confirm stabilization was successful and to determine the proper disposition of the treated waste. The treated waste would then be manifested and transported (intermodal) to an off-site transfer station for shipment by rail to a licensed, off-site disposal facility. There is a potential for cost savings should the material being shipped off-site meet the WAC for Subtitle C facilities, as discussed in Sections 2.3.1.5.2 and 2.3.2.6; however, there will be an increase in the volume to be shipped. There are uncertainties associated with what volume, if any, could be shipped to such facilities; therefore, the cost estimates assume the total volume would be shipped to a radioactive licensed facility for disposal.

In addition, Building G-1 would be dismantled to allow for removal of contaminated building materials and to access impacted soil beneath the building slab/foundation. The building debris would be crushed on-site and processed through the waste minimization practices and technologies. As with the impacted soil, it is assumed that 50% of the debris passing through the waste minimization practices would be above PRGs. The material to be shipped to the off-site disposal facility would be placed in intermodal containers and sent by truck to a transfer facility (an off-site railcar loading facility) for shipment to the disposal facility. Contaminated building material above PRGs at the remaining buildings would be removed. Confirmation sampling would be performed to verify PRGs are achieved. All remediated areas would be restored at the completion of the project. Cleanup levels would achieve the unrestricted release standards in 10 CFR 20.1402. Alternative 4 would also include five-year reviews to verify continued protectiveness. More information concerning each component of this alternative is presented in Appendix C.

4.2.4.2 Assessment

Overall Protection of Human Health and the Environment

Alternative 4 is protective of human health and the environment. Removal of radiologically contaminated soil would achieve the PRGs in OU-1 and would limit risks from exposure to contaminated soil. Contaminated building material above PRGs at OU-1 buildings would be decontaminated to remove radiological contamination. The primary method for decontamination of building material would be vacuuming and scabbling. Radiological contamination surveys would be conducted after treatment to determine if building surfaces meet PRGs or if additional decontamination is necessary. Where decontamination is not cost effective or implementable, building material would be removed using conventional methods. The building material and soil that do not meet the PRGs would be placed in a properly permitted off-site disposal facility that would provide for protective management and appropriate monitoring of potential releases of any residual contaminants.

Groundwater contamination is present in the shallow aquifer beneath OU-1. However, groundwater is not an exposure pathway based on the critical group selected for OU-1. Additionally, the removal of the soil contamination beneath and in the vicinity of Building G-1, as well as removal of the soil contamination located in other areas of OU-1, would remove potential sources of groundwater contamination and is expected to have a beneficial effect on contaminant levels in groundwater over time. The update to the Groundwater Flow and Contaminant Transport Modeling Report (Appendix D) concluded that (1) the proposed soil PRGs for total uranium, thorium-230, thorium-232, and radium-226 in OU-1 are protective of groundwater; and (2) model simulations predict very little transport of or change in the total uranium plume over the 1,000-year period of the FS alternatives. Groundwater is currently not used at the site for drinking water or industrial purposes. Future use of groundwater as a drinking water source is unlikely because the water-bearing zone below the site generally has poor quality and low well yields and sufficient municipal water supplies are available. In addition, existing governmental restrictions would

make current or future exposures to the existing groundwater contamination unlikely. Under Ohio's VAP, because the Former Harshaw Chemical Company Site is situated within the buffer zone of two USDs for Cleveland, Ohio, no new groundwater wells are permitted at the site for drinking water purposes.

Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 4 would comply with ARARs identified for complete removal alternatives. It would achieve the unrestricted release conditions of 10 CFR 20.1402, which require residual radioactivity that is distinguishable from background radiation to result in a TEDE that does not exceed 25 mrem/yr for an average member of the critical group. Alternative 4 would ensure the maximum dose to the average member of the critical group at OU-1 (the construction worker) would not exceed the 25 mrem/yr dose limit through the removal, treatment, and off-site disposal of contaminated media. An ALARA analysis would be performed as part of the remedial design to ensure the remedy achieves residual levels of contamination that are ALARA. Therefore, Alternative 4 would be compliant with this ARAR.

Long-Term Effectiveness and Permanence

Alternative 4 would achieve long-term effectiveness and permanence because contaminated media at OU-1 would be removed, treated, and disposed of in a properly permitted off-site disposal site. The off-site disposal would permanently reduce contaminant concentrations at OU-1 to provide protection of human health and the environment over the long term. Therefore, the long-term effectiveness and permanence of Alternative 4 is rated high.

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Alternative 4 satisfies the statutory preference for treatment as a principal element of the remedy. It involves the use of S/S to treat soil contaminated by radionuclides and metals. S/S technologies physically bind or enclose contaminants within a stabilized mass (solidification) and/or induce chemical reactions between a stabilizing agent and radiological contaminants to reduce their mobility (stabilization). Alternative 4 would achieve an irreversible reduction in contaminant mobility through treatment but would not reduce contaminant toxicity. The total volume of waste requiring disposal would be increased by 25% as a result of the S/S process. Waste minimization practices proposed under Alternative 4, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal.

Short-Term Effectiveness

Alternative 4 could involve short-term risks to site workers and the surrounding community as a result of excavation, treatment, decontamination, transport, and disposal activities. There would be additional short-term risks due to the potential exposure to workers from mixing and handling waste during treatment and subsequent handling of a larger volume of waste. Air quality could be affected by release of particulates during soil excavation. During excavation activities, dust suppression measures would be required to mitigate fugitive dust emissions. The short-term risks to workers resulting from remediation activities would be mitigated through the use of good safety practices and PPE. Some minimal short-term risks to the surrounding community would result from the transport of wastes off-site through nearby residential areas. The transportation of approximately 26,037 yd^3 (19,907 m^3) of contaminated soil and 5,675 yd^3 (4,339 m^3) of contaminated building materials to an off-site disposal location is required as part of this alternative, which presents transportation-related risks. Dispersal and subsequent exposures to contaminated materials would be mitigated by packaging them in accordance with DOT regulations to

ensure the contents remain safely enclosed in the event of an accident. Treatment of soil by solidification would pose minimal risks to the local community. A site-specific health and safety plan would address potential exposures and monitoring requirements to ensure protection of workers and the community.

Short-term environmental impacts (such as loss of vegetation, disturbance of soil, and increased erosion) could result from Alternative 4. Excavation could potentially negatively impact animals and plants at the excavated locations and disturb existing features of the environment that may provide habitat or food to plants and animals. If needed, erosion control materials such as silt fences and straw bales would be installed to minimize erosion and reduce surface water runoff during excavation activities. Special precautions, including the installation of sheet piling, would be taken prior to excavating along the banks of the Cuyahoga River to reduce environmental impacts to the river.

The amount of time to achieve RAOs is relatively short (approximately 2 to 3 years, assuming funding is available), but the remediation timeframe also includes an O&M period of 1,000 years for performance of five-year reviews. Because remediation activities would involve short-term risks to the community and workers but mitigative measures would be taken to minimize risks, Alternative 4 is rated moderately effective in the short term.

Implementability

Alternative 4 has high technical and administrative implementability. Excavation, transport, and off-site disposal activities are common, proven methods for site remediation and would be easily implemented. Treatment using ex-situ S/S is well demonstrated and easy to implement. Most reagents and additives for S/S are widely available and relatively inexpensive industrial commodities, and qualified vendors and equipment are readily available to perform the S/S treatment. Therefore, the technical implementability of Alternative 4 is rated high.

No administrative problems are anticipated that would limit the implementability of Alternative 4. This alternative would require close coordination of remediation activities with the land owners, but no problems are anticipated. In addition, no problems related to obtaining approvals from other agencies are expected for this alternative. Therefore, Alternative 4 is rated high for administrative implementability.

Cost

The estimated total cost (present worth) for Alternative 4 is $76,410,747. This includes capital costs of $76,257,108 and O&M costs of $153,639. The capital cost includes preparation of a remedial design plan, building decontamination, building dismantlement, excavation, ex-situ treatment, confirmatory sampling, transport, off-site disposal, site restoration, and preparation of a Remedial Action Completion Report. O&M costs include the costs of preparing five-year reviews. The estimated total non-discounted cost for Alternative 4 over a 1,000-year period is $83,139,588, which includes capital costs of $76,257,108 and O&M costs of $6,882,480. The disposal costs (i.e., containers, transport, and disposal) associated with the increased disposal volume due to treatment is approximately $10,000,000 more than that associated with the total disposal costs for the non-treated wastes in Alternative 3. Additional detailed cost information may be found in Table C-3 in Appendix C of this FS Report.

4.2.5 Alternative 5 - No Action (OU-2)

The No Action alternative is required by the NCP [40 CFR §300.430(e)(6)] and CERCLA guidance (USEPA 1988) to provide a baseline to which all other remedial alternatives are compared.

4.2.5.1 Description

Alternative 5 assumes that no remedial actions would be implemented to address the radiological contamination in soil at OU-2. Impacted soil would remain at current locations. In addition, any access controls currently in place would not be maintained and annual groundwater monitoring would no longer be performed. The No Action alternative provides no additional protection to human health and the environment over current conditions.

4.2.5.2 Assessment

Overall Protection of Human Health and the Environment

Alternative 5 is not protective of human health. Results of the BRA indicate several MED/AEC-related radiological constituents present in soil at OU-2 pose potential unacceptable risk or radiological dose to human receptors. Under Alternative 5, the exposure from direct contact, ingestion, and inhalation would continue and could increase because current access control measures would not be maintained, and no additional land-use controls would be implemented. The potential for human exposure to COCs and the potential for off-site migration could increase over time as a result of disturbances by humans and natural processes. Based on the results of the SLERA, ecological risk from FUSRAP constituents is negligible. Therefore, Alternative 5 is considered protective of the environment (i.e., ecological receptors).

Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 5 does not comply with ARARs. Because no remedial action would be implemented, current conditions would not change. The current concentrations of radionuclides in the soil at OU-2 exceed ARAR-based dose standards in 10 CFR Part 20 Subpart E, the potential chemical-specific ARAR at the Former Harshaw Chemical Company Site. Alternative 5 would not meet the unrestricted release conditions of 10 CFR 20.1402, which require residual radioactivity that is distinguishable from background radiation results in TEDE to an average member of the critical group to not exceed 25 mrem/yr and the residual radioactivity to be reduced to levels that are ALARA. Alternative 5 also would not comply with the restricted release provisions of 10 CFR 20.1403(b), which mandate enforceable institutional controls to provide reasonable assurance that the annual dose to an average member of the critical group does not exceed 25 mrem/yr. Implementation of such controls cannot be accomplished under the No Action alternative. For the soil at OU-2, the critical receptor is the residential adult. The release conditions given in 10 CFR 20.1403(e) limit the annual dose to an average member of the critical group to 100 mrem/yr (or 500 mrem/yr, as applicable) if land-use controls are no longer in effect. The maximum dose to the average member of the critical group at OU-2 (71 mrem/yr for the residential adult) exceeds the 25 mrem/yr dose limit unless controls are put into place, which is not the case for this alternative. As such, Alternative 5 does not comply with the ARAR.

Long-Term Effectiveness and Permanence

Alternative 5 would allow contamination to remain on-site. Potential future exposures would remain at unacceptable levels because potential exposures currently exceed target levels, and none of the contaminated soil would be remediated. In addition, Alternative 5 includes no long-term measures to prevent exposures or the spread of contamination. This alternative assumes controls would not be maintained and provides no additional controls to prevent or reduce exposure to contaminants. Over a period of time, natural processes (such as radioactive decay and wind or surface water erosion) would result in some contaminant mass reduction on-site; however, this process would be slow and would not be monitored. Under the current and expected future land-use scenarios, there are potential risks to human

health if contamination remains in place. Therefore, Alternative 5 would not be effective in the long term and would not achieve any level of permanence.

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

No reduction in contaminant toxicity, mobility, or volume through treatment is achieved because no treatment process is proposed under Alternative 5.

Short-Term Effectiveness

There are no short-term risks associated with Alternative 5 beyond baseline conditions. There would be no additional short-term health risks to the community, site workers, or the environment because no remedial actions would be implemented.

Implementability

No actions are required for this alternative.

Cost

This alternative is the baseline scenario and requires no action. Therefore, the present value cost of this alternative is $0.

4.2.6 Alternative 6 - Limited Action and Land-Use Controls (OU-2)

4.2.6.1 Description

Alternative 6 is a limited action alternative consisting of land-use controls, site monitoring, and five-year reviews. Under this alternative, impacted media at OU-2 would be left in place, with no active remedial measures implemented. A detailed description of Alternative 6 was provided in Section 3.1.6.

The BRA concluded that exposure of certain potential receptors (residential adult, industrial worker, maintenance worker, construction worker, and subsistence farmer) to contaminated soil at some areas of OU-2 could result in radiological doses above acceptable dose limits. Several forms of land-use controls, including institutional (administrative and/or legal) controls and physical controls (such as fences), would be implemented to eliminate or reduce potential exposure pathways. The only land uses allowed under this alternative would be passive recreation (e.g., concreted bike or walking paths) without the use of full-time maintenance or commercial workers at any recreational facility.

Because future land use at OU-2 could include residential use, the land-use controls implemented under Alternative 6 would include environmental covenants that would prevent the exposure of residents, as well as construction workers, industrial workers, and maintenance workers, to contaminated soil. The environmental covenant for OU-2 could allow construction or maintenance activities involving drilling, boring, trenching or digging as long as specified safety measures are followed, and the excavated contaminated soil is properly managed in order to ensure that exposures would be minimal. The covenant could also be used to prohibit the drilling of on-site water wells.

These land-use controls, if properly maintained and enforced, minimize exposure risks due to contaminated soil and groundwater at OU-2. A Land-Use Control Plan would be developed after the

approval of the ROD to describe the controls, including environmental covenants, and would include notification requirements for changes in land use.

Site monitoring would be conducted to document the effectiveness of this remedial action. Monitoring would involve periodic inspections of the properties during the five-year reviews to evaluate and document any changes to site conditions that could affect protectiveness.

Five-year reviews would be required under Alternative 6. Consistent with the NCP [40 CFR §300.430(f)(4)(ii)], five-year reviews must be conducted at sites where the remedy does not allow for unlimited use/unrestricted exposure. The five-year reviews would help ensure controls are maintained and the remedy remains protective of human health and the environment.

4.2.6.2 Assessment

Overall Protection of Human Health and the Environment

Alternative 6 is protective of human health with the use of land-use controls to preclude residential use (critical receptor) of the land so as to meet the ARARs, which are presumed to be protective, for the restricted use of the OU. As discussed below regarding complianc with ARARs, should these land-use controls fail, the ARAR standards are met and thuse considered to be protective. Land-use controls would ensure human health protectiveness by limiting direct access to contaminated soil for the critical group (resident). Potential future soil and groundwater exposure pathways are limited through the use of environmental covenants to restrict construction or maintenance activities involving drilling, boring, trenching, or digging and would prohibit the drilling of on-site water wells. The environmental covenants would ensure residents and workers are not exposed to unacceptable health risks, and future land owners would be aware of the environmental conditions of the property prior to purchase. Although the land-use controls would be in-place to preclude residential development of OU-2, passive recreational use of the OU would be acceptable and protective and could be allowed by the land-use controls. The overall protection of human health is maintained even if the land-use controls are lost since the exposure to the critical group under those conditions would meet the ARAR criteria as discussed below. Therefore, Alternative 6 is protective of human health.

Based on the results of the SLERA, no remedial action is required to address ecological risk. Because no active remediation is conducted under Alternative 6, there would be no loss of vegetation, disruption of soil, or increased erosion resulting from remedial action. Alternative 6 does not prevent the leaching of contaminants to groundwater from contaminated soil. However, soil contamination identified at OU-2 is located in shallow soil and is not present in sufficient quantities to represent a significant potential source for groundwater contamination in this area which is supported by the lack of evidence of groundwater contamination in OU-2. Therefore, Alternative 6 is protective of the environment.

Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 6 would comply with ARARs identified for limited action alternatives. It would achieve the restricted release standard under 10 CFR 20.1403, which requires residual radioactivity results in a TEDE to an average member of the critical group to not exceed 25 mrem/yr. This assumes land-use controls are maintained. 10 CFR 20.1403 also requires residual radioactivity at the site to be reduced so that if the institutional controls are lost, there is reasonable assurance the TEDE would not exceed 100 mrem/yr. If controls are lost under Alternative 6, the dose to the average member of the critical group at OU-2 (71 mrem/yr for the residential adult) would not exceed this dose limit. Therefore, Alternative 6 would be compliant with this ARAR.

Long-Term Effectiveness and Permanence

Alternative 6 relies on land-use controls, site monitoring, and five-year reviews to eliminate or reduce exposures to contaminants. Although Alternative 6 would not reduce the amount of contaminated material remaining on-site, future risk would be maintained at acceptable levels through the implementation and maintenance of land-use controls. It is reasonably expected that land-use controls can be implemented and would be effective in protecting human health but would not result in permanent reduction of site risks unless the controls are maintained perpetually. However, the NCP [40 CFR §300.430(a)(1)(iii)(D)] states that "institutional controls shall not substitute for active response measures…as the sole remedy unless active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during the section of [the] remedy."

There are uncertainties regarding the ability of land-use controls to ensure protectiveness over the long term. Due to the slow rate of radioactive decay, land-use controls would have to be maintained and enforced over a long time period. For purposes of this document, it is assumed the land-use controls would be required for a period of 1,000 years. It is expected that land ownership would change over this time period, making maintenance and enforcement of the controls more uncertain.

Mitigative measures would be taken to reduce the uncertainties regarding land-use controls. The proprietary land-use controls would be structured to be binding and transferable for subsequent landowners. In addition, Alternative 6 includes requirements to verify the maintenance of land-use controls through continued site monitoring (surveillance) to identify any changes in site conditions that affect protectiveness. The long-term roles and responsibilities for monitoring, maintaining, and enforcing the land-use controls would be specified in the Land-Use Control Plan. Five-year reviews would be conducted to evaluate the effectiveness of land-use controls and ensure any land-use changes are identified. The long-term effectiveness and permanence of Alternative 6 is rated moderate.

To maintain the effectiveness of controls and ensure continued protectiveness, Alternative 6 includes requirements to verify the maintenance of the land-use controls through continued site monitoring (surveillance) to identify any changes in site conditions that affect land use. In addition, five-year reviews would be conducted to evaluate the effectiveness of land-use controls and ensure any land use changes are identified.

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

No reduction in contaminant toxicity, mobility, or volume through treatment is achieved because no treatment process is proposed under Alternative 6.

Short-Term Effectiveness

Alternative 6 is highly effective in the short term. There would be no additional short-term risks to the community or the environment under this alternative. Because Alternative 6 would utilize land-use controls rather than active remediation to minimize exposures, it avoids potential adverse short-term impacts to the community, workers, or the environment due to construction or transportation activities associated with active remedial technologies. There may be potential short-term risks to workers during periodic monitoring activities and the installation/maintenance of fences and signage; however, the risk is considered minimal. Alternative 6 would require less than one year to implement, but would include a 1,000-year O&M period during which periodic site monitoring and five-year reviews would be conducted. However, the NCP [40 CFR §300.430(a)(1)(iii)(D)] states that "institutional controls shall not substitute for active response measures…as the sole remedy unless active measures are determined not to

be practicable, based on the balancing of trade-offs among alternatives that is conducted during the section of [the] remedy."

Implementability

Alternative 6 would be easy to implement technically because no active remediation is required. Land-use controls are readily available and proven methods for addressing risk. Installation of physical controls (e.g., fences, signs) and monitoring pose no significant technical difficulties. The materials and services needed to implement Alternative 6 are readily available. Therefore, Alternative 6 is rated high for technical implementability.

Because USACE does not own the property, some of the land-use controls may be administratively difficult to implement. Implementation of land-use controls would require involvement of the local government and the land owners. There could be difficulties implementing land-use controls due to multiple land owners. One type of land-use control that would be implemented under Alternative 6 is a restrictive covenant. Restrictive covenants require the consent of the owner of each property to which a restrictive covenant is applied. USACE has not secured property owner approval or authorization to acquire such interests in the property to establish appropriate land-use controls. USACE may need to secure these agreements prior to the approval of the ROD in order to establish the types of land-use controls that would be implemented at each property and identify the parties responsible for securing, maintaining, and enforcing controls. Uncertainties concerning whether landowners would be willing to accept and comply with the terms of these agreements make this alternative difficult to implement administratively. Therefore, Alternative 6 is rated low for administrative implementability.

The overall implementability rating is based on the lower of the technical and administrative implementability ratings. Therefore, the overall implementability of Alternative 6 is rated low, based on the low administrative implementability.

Cost

The estimated total cost (present worth) for Alternative 6 over the 1,000-year period is $2,228,575. The total cost would include implementation and maintenance of land-use controls, preparation of a site monitoring plan, site monitoring (including site inspections, sample collection, and laboratory analysis), data evaluation and reporting, and the performance of five-year reviews. Estimated capital costs of $1,400,265 include administrative costs associated with planning, implementing, monitoring and enforcing land-use controls for the first year, preparation of a site monitoring plan, and installation of physical land-use controls (e.g., fences, signs, and gates). O&M costs of $828,310 (for maintenance of land-use controls and five-year reviews) are estimated for a 1,000-year period. The estimated total non-discounted cost for Alternative 6 over a 1,000-year period is $36,047,405, which includes capital costs of $1,400,265 and O&M costs of $34,647,140. Additional detailed cost information may be found in Table C-3 in Appendix C of this FS Report.

4.2.7 Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)

4.2.7.1 Description

Alternative 7 consists of the excavation of impacted soil exceeding the PRGs in OU-2 and subsequent transport to a properly permitted off-site disposal facility, consistent with disposal site WAC. Approximately 3,624 yd^3 (2,771 m^3) (in-situ) of impacted soil would be excavated from OU-2. Similar to Alternative 3, the soil would be staged at an on-site staging area and processed using waste minimization

practices and technologies (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system). The estimated ex-situ soil volume (after waste minimization practices) is 2,945 yd^3 (2,252 m^3). A detailed description of Alternative 7 was provided in Section 3.1.7.

Based on previous volume reduction experience at other FUSRAP sites, the cost estimate for this alternative assumes 50% of the material processed through the waste minimization practices would be above PRGs. The material that is above PRGs would be sampled in accordance with the disposal facility's WAC. For the purposes of this FS, it is assumed approximately 10% of the material above PRGs would also be considered characteristically hazardous waste and would require disposal as mixed LLRW. This assumption is based on the history of operations at the site during which metals were used extensively as part of the commercial process. This percentage is less than that assumed for OU-1 given a majority of the chemical processing occurred in OU-1. The material below PRGs would also be sampled to determine if it is characteristically hazardous. This FS assumes that approximately 10% of this material would be considered characteristically hazardous. This material would be segregated and coordination with the property owner would occur. Non-hazardous material below PRGs would be used as backfill at the site. The material above the PRGs to be shipped to an off-site disposal facility would be placed in intermodal containers and sent by truck to a transfer facility (an off-site railcar loading facility) for shipment to the disposal facility. There is a potential for cost savings if the materials being shipped off-site meet the WAC for Subtitle C facilities, as discussed in Sections 2.3.1.5.2 and 2.3.2.6. There are uncertainties associated with what volume, if any, could be shipped to such facilities; therefore, cost estimates assume the entire volume would be shipped to a radioactive-licensed facility for disposal.

This alternative would require close coordination of remediation with the land owner(s) and/or tenants in an effort to minimize health and safety risks to on-site personnel. All remediated areas would be restored at the completion of the project. More information concerning each component of this alternative is presented in the Key Parameters and Assumptions Table in Appendix C (Detailed Cost Estimates).

4.2.7.2 Assessment

Overall Protection of Human Health and the Environment

Alternative 7 is protective of human health and the environment. Removal of radiologically contaminated soil would achieve the PRGs in OU-2 and would limit risks from exposure to contaminated soil to within acceptable levels. The soil that does not meet the PRGs would be placed in a properly permitted off-site disposal facility that would provide protective management and appropriate monitoring of potential releases of any residual contaminants. Environmental protection at OU-2 would be enhanced by removal of the contaminated soil for off-site disposal. Although there is lack of evidence of groundwater contamination in OU-2, the update to the groundwater flow and contaminant transport modeling contained in Appendix D concluded that the proposed soil PRGs for total uranium, thorium-230, thorium-232, and radium-226 in OU-2 are protective of groundwater.

Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 7 would comply with ARARs identified for complete removal alternatives. It would achieve the unrestricted release conditions of 10 CFR 20.1402, which require residual radioactivity that is distinguishable from background radiation to result in a TEDE to not exceed 25 mrem/yr for an average member of the critical group. Alternative 7 would ensure that the maximum dose to the average member of the critical group at OU-2 (the adult resident) would not exceed the 25 mrem/yr dose limit through the removal and off-site disposal of contaminated media exceeding the PRGs.

An ALARA analysis would be performed as part of the remedial design to ensure the remedy achieves residual levels of contamination that are ALARA. Therefore, Alternative 7 would be compliant with this ARAR.

Long-Term Effectiveness and Permanence

Alternative 7 would achieve long-term effectiveness and result in a permanent reduction in site risk. The magnitude of residual risk at OU-2 would be low as a result of the excavation, transport, and off-site disposal of soil exceeding the PRGs. Therefore, this alternative is rated high for long-term effectiveness and permanence.

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Waste minimization practices proposed under Alternative 7, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal.

Short-Term Effectiveness

The excavation, transport, and disposal activities under Alternative 7 could pose short-term risks to site workers and the surrounding community. Air quality could be affected by release of particulates during soil excavation. During excavation activities, dust suppression measures would be required to mitigate fugitive dust emissions. The short-term risks to workers resulting from remediation activities would be mitigated through the use of good safety practices and PPE. Some minimal short-term risks to the surrounding community would result from the transport of wastes off-site through nearby residential areas. The transportation of approximately 2,945 yd^3 (2,252 m^3) of contaminated soil to an off-site disposal location is required as part of this alternative, which presents transportation-related risks. Dispersal and subsequent exposures to contaminated materials would be mitigated by packaging them in accordance with DOT regulations to ensure the contents remain safely enclosed in the event of an accident. A site-specific health and safety plan would address potential exposures and monitoring requirements to ensure protection of workers and the community.

Short-term environmental impacts (such as loss of vegetation, disturbance of soil, and increased erosion) could result from Alternative 7. Excavation could potentially negatively impact animals and plants at the excavated locations and disturb existing features of the environment that may provide habitat or food to plants and animals. If needed, erosion control materials such as silt fences and straw bales would be installed to minimize erosion and reduce surface water runoff during excavation activities.

The amount of time to achieve the RAOs is relatively short (approximately 2 to 3 years, assuming funding is available). Because remediation activities would involve short-term risks to the community and workers but mitigative measures would be taken to minimize risks, this alternative is rated moderately effective in the short term.

Implementability

Alternative 7 would be technically easy to implement. No specialized equipment, personnel, or services would be required. Soil excavation uses readily available resources and conventional earthmoving equipment. Transport and disposal activities are common, proven methods for site remediation and would be easily implemented. Therefore, the technical implementability of Alternative 7 is rated high.

No administrative problems are anticipated that would limit the implementability of Alternative 7. This alternative would require coordination of remediation activities with the land owner(s) and/or tenants to minimize health and safety risks to on-site personnel, but it is expected this would be successfully accomplished. In addition, no problems related to obtaining approvals from other agencies are expected for this alternative. Therefore, Alternative 7 is rated high for administrative implementability.

Cost

The estimated total cost (present worth) for Alternative 7 is $6,617,430. The capital costs of $6,617,430 include preparation of a remedial design plan, excavation, confirmatory sampling, transport, off-site disposal, site restoration, and preparation of a Remedial Action Completion Report. The estimated total non-discounted cost for Alternative 7 over a 2 to 3-year period is $6,617,430, which is all capital costs since there are no O&M costs for this alternative. Detailed information concerning costs is provided in the Key Parameters and Assumptions Table for Alternative 7 in Appendix C.

4.2.8 Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)

4.2.8.1 Description

Alternative 8 consists of excavation of impacted soil exceeding the PRGs in OU-2, ex-situ treatment by S/S, and subsequent transport to a properly permitted off-site disposal facility, consistent with disposal site WAC. Similar to Alternative 7, approximately 3,624 yd^3 (2,771 m^3) (in-situ) of impacted soil would be excavated from OU-2, transported to an on-site staging area, and processed using waste minimization practices and technologies (e.g., sorting by manual radiological contamination scanning, sampling and laboratory analysis, or the use of an automated soil segregation system). Based on previous experience at other FUSRAP sites, the cost estimate for this alternative assumes 50% of the material processed through the waste minimization practice would be above PRGs. The estimated ex-situ soil volume (after waste minimization practices and ex-situ treatment) is 3,927 yd^3 (3,002 m^3). A detailed description of Alternative 8 was provided in Section 3.1.8.

The material that is above PRGs would be sampled in accordance with the disposal facility's WAC. For the purposes of this FS, it is assumed 10% of the material above PRGs would also be considered characteristically hazardous waste and would require disposal as mixed LLRW. This assumption is based on the history of operations at the site during which metals were used extensively as part of the commercial process. This percentage is less than that assumed for OU-1 given a majority of the chemical processing occurred in OU-1. The material below PRGs would also be sampled to determine if it is characteristically hazardous. This FS assumes approximately 10% of this material would be considered characteristically hazardous. This material would be segregated and coordination with the property owner would occur. Non-hazardous material below PRGs would be used as backfill at the site.

The S/S process involves mixing the contaminated wastes with water, additives, and fly ash, kiln dust, or cement. Contaminated soil would require excavation and transport to a central staging area for ex-situ S/S treatment. Samples of the treated materials would be collected and analyzed to confirm stabilization was successful and determine the proper disposition of the treated waste. The treated waste would then be manifested and transported (intermodal) to an off-site transfer station for shipment by rail to a licensed off-site disposal facility. There is a potential for cost savings if the materials being shipped off-site meet the WAC for Subtitle C facilities, as discussed in Sections 2.3.1.5.2 and 2.3.2.6. There are uncertainties associated with what volume, if any, could be shipped to such facilities; therefore, the cost estimates assume the entire volume would be shipped to a radioactive-licensed facility for disposal.

Confirmation sampling would be performed to verify PRGs are achieved. All remediated areas would be restored at the completion of the project. More information concerning each component of this alternative is presented in Appendix C.

4.2.8.2 Assessment

Overall Protection of Human Health and the Environment

Alternative 8 is protective of human health and the environment. Removal of radiologically contaminated soil would achieve the PRGs in OU-2 and would limit risk from exposure to contaminated soil. Although there is lack of evidence of groundwater contamination in OU-2, the update to the groundwater flow and contaminant transport modeling contained in Appendix D concluded that the proposed soil PRGs for total uranium, thorium-230, thorium-232, and radium-226 in OU-2 are protective of groundwater. There would be additional short-term risks due to the potential exposure to workers from mixing and handling the waste during treatment. The treated waste would be placed in a properly permitted off-site disposal facility that would provide for protective management and appropriate monitoring of potential releases of any residual contaminants.

Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 8 would comply with ARARs identified for complete removal alternatives. It would achieve the unrestricted release conditions of 10 CFR 20.1402, which require residual radioactivity that is distinguishable from background radiation to result in a TEDE to not exceed 25 mrem/yr for an average member of the critical group. Alternative 8 would ensure the maximum dose to the average member of the critical group at OU-2 (the adult resident) would not exceed the 25 mrem/yr dose limit through the removal and off-site disposal of contaminated media. An ALARA analysis would be performed as part of the remedial design to ensure the remedy achieves residual levels of contamination that are ALARA. Therefore, Alternative 8 would be compliant with this ARAR.

Long-Term Effectiveness and Permanence

Alternative 8 would achieve long-term protection because contaminated media at OU-2 would be removed, treated, and disposed of in a properly permitted off-site disposal site. The off-site disposal would permanently reduce contaminant concentrations at OU-2 to provide protection of human health and the environment over the long term. Therefore, the long-term effectiveness and permanence of Alternative 8 is rated high.

Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Alternative 8 satisfies the statutory preference for treatment as a principal element of the remedy. This alternative would achieve an irreversible reduction in contaminant mobility through the use of S/S to treat soil contaminated by radionuclides and metals. It would not reduce contaminant toxicity and would increase the total volume of wastes requiring disposal by 25% as a result of the S/S process. Waste minimization practices proposed under Alternative 8, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal.

Short-Term Effectiveness

Alternative 8 could involve some short-term risks to site workers as a result of excavation, treatment, transport, and disposal activities. There would be additional short-term risks due to potential exposure to

workers from the mixing and handling of the waste during treatment. Air quality could be affected by release of particulates during soil excavation. During excavation activities, dust suppression measures would be required to mitigate fugitive dust emissions. The short-term risk to workers resulting from remediation activities would be mitigated through the use of good safety practices and PPE. Some minimal short-term risk to the surrounding community would result from the transport of waste off-site through nearby residential areas. The transportation of approximately 3,927 yd^3 (3,002 m^3) of contaminated soil to an off-site disposal location is required as part of this alternative, which presents transportation-related risks. Dispersal and subsequent exposures to contaminated material would be mitigated by packaging them in accordance with DOT regulations to ensure contents remain safely enclosed in the event of an accident. Treatment of soil by solidification would pose minimal risks to the local community. A site-specific health and safety plan would address potential exposures and monitoring requirements to ensure protection of workers and the community.

Short-term environmental impacts (such as loss of vegetation, disturbance of soil and increased erosion) could result from Alternative 8. Excavation could potentially negatively impact animals and plants at the excavated locations and disturb existing features of the environment that may provide habitat or food to plants and animals. If needed, erosion control materials, such as silt fences and straw bales, would be installed to minimize erosion and reduce surface water runoff during excavation activities.

The amount of time to achieve RAOs is relatively short (approximately 2 to 3 years, assuming funding is available). Because remediation activities would involve short-term risks to the community and workers but mitigative measures would be taken to minimize risks, Alternative 8 is rated moderately effective in the short term.

Implementability

Alternative 8 has high technical and administrative implementability. The main components of Alternative 8 (excavation, ex-situ S/S treatment, transport, and disposal) are proven methods for site remediation and would be easy to implement. The materials, equipment, and qualified vendors required to implement this alternative are readily available. Treatment using ex-situ S/S is well demonstrated and easy to implement. Most reagents and additives for S/S are widely available, relatively inexpensive industrial commodities, and qualified vendors and equipment are readily available to perform the S/S treatment. Therefore, the technical implementability of Alternative 8 is rated high.

No administrative problems are anticipated that would limit the implementability of Alternative 8. No significant problems related to obtaining approvals from other agencies or coordinating remediation activities with land owners and/or tenants are expected for this alternative. Therefore, Alternative 8 is rated high for administrative implementability.

Cost

The estimated total cost (present worth) for Alternative 8 is $9,562,520, which is all capital costs since there are no O&M costs associated with this alternative. The capital costs would include preparation of a remedial design plan, excavation, ex-situ treatment, confirmatory sampling, transport, off-site disposal, site restoration, and preparation of a Remedial Action Completion Report. The estimated total non-discounted cost for Alternative 8 over a 2 to 3-year period is $9,562,520. The disposal costs (i.e., containers, transport and disposal) associated with the increased disposal volume due to treatment is approximately $1,600,000 more than that associated with the total disposal costs for the non-treated wastes in Alternative 7. Additional detailed cost information may be found in Table C-3 in Appendix C of this FS Report.

4.3 COMPARATIVE ANALYSIS

Alternatives undergo comparative analysis to identify the relative advantages and disadvantages of retained alternatives on the basis of the previously detailed analysis (Section 4.2). Table 4-3 summarizes the results of the comparative analysis for the four remedial action alternatives for OU-1 (Alternatives 1 through 4). Table 4-4 summarizes the results of the comparative analysis for the four remedial action alternatives for OU-2 (Alternatives 5 through 8).

4.3.1 Overall Protection of Human Health and the Environment

OU-1

Alternative 1 (No Action) provides no increased protection over the current site conditions and would not be protective of human health and the environment over the long term for foreseeable future land uses. The overall levels of protectiveness for Alternatives 2 (Limited Action and Land-Use Controls), 3 (Complete Removal and Off-Site Disposal), and 4 (Complete Removal with Ex-Situ Treatment and Off-Site Disposal) are considered to be the same because each provide for either long-term off-site disposal and/or control of the MED/AEC-related material. Alternative 2 restricts access to the site to preclude the public from coming into contact with the MED/AEC-related materials remaining on-site. Alternatives 3 and 4 involve the isolation of the MED/AEC-related materials off-site in a disposal facility designed to be protective of human health and the environment.

OU-2

Alternative 5 (No Action) provides no increased protection over the current site conditions and would not be protective of human health and the environment over the long term for foreseeable future land uses. The overall levels of protectiveness for Alternatives 6 (Limited Action and Land-Use Controls), 7 (Complete Removal and Off-Site Disposal), and 8 (Complete Removal with Ex-Situ Treatment and Off-Site Disposal) are considered to be the same because each provide for either long-term off-site disposal and/or control of the MED/AEC-related material. Alternative 6 restricts access to the site to preclude the public from coming into contact with the MED/AEC-related materials remaining on-site. Alternatives 7 and 8 involve the isolation of the MED/AEC-related materials off-site in a disposal facility designed to be protective of human health and the environment.

4.3.2 Compliance with Applicable or Relevant and Appropriate Requirements

OU-1

Alternative 1 (No Action) does not comply with potential chemical-specific ARARs. The maximum dose to the average member of the critical group (construction worker at OU-1) is 7,453 mrem/yr at Building G-1. Therefore, Alternative 1 would not achieve the 25 mrem/yr dose standards of 10 CFR 20.1402 and 10 CFR 20.1403. Alternative 2 (Limited Action and Land-Use Controls) would comply with the limited action ARARs and achieve the 25 mrem/yr restricted release standard in 10 CFR 20.1403(b) by dismantling Building G-1 and restricting exposure to contaminated soil that exceeds the 25 mrem/yr standard through the implementation of various land-use controls. Alternative 2 would also comply with the release condition given in 10 CFR 20.1403(e), which limits the annual dose to an average member of the critical group to 100 mrem/yr (or 500 mrem/yr, as applicable) if land-use controls are no longer in effect. The dose from exposure to only contaminated soil left in place at OU-1 to the average member of the critical group (i.e., 39 mrem/yr for the construction worker at OU-1) does not exceed this dose limit.

Alternatives 3 and 4 comply with the potential chemical-specific ARAR associated with complete removal alternatives. Alternatives 3 and 4 achieve the unrestricted release standards in 10 CFR 20.1402 through removal and off-site disposal of contaminated media.

OU-2

At OU-2, only Alternative 5 (No Action) does not comply with the potential chemical-specific ARARs (10 CFR 20.1402 and 10 CFR 20.1403). Alternative 6 complies with the limited action ARARs which are the restricted release conditions of 10 CFR 20.1403, and Alternatives 7 and 8 comply with the complete removal ARARs which are the unrestricted release conditions of 10 CFR 20.1402.

4.3.3 Long-Term Effectiveness and Permanence

OU-1

Alternative 1 (No Action) does not achieve long-term effectiveness or permanence. Alternative 1 leaves the contaminants in place, which could continue to affect human health and the environment.

Alternatives 3 and 4 remove the contaminated media from the site and result in less residual exposure at OU-1 at the conclusion of the remedial activities than Alternative 2, which addresses residual exposure by dismantlement and removal of Building G-1, implementation of land-use controls, and periodic monitoring. Therefore, Alternative 2 is ranked higher in long-term effectiveness and permanence than Alternative 1 but lower than Alternatives 3 and 4.

Alternatives 3 and 4 were found to be generally comparable with respect to long-term effectiveness and permanence. Both of these alternatives involve the excavation of contaminated soil to achieve industrial PRGs and would eliminate the potential for contaminant exposure. Alternatives 3 and 4 would also include five-year reviews.

OU-2

Alternative 5 (No Action) does not achieve long-term effectiveness or permanence. Both alternatives 5 and 6 leave the contaminants in place, which could continue to affect human health and the environment.

Alternatives 7 and 8 remove the contaminated media from the site and result in less residual risk at OU-2 at the conclusion of the remedial activities than Alternative 6, which addresses residual risk by implementing land-use controls and periodic monitoring. Therefore, Alternative 6 is ranked higher in long-term effectiveness and permanence than Alternative 5 but lower than Alternatives 7 and 8.

Alternatives 7 and 8 were found to be generally comparable with respect to long-term effectiveness and permanence. Both of these alternatives involve the excavation of contaminated soil to achieve the residential PRGs and would eliminate the potential for contaminant exposure.

4.3.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

OU-1

Alternatives 1, 2, and 3 do not use any treatment technologies to permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances. Waste minimization practices proposed under Alternatives 3 and 4, such as radiological scanning and soil sorting, may reduce the volume of

contaminated soil requiring disposal. Alternative 4 uses ex-situ S/S treatment to reduce the contaminant mobility. However, the volume of the treatment residuals would be greater (by approximately 25%) than the original soil volume. S/S treatment would not affect the toxicity of the contaminants.

OU-2

Alternatives 5, 6, and 7 do not use any treatment technologies to permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances. Waste minimization practices proposed under Alternatives 7 and 8, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal. Alternative 8 uses S/S treatment to reduce the contaminant mobility. However, the volume of the treatment residuals would be greater (by approximately 25%) than the original soil volume. S/S treatment would not affect the toxicity of the contaminants.

4.3.5 Short-Term Effectiveness

OU-1

Alternative 1 (No Action) is rated highest with respect to short-term effectiveness because no remedial activities would be conducted that would have the potential to impact the health and safety of workers and the surrounding community. Alternative 2 (Limited Action and Land-Use Controls) is rated higher than the remaining alternatives with respect to short-term effectiveness since there would be minimal risks to the community and workers during the building dismantlement and periodic monitoring activities. For Alternatives 3 and 4, short-term risks for workers and the public are increased as a result of excavation activities. Alternative 3 is rated third in short-term effectiveness because it does not involve treatment but would have increased risks resulting from off-site disposal. Alternative 4 is rated lowest in short-term effectiveness because there would be additional short-term risks to workers due to the treatment activities and increased transportation-related risks due to the higher volume of contaminated materials requiring transport to an off-site disposal location.

Short-term impacts to the environment would occur as a result of excavation activities conducted under Alternatives 3 and 4. The degree of short-term damage to the environment increases with the amount of surface area subject to disturbance.

Remediation timeframe is the total period of time it takes to complete remedial design, site mobilization/demobilization, actual field remediation (e.g., soil excavation, building dismantlement, treatment, etc.), verification sampling and analysis, loading and transporting the contaminated waste material to the off-site disposal facility, site restoration, and long-term surveillance and maintenance, if appropriate. The longest remediation timeframes are required under Alternative 2, which assumes continued maintenance of land-use controls and performance of site monitoring over a period of 1,000 years. The attainment of the PRGs is estimated to take less than three years under all action alternatives. The remediation timeframes do not vary appreciably for Alternatives 3 and 4, which is estimated to be two to three years. Additional time would be required under Alternative 4 for design, approval, construction, and operation of the S/S treatment facility.

OU-2

Alternative 5 (No Action) is rated highest with respect to short-term effectiveness because no remedial activities would be conducted that would have the potential to impact the health and safety of workers and the surrounding community. Alternative 6 (Limited Action and Land-Use Controls) is rated higher than the remaining alternatives with respect to short-term effectiveness since there would be no risks to the

community and only minimal risks to workers during the periodic monitoring activities. For Alternatives 7 and 8, short-term risks for workers and the public are increased as a result of excavation activities. Alternative 7 is rated third in short-term effectiveness because it does not involve treatment but would have increased risks resulting from off-site disposal. Alternative 8 is rated lowest in short-term effectiveness because there would be additional short-term risks to workers due to the treatment activities and increased transportation-related risks due to the higher volume of contaminated materials requiring transport to an off-site disposal location.

Short-term impacts to the environment would occur as a result of excavation activities conducted under Alternatives 7 and 8. The degree of short-term damage to the environment increases with the amount of surface area subject to disturbance. Alternative 8 would have a slightly greater short-term impact than Alternative 7 due to the operation of the treatment unit as well as the handling of an increased waste disposal volume.

Remediation timeframe is the total period of time it takes to complete remedial design, site mobilization/demobilization, actual field remediation (e.g., soil excavation, building dismantlement, treatment, etc.), verification sampling and analysis, loading and transporting the contaminated waste material to the off-site disposal facility, site restoration, and long-term surveillance and maintenance, if appropriate. The longest remediation timeframes are required under Alternative 6, which assumes continued maintenance of land-use controls and performance of site monitoring over a period of 1,000 years. The attainment of the PRGs is estimated to take less than three years under all action alternatives. The remediation timeframes do not vary appreciably among the remaining alternatives. The timeframe for these two alternatives is approximately two to three years. Additional time would be required under Alternative 8 for design, approval, construction, and operation of the S/S treatment facility.

4.3.6 Implementability

OU-1

Because it requires no action, Alternative 1 is not rated with respect to the implementability of the action. The remaining OU-1 alternatives are all implementable but vary in their ease of implementation. Alternatives 2, 3 and 4 all involve the dismantlement and shipment off-site for disposal of Building G-1; however, Alternative 2 is rated higher than the remaining alternatives with respect to soil remediation in terms of technical implementability because no active soil remediation is required. Alternatives 3 and 4 are similarly highly implementable from a technical standpoint. Alternatives 3 and 4 are rated lower in technical implementability than Alternative 2 due to the technical difficulties that are associated with the excavation, transportation, and off-site disposal of soil. There would be a slightly higher degree of difficulty in implementing Alternative 4 due to the additional technical requirements for conducting the S/S treatment activities.

The administrative implementability of Alternative 2 is rated lowest because it involves the implementation of land-use controls and is administratively more complex than the remaining alternatives. In addition, there may be administrative difficulties implementing land-use controls and scheduling and coordinating monitoring activities due to the multiple land owners. Alternative 2 is rated low in administrative implementability. Alternatives 3 and 4 are rated highest in administrative implementability because no significant problems related to obtaining approvals from other agencies or coordinating remediation activities with land owners are expected for these alternatives.

OU-2

Because it requires no action, Alternative 5 is not rated with respect to the implementability of the action. The remaining OU-2 alternatives are all implementable but vary in their ease of implementation. Alternative 6 (Limited Action and Land-Use Controls) is rated higher than the remaining soil alternatives in technical implementability because no active remediation is required. Alternatives 7 and 8 are similarly highly implementable from a technical standpoint. Alternatives 7 and 8 are rated lower in technical implementability than Alternative 6 due to the technical difficulties that are associated with the excavation, transportation, and off-site disposal of soil. There would be a slightly higher degree of difficulty in implementing Alternative 8 due to the additional technical requirements for conducting the S/S treatment activities.

The administrative implementability of Alternative 6 is rated lowest because it involves the implementation of land-use controls and is administratively more complex than the remaining alternatives. In addition, there may be administrative difficulties implementing land-use controls and scheduling and coordinating monitoring activities due to the multiple land owners. Alternative 6 is rated low in administrative implementability. Alternatives 7 and 8 are rated highest in administrative implementability because no significant problems related to obtaining approvals from other agencies or coordinating remediation activities with land owners are expected for these alternatives.

4.3.7 Cost

OU-1

The estimated total costs for the OU-1 alternatives are listed below. Costs for each alternative and itemization of individual components can be found in Appendix C.

Comparison of Costs for OU-1 Remedial Alternatives

Alternative	Estimated Total (Present Worth) Cost[a]	Estimated Total (Non-Discounted) Cost[b,c]
1 No Action (OU-1)	$0	$0
2 Limited Action and Land-Use Controls (OU-1)	$12,406,557	$56,604,601
3 Complete Removal with Off-Site Disposal (OU-1)	$55,185,927	$61,829,592
4 Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)	$76,410,747	$83,139,588

[a]Discount rate used was 4.125%
[b]Durations for Alternative 1 was 0 years and 1,000 years for Alternatives 2, 3, and 4 each.
[c]The difference between the Present Worth Cost and Non-Discounted Cost for Alternatives 3 and 4 is the cost associated with conducting 5-year reviews over a 1,000-year period.
$ = Dollar
% = Percent
OU = Operable Unit

OU-2

The estimated total costs for the OU-2 alternatives are listed below. Costs for each alternative and itemization of individual components can be found in Appendix C.

Comparison of Costs for OU-2 Remedial Alternatives

Alternative	Estimated Total (Present Worth) Cost[a]	Estimated Total (Non-Discounted) Cost[b,c]
5 No Action (OU-2)	$0	$0
6 Limited Action and Land-Use Controls (OU-2)	$2,228,575	$36,047,405
7 Complete Removal with Off-Site Disposal (OU-2)	$6,617,430	$6,617,430
8 Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)	$9,562,520	$9,562,520

[a]Discount rate used was 4.125%
[b]Durations for Alternative 5 was 0 years, 1,000 years for Alternative 6, and 2-3 years for Alternatives 7 and 8 each.
[c]Note: There is no difference between the Present Worth Cost and Non-Discounted Cost for Alternatives 7 and 8 since there is no need for 5-year reviews over a 1,000-year period.
$ = Dollar
OU = Operable Unit

4.4 ELEMENTS COMMON TO MOST ALTERNATIVES

All of the alternatives except for the No Action alternatives (Alternatives 1 and 5) and the Limited Action alternative (Alternative 6) incorporate the elements discussed below.

4.4.1 Monitoring and Mitigative Measures

A mitigation plan would be developed during the remedial design to specify measures that would be taken during implementation of the remedial action to minimize unacceptable exposure to human health and the environment (e.g., environmental controls and contingency response actions). The primary monitoring and mitigative measures that would be used at the site are described in the following sections. These measures would be effective in minimizing the potential adverse effects associated with implementation of the alternatives.

4.4.1.1 Construction Activities

Construction practices to control potential releases to the environment would include management and engineering practices. Erosion and sedimentation controls, such as hay bales and silt fences, would be used to prevent soil transport in surface water runoff. Wetting surface materials with water or dust control chemicals would mitigate fugitive dust impacts. Regular surface wetting can reduce the dust loads from construction sites and storage/staging piles by as much as 50%. Chemical wetting agents can further reduce the dust loads. In addition, storage/staging piles and inactive areas would be covered to reduce wind erosion. All equipment would be decontaminated prior to release from the site. All disturbed areas would be restored and seeded.

4.4.1.2 Transportation

Wastes would be containerized and fitted with a cover and/or liner when transported across public roads. Vehicles would be decontaminated and inspected prior to release from contaminated areas.

4.4.1.3 Worker Protection

Activities would be conducted in accordance with approved health and safety plans. PPE, personal monitoring devices, and decontamination procedures would be used to minimize exposure to and spread of contamination. The potential for worker exposure would be mitigated through these measures.

Personal monitoring devices and a medical monitoring program would be used to ensure workers do not receive exposures that would result in adverse health effects.

4.4.1.4 Protection of the General Public

Mitigation measures for controlling releases of material off-site to protect the general public would include those identified in Sections 4.4.1.1 and 4.4.1.2, regarding control of surface water runoff and fugitive dust emissions that might contain contaminants. Access controls, including fencing and security personnel, would be used to restrict public access to construction areas.

4.4.2 Impact of Potential Loss of Land-Use Controls

Table 4-5 summarizes the impacts from a potential loss of land-use controls at the site.

4.4.3 Short-term Uses and Long-term Productivity

Implementation of any of the alternatives would require the use of the site to support cleanup activities and the use of depletable resources, such as construction materials, fuel, and petroleum-based products. Alternatives that include excavation and disposal would require the long-term commitment of land for waste disposal at an off-site disposal facility.

The short-term use of the site for remedial activities could adversely affect tenant operations, mainly in OU-2. Planning would be required prior to implementing any of the alternatives to reduce risks to the current tenants and impact to operations. Long-term effect on the current tenants would be taken into account when analyzing each alternative.

4.4.4 Final Status Surveys

USACE intends to use the MARSSIM (DoD 2000) to ensure the combined exposure to all radiological contaminants would not exceed dose-based limits. Alternatives 3, 4, 7, and 8 include the MARSSIM approach as part of the confirmatory sampling to be completed after remediation of the site. MARSSIM provides a consistent and scientifically rigorous approach for demonstrating radionuclide-specific derived concentration guideline levels (DCGLs) for surface soil and building surfaces have been achieved. The approach includes the development of surveying and sampling criteria for the final site investigation prior to release, referred to as the “final status survey.” The approach considers contaminant concentrations averaged over entire EUs or limited to small areas of elevated activity. A final status survey plan based on the MARSSIM methodology would be developed and implemented to assure current or potential future doses are acceptable (as defined by the restrictions of the remedial alternatives). The final status survey plan would be developed as part of the remedial design and is not included in this report.

4.5 QUALITATIVE ANALYSIS OF SELECT ALTERNATIVES

The previous sections evaluated each of the alternatives for OU-1 and OU-2 separately and did not take into consideration combining similar alternatives between the two OUs to realize potential cost savings due to economies-of-scale when implementing both together. The following material provides a qualitative assessment of what the estimated potential cost savings could be if similar alternatives for OU-1 and OU-2 are selected and implemented at or near the same time. The similar alternatives being addressed are:

- Complete Removal with Off-Site Disposal (Alternative 3 [OU-1 and Alternative 7 [OU-2]); and

- Complete Removal with Ex-Situ Treatment and Off-Site Disposal (Alternative 4 [OU-1] and Alternative 8 [OU-2]).

There were no economies-of-scale identified for selecting the Limited Action and Land-Use Controls alternatives for OU-1 and OU-2. The qualitative evaluations in the following sections will focus on the CERCLA evaluation criteria of "Cost." The evaluation against all other CERCLA criteria for these combined alternatives will remain the same for the individual OU alternatives evaluated above, unless otherwise noted.

4.5.1 Complete Removal with Off-Site Disposal (Alternative 3 [OU-1] and Alternative 7 [OU-2])

There is potential for cost savings if the final remedial alternative decision for both OU-1 and OU-2 is the "Complete Removal with Off-Site Disposal" alternative. The savings would be realized if the remedial actions were conducted at the same time. The key areas for cost savings are associated with remedial design and mobilization/demobilization. There would be minimal, if any, costs savings associated with the packaging, handling, and transportation of the waste materials off-site. Actual costs savings will be dependent on whether the two remedial actions are conducted at or near the same time or at separate times (e.g., OU-2 remediation occurs one or more years after completion of OU-1 remediation). Due to this uncertainty as to when both remedial actions would occur, a range of potential costs savings is considered.

The costs savings that could be realized associated with the remedial design costs are based on there being no need to conduct two remedial design efforts (e.g., remedial design development, reviews, approvals). The greatest cost savings for this effort would occur if both remedial actions (OU-1 and OU-2) were conducted at the same time or consecutively, resulting in only one remedial design phase. However, should the remedial action for OU-2 be delayed until a year or more after OU-1 remediation has been completed, the cost savings will be significantly less. For the latter case, remedial design efforts would be needed to address OU-2 waste since OU-1 remediation would be considered complete. The potential cost savings associated with this component could range from $0 (where remediation of OU-2 occurs a year or more after completion of OU-1 remediation) to approximately $300,000 (where both units are remediated at the same time or consecutively).

As discussed above, another potential cost saving could be realized with equipment and contractor mobilization and demobilization efforts. This cost component does not include the equipment and manpower costs associated with the remedial actions in the field. It only considers mobilization and demobilization. This cost saving can only be realized if remediation of both OU-1 and OU-2 occur at the same time. Should they occur consecutively or separately, there is no cost savings to be realized for this cost component. Therefore, the range of potential cost savings associated with the mobilization and demobilization ranges from $0 to approximately $200,000.

Based on the key potential cost saving areas discussed above, if the same remedial decision (complete removal with off-site disposal) is made for both OU-1 and OU-2, the potential costs savings could range from $0 to $500,000. An additional cost savings could be recognized if the five-year reviews were conducted concurrently for both OU-1 and OU2, which would result in a potential cost savings ranging from approximately $0 to $40,000.

4.5.2 Complete Removal with Ex-Situ Treatment and Off-Site Disposal (Alternative 4 [OU-1] and Alternative 8 [OU-1])

There is the potential for costs savings if the final remedial alternative decision for both OU-1 and OU-2 is the "Complete Removal with Ex-Situ Treatment and Off-Site Disposal" alternative. Instead of having two separate on-site ex-situ treatment capabilities present, only one (in OU-1) would be needed to handle all excavated waste material from both OU-1 and OU-2 remedial actions. The key areas for cost savings are those associated with remedial design and mobilization/demobilization. Actual costs savings will be dependent on whether the two remedial actions are conducted at or near the same time or at separate times (e.g., OU-2 remediation occurs one or more years after completion of OU-1 remediation). Due to this uncertainty as to when both remedial actions would occur, a range of potential costs savings is considered.

The costs savings that could be realized associated with the remedial design costs are based on there being no need to conduct two remedial design efforts (e.g., remedial design development, reviews, approvals). The greatest cost savings for this effort would occur if both remedial actions (OU-1 and OU-2) were conducted at the same time or consecutively, resulting in only one remedial design phase. However, should the remedial action for OU-2 be delayed until a year or more after OU-1 remediation has been completed, the cost savings will be significantly less. For the latter case, remedial design efforts would be needed to address OU-2 waste since OU-1 remediation would be considered complete. The potential cost savings associated with this component could range from $0 (where remediation of OU-2 occurs a year or more after completion of OU-1 remediation) to approximately $400,000 (where both units are remediated at the same time or consecutively).

As discussed above, another potential cost saving could be realized with equipment and contractor mobilization and demobilization efforts. This cost component does not include the equipment and manpower costs associated with the remedial actions in the field. It only considers mobilization and demobilization. This cost saving can only be realized if remediation of both OU-1 and OU-2 occur at the same time. Should they occur consecutively or separately, there is no cost savings to be realized for this cost component. Therefore, the range of potential cost savings associated with the mobilization and demobilization ranges from $0 to approximately $200,000.

Based on the key potential cost saving areas discussed above, if the same remedial decision (removal, ex-situ treatment, and off-site disposal) is made for OU-1 and OU-2, the potential cost savings could range from approximately $0 to $600,000. The short-term effectiveness would also be impacted. However, there would be an increase in transport distances associated with moving the waste from OU-2 to the ex-situ treatment facility at OU-1, rather than treating the OU-2 waste at an OU-2 location.

An additional cost savings could be recognized if the five-year reviews were conducted concurrently for both OU-1 and OU2, which would result in a potential cost savings ranging from approximately $0 to $40,000.

4.6 AGENCY COORDINATION AND PUBLIC INVOLVEMENT

This section reviews actions that have been conducted and those that are planned to ensure regulatory agencies and the public have the appropriate opportunities to stay informed of progress on the Former Harshaw Chemical Company Site remediation.

As described in Section 4.1.3, two of the nine NCP [40 CFR §300.430(f)(i)(C)] evaluation criteria are known as "modifying criteria." These are State Acceptance and Community Acceptance. These criteria

provide a framework for obtaining the necessary agency coordination and public involvement in the remedy selection process.

4.6.1 State Acceptance

State Acceptance considers comments received from agencies of the state of Ohio. The primary state agencies supporting this investigation are the Ohio EPA and the ODH. Input has been encouraged during the ongoing investigation process to ensure the remedy ultimately selected for the Former Harshaw Chemical Company Site meets the needs of the state of Ohio. Final comments will be received from state agencies after the PP is issued. These comments will be considered in the final selection of a remedy, and responses will be documented in the responsiveness summary of the subsequent ROD.

4.6.2 Community Acceptance

Community acceptance considers community comments regarding the alternatives being considered. CERCLA 42 U.S.C. 9617(a) emphasizes early, constant, and responsive community relations. A community relations program for the FUSRAP Former Harshaw Chemical Company Site is in place. The community relations program interacts with the public through news releases, public meetings, public workshops, and meetings with local officials and interest groups and also receives and responds to public comments through correspondence and the USACE FUSRAP Public Information Center. Similar to state agencies, final comments will be received from the community after the PP is issued. These comments will be considered in the final selection of a remedy and will be addressed in the responsiveness summary of the ROD.

CERCLA 42 U.S.C. 9617(a) requires that an Administrative Record be established "at or near the facility at issue." Relevant documents regarding the Former Harshaw Chemical Company Site have been made available to the public for review. The Administrative Record for the project is available at the following locations in the formats indicated:

Cuyahoga County Public Library - Brooklyn Branch (electronic copy only)
4480 Ridge Rd.
Brooklyn, OH 44144

Cleveland Public Library (electronic and paper copy)
325 Superior Avenue NE
Cleveland, OH 44114

USACE FUSRAP Public Information Center (electronic and paper copy)
CERCLA Records Room (by appointment)
1776 Niagara Street
Buffalo, NY 14207
1.800.833.6390 (press "4" at the recorded message)

Key documents are also available at: www.lrb.usace.army.mil/fusrap/harshaw/#Documents

4.7 CONCLUSION

The CERCLA remedy selection process consists of a PA, site inspection, RI, and FS, followed by presentation of the preferred remedy in the PP and selection of the final remedy in the ROD. To date, several of these steps have been completed. These efforts have compiled and evaluated essential

information characterizing the nature and extent of contamination resulting from past operations at the Former Harshaw Chemical Company Site.

The primary purpose of this FS is to screen and evaluate remedial alternatives using the data collected during the RI as well as other relevant information. The detailed and comparative analysis of alternatives presented in this FS provides the basis for the evaluation and the selection of the preferred alternative for OU-1 and OU-2 that will be presented in the PP.

The site exposure model used as the basis for the FS Alternative rankings relies on potential pathways to a future construction worker. The distribution of MED-related constituents in groundwater is correlated directly to areas of impacted soils and exhibits little migration due to soil partitioning. Although USEPA MCLs are exceeded in portions of the site, the existing site use (passive industrial) poses no current unacceptable risk to human health and the environment. Consequently, RAOs were not developed for groundwater at this time. Groundwater on and near the site is not usable as a drinking water source because groundwater quality and yield are not suitable for use by industries or residents and current and future residents and industry in the area rely solely on municipal water as previously described in Sections 1.2.3.3 and 1.3.2 in this FS Report.

It is premature to develop and evaluate remedial alternatives to address impacted groundwater in this Feasibility Study because the remedial alternative selected for soil contamination may impact the distribution and concentration of groundwater contamination at the site and will affect the alternatives evaluated for addressing groundwater. To ensure complete consideration of impacted media on-site, groundwater conditions will be re-evaluated upon completion of a soils remedy. If the USACE determines that a potential exists for an unacceptable risk from groundwater impacted by FUSRAP-related materials, then, remedial alternatives will be evaluated and a separate Feasibility Study, Proposed Plan and Record of Decision will be completed for groundwater.

The following eight alternatives were evaluated:

- Alternative 1: No Action (OU-1);
- Alternative 2: Limited Action and Land-Use Controls (OU-1);
- Alternative 3: Complete Removal with Off-Site Disposal (OU-1);
- Alternative 4: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1);
- Alternative 5: No Action (OU-2);
- Alternative 6: Limited Action and Land-Use Controls (OU-2);
- Alternative 7: Complete Removal with Off-Site Disposal (OU-2); and
- Alternative 8: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2).

The preferred alternative(s) will be described in the PP.

This FS evaluated and compared each remedial alternative using the following CERCLA criteria:

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

Two additional criteria, State Acceptance and Community Acceptance, are not evaluated in this FS because they will be evaluated in the ROD after comments on the PP have been received. The following paragraphs briefly summarize which alternatives best satisfy each criteria.

Overall Protection of Human Health and the Environment: Alternatives 3 and 4 (OU-1) and Alternatives 7 and 8 (OU-2) are protective of human health and the environment for the site because the impacted media would be removed from its present location and transported to an off-site facility for disposal. Alternatives 2 and 6 are protective of human health and the environment but rely on land-use controls to achieve and maintain protectiveness. Alternatives 1 and 5 (No Action) are not protective of human health.

Compliance with ARARs: Alternatives 2, 3, and 4 (OU-1) and Alternatives 6, 7, and 8 (OU-2) comply with ARARs. Following completion of Alternatives 2 and 6, OU-1 and OU-2 would meet the restricted release conditions of 10 CFR 20.1403. Alternatives 2 and 6 would require land-use controls to be implemented and maintained. Alternatives 3 and 4 for OU-1 and Alternatives 7 and 8 for OU-2 would meet the unrestricted release conditions of 10 CFR 20.1402. Alternatives 1 and 5 do not meet the ARARs.

Long-Term Effectiveness and Permanence: The alternatives involving complete removal with off-site disposal (Alternatives 3 and 4 for OU-1 and Alternatives 7 and 8 for OU-2) provide the best long-term effectiveness and permanence. Impacted soil would be excavated and removed from the site. With the exception of five-year reviews for the removal alternatives, there would not be any monitoring and maintenance associated with these alternatives.

Reduction in Toxicity, Mobility, or Volume through Treatment: Alternative 4 (OU-1) and Alternative 8 (OU-2) have the greatest reduction in mobility. However, both alternatives result in an overall increase in the volume of waste material to be handled and shipped off-site for disposal.

Short-Term Effectiveness: Alternative 2 (OU-1) and Alternative 6 (OU-2) require minimal remediation activities; therefore, no significant risks to on-site workers, the community, or the environment are expected during the implementation of these alternative in the short term. These alternatives provide the greatest measure of short-term effectiveness with the least short-term risks.

Implementability: Complete Removal with Off-Site Disposal (Alternatives 3 and 7) would be the easiest to implement administratively. No significant problems related to obtaining approvals from other agencies or coordinating remediation activities with land owners are expected for these alternatives. Among the action alternatives, the alternatives involving limited action and land-use controls (Alternatives 2 and 6) are rated highest in technical implementability because no excavation activities would be required. However, Alternatives 3 and 7 (Complete Removal with Off-Site Disposal) are only slightly lower in technical implementability than the limited action alternatives because removal and off-site disposal activities are generally easy to implement, using common equipment, materials, and supplies.

Cost: With the exception of the No Action alternatives, the alternatives involving limited action and land-use controls (Alternatives 2 and 6) have the lowest estimated costs to complete.

After completion of the FS, the next step in the CERCLA process is to prepare a PP to solicit public input on the remedial alternatives. The PP will present the alternatives evaluated in the FS and will identify the preferred alternatives for remediating OU-1 and OU-2 at the Former Harshaw Chemical Company Site.

The PP will be submitted to the public and regulators for review. Public comments received on the PP also will be evaluated.

The ROD will select the final remedies for OU-1 and OU-2 at the Former Harshaw Chemical Company Site. Comments on the PP received from state and Federal agencies and the public will be considered when preparing the ROD. The ROD will describe the CERCLA remedy selection process and provide a brief summary of the history, characteristics, risks, and alternatives for site remediation. The ROD also will include a responsiveness summary, addressing comments received on the PP.

Table 4-1. Summary of Detailed Analysis of Remedial Alternatives for OU-1

Criteria	Alternative 1: No Action (OU-1)	Alternative 2: Limited Action and Land-Use Controls (OU-1)	Alternative 3: Complete Removal with Off-Site Disposal (OU-1)	Alternative 4: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Human Health	Not protective.	Protective. Land-use controls provide protectiveness for those areas where contamination remains in place above the PRGs.	Protective. Removal of contaminated soil and decontamination/ dismantlement of buildings provide protectiveness.	Protective. Removal of contaminated soil and decontamination/ dismantlement of buildings provide protectiveness.
Environment	Protective. Ecological risk from FUSRAP constituents is negligible.	Protective. Ecological risk from FUSRAP constituents is negligible.	Protective. Action designed to address human health risk. However, removal of contaminated soil and buildings also provides environmental protectiveness.	Protective. Action designed to address human health risk. However, removal of contaminated soil and buildings also provides environmental protectiveness.
ARARs	Not compliant.	Compliant with limited action ARARs, the restricted release conditions given in 10 CFR 20.1403, which require the annual dose to an average member of the critical group to not exceed 100 mrem/yr (or 500 mrem/yr if applicable) if land-use controls are lost.	Compliant with complete removal ARARs, the unrestricted release conditions of 10 CFR 20.1402 (i.e., 25 mrem/yr to average member of the critical group [construction worker at OU-1]).	Compliant with complete removal ARARs, the unrestricted release conditions of 10 CFR 20.1402 (i.e., 25 mrem/yr to average member of the critical group [construction worker at OU-1]).
Need for Waivers	Not appropriate.	No waiver would be required.	No waiver would be required.	No waiver would be required.
Magnitude of Remaining Risk	High. Residual exposure exceeds acceptable levels due to contamination remaining in place.	High. Residual exposure exceeds acceptable levels due to soil contamination remaining in place. Residual risk is acceptable as long as land-use controls are maintained.	Low. Meets acceptable exposure levels for reasonable future land use and critical group.	Low. Meets acceptable exposure levels for reasonable future land use and critical group.

Table 4-1. Summary of Detailed Analysis of Remedial Alternatives for OU-1 (continued)

Criteria	Alternative 1: No Action (OU-1)	Alternative 2: Limited Action and Land-Use Controls (OU-1)	Alternative 3: Complete Removal with Off-Site Disposal (OU-1)	Alternative 4: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Adequacy of Controls	No land-use controls.	Land-use controls would be adequate for achieving RAOs.	Existing controls would ensure continued industrial land use.	Existing controls would ensure continued industrial land use.
Reliability of Controls	No land-use controls.	There are uncertainties regarding the ability of the controls to ensure protectiveness over a 1,000-year period. Land use limited to passive recreational use.	Continued industrial land use.	Continued industrial land use.
Long-Term Management	No long-term management.	Periodic site monitoring and five-year reviews would be required to verify maintenance of land-use controls.	Five-year reviews would be required.	Five-year reviews would be required.
Contaminant Toxicity, Mobility, or Volume through treatment	None.	None.	None[a].	Ex-situ S/S would reduce mobility. Volume of treatment residuals would be higher than original soil volume. No reduction in toxicity.
Protection of Community	No additional short-term risk to community due to no action taken.	Minimal additional short-term risk to community from building dismantlement activities, but risks would be controlled by mitigative measures.	Slight potential for an increase in short-term risk from excavation and transportation, but risks would be controlled by mitigative measures.	Slight potential for an increase in short-term risk from excavation, treatment, and transportation, but risks would be controlled by mitigative measures.
Protection of Site Workers	No additional short-term risk to site workers.	Minimal short-term risk from building dismantlement and monitoring activities would be reduced by mitigative measures.	Short-term risk from excavation and transportation would be reduced by mitigative measures.	Short-term risk from excavation, treatment, and transportation would be reduced by mitigative measures.

Table 4-1. Summary of Detailed Analysis of Remedial Alternatives for OU-1 (continued)

Criteria	Alternative 1: No Action (OU-1)	Alternative 2: Limited Action and Land-Use Controls (OU-1)	Alternative 3: Complete Removal with Off-Site Disposal (OU-1)	Alternative 4: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Environmental Impacts	No additional short-term impacts to the environment due to no action taken.	Minimal additional short-term impacts to the environment.	Short-term impacts to the environment resulting from excavation and transportation.	Short-term impacts to the environment resulting from excavation and transportation.
Time until RAOs are achieved	RAOs would not be achieved.	Very short timeframe (1 to 2 years) to conduct building dismantlement and implement land-use controls. Long O&M period (1,000 years).	Relatively short timeframe (2 to 3 years) to achieve cleanup objectives. Assumes an O&M period of 1,000 years (five-year reviews).	Relatively short timeframe (2 to 3 years) to achieve cleanup objectives. Assumes an O&M period of 1,000 years (five-year reviews).
Technical	Not applicable; no action would be implemented.	Building dismantlement, land-use controls, and periodic monitoring are easy to implement.	Relatively easy. Uses proven technologies and readily available equipment.	Similar to Alternative 3. Additional component (S/S treatment) is well proven, and vendors are readily available.
Administrative	Not applicable; no action would be implemented.	Low administrative implementability. There could be difficulties implementing land-use controls due to multiple land owners.	Relatively easy. No significant difficulties expected with respect to scheduling and coordinating remediation activities with land owners.	Similar to Alternative 3. Additional component (S/S treatment) not expected to have significant effect on administrative implementability.
Cost Present Worth (Non-Discounted)[b]				
Total Cost Over 1,000-Year Period	$0 ($0)	$12,406,557 ($56,604,601)	$55,185,927 ($61,829,592)	$76,410,747 ($83,139,588)

[a]Waste minimization practices proposed under this alternative, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal.
[b]Non-discount values do not consider the time value of money. In other words, each dollar earned in the future is assumed to have the same value as each dollar that was invested many years earlier.
$ = Dollar
% = Percent
ARAR = Applicable or Relevant and Appropriate
CFR = Code of Federal Regulations
FUSRAP = Formerly Utilized Sites Remedial Action Program
mrem/yr = Millirem Per Year
O&M = Operation and Maintenance
OU = Operable Unit
RAO = Remedial Action Objective
S/S = Solidification/Stabilization

Table 4-2. Summary of Detailed Analysis of Remedial Alternatives for OU-2

Criteria	Alternative 5: No Action (OU-2)	Alternative 6: Limited Action and Land-Use Controls (OU-2)	Alternative 7: Complete Removal with Off-Site Disposal (OU-2)	Alternative 8: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Human Health	Not protective.	Protective. Land-use controls provide protectiveness for those areas where contamination remains in place above the PRGs.	Protective. Removal of contaminated soil and isolation in an off-site disposal facility provides protectiveness.	Protective. Removal of contaminated soil and isolation in an off-site disposal facility provides protectiveness.
Environment	Protective. Ecological risk from FUSRAP constituents is negligible.	Protective. Ecological risk from FUSRAP constituents is negligible.	Protective. Action designed to address human health risk. However, removal of contaminated soil also increases environmental protectiveness.	Protective. Action designed to address human health risk. However, removal of contaminated soil also increases environmental protectiveness.
ARARs	Not Compliant.	Compliant with limited action ARARs, the restricted release conditions given in 10 CFR 20.1403, which require that the annual dose to an average member of the critical group not exceed 100 mrem/yr (or 500 mrem/yr if applicable) if land-use controls are lost.	Compliant with complete removal ARARs, 10 CFR 1402, (i.e., 25 mrem/yr under unrestricted release conditions) at OU-2.	Compliant with complete removal ARARs, 10 CFR 1402, (i.e., 25 mrem/yr under unrestricted release conditions) at OU-2.
Need for Waivers	Not appropriate.	No waiver would be required.	No waiver would be required.	No waiver would be required.
Magnitude of Remaining Risk	High. Residual exposure exceeds acceptable levels due to contamination remaining in place.	High. Residual exposure exceeds acceptable levels due to soil contamination remaining in place. Residual risk is acceptable as long as land-use controls are maintained.	Low. Meets acceptable exposure levels for reasonable future land use and critical group.	Low. Meets acceptable exposure levels for reasonable future land use and critical group.

Table 4-2. Summary of Detailed Analysis of Remedial Alternatives for OU-2 (continued)

Criteria	Alternative 5: No Action (OU-2)	Alternative 6: Limited Action and Land-Use Controls (OU-2)	Alternative 7: Complete Removal with Off-Site Disposal (OU-2)	Alternative 8: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Adequacy of Controls	No land-use controls.	Land-use controls would be adequate for achieving RAOs.	No land-use controls.	No land-use controls.
Reliability of Controls	No land-use controls.	There are uncertainties regarding the ability of the controls to ensure protectiveness over a 1,000-year period. Land use limited to passive recreational use.	No land-use controls.	No land-use controls.
Long-Term Management	No long-term management.	Periodic site monitoring and five-year reviews would be required to verify maintenance of land-use controls.	None.	None.
Contaminant Toxicity, Mobility, or Volume through treatment	None.	None.	None[a].	Ex-situ S/S would reduce mobility. Volume of treatment residuals would be higher than original soil volume. No reduction in toxicity.
Protection of Community	No additional short-term risk to community due to no action taken.	No additional short-term risk to community.	Slight potential for an increase in short-term risk from excavation and transportation, but risks would be controlled by mitigative measures.	Slight potential for an increase in short-term risk from excavation, treatment, and transportation, but risks would be controlled by mitigative measures.

Table 4-2. Summary of Detailed Analysis of Remedial Alternatives for OU-2 (continued)

Criteria	Alternative 5: No Action (OU-2)	Alternative 6: Limited Action and Land-Use Controls (OU-2)	Alternative 7: Complete Removal with Off-Site Disposal (OU-2)	Alternative 8: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Protection of Site Workers	No additional short-term risk to site workers.	Minimal short-term risk from monitoring activities would be reduced by mitigative measures.	Short-term risk from excavation and transportation would be reduced by mitigative measures.	Short-term risk from excavation, treatment, and transportation would be reduced by mitigative measures.
Environmental Impacts	No additional short-term impacts to the environment due to no action taken.	No additional short-term impacts to the environment.	Short-term impacts to the environment resulting from excavation and transportation.	Short-term impacts to the environment resulting from excavation and transportation.
Time until RAOs are achieved	RAOs would not be achieved.	Very short timeframe (1 to 2 years) to implement land-use controls, long O&M period (1,000 years).	Relatively short timeframe (2 to 3 years) to achieve cleanup objectives.	Relatively short timeframe (2 to 3 years) to achieve cleanup objectives.
Technical	Not applicable; no action would be implemented.	Land-use controls and periodic monitoring are easy to implement.	Relatively easy. Uses proven technologies and readily available equipment.	Similar to Alternative 7. Additional component (S/S treatment) is well proven and vendors are readily available.
Administrative	Not applicable; no action would be implemented.	Low administrative implementability. There could be difficulties implementing land-use controls due to multiple land owners.	Relatively easy. No significant difficulties expected with respect to scheduling and coordinating remediation activities with land owners.	Similar to Alternative 7. Additional component (S/S treatment) not expected to have significant effect on administrative implementability
Cost Present Worth (Non-Discounted)[b]				
Total Cost Over 1,000-Year Period	$0 ($0)	$2,228,575 ($36,047,405)	$6,617,430 ($6,617,430)	$9,562,520 ($9,562,520)

[a]Waste minimization practices proposed under this alternative, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal.
[b]Non-discount values do not consider the time value of money. In other words, each dollar earned in the future is assumed to have the same value as each dollar that was invested many years earlier.
$ = Dollar
% = Percent
ARAR = Applicable or Relevant and Appropriate
CFR = Code of Federal Regulations
FUSRAP = Formerly Utilized Sites Remedial Action Program
mrem/yr = Millirem Per Year
O&M = Operation and Maintenance
OU = Operable Unit
RAO = Remedial Action Objective
S/S = Solidification/Stabilization

Table 4-3. Summary of Comparative Analysis of Remedial Alternatives for OU-1

CERCLA Criteria	Alternative 1: No Action (OU-1)	Alternative 2: Limited Action and Land-Use Controls (OU-1)	Alternative 3: Complete Removal with Off-Site Disposal (OU-1)	Alternative 4: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Overall Protection of Human Health and the Environment	Not Protective	Protective	Protective	Protective
Compliance with ARARs	Not Compliant	Compliant	Compliant	Compliant
Long-Term Effectiveness and Permanence	Low	Moderate	High	High
Reduction of contaminant toxicity, mobility, or volume through treatment	None	None	None[a]	Moderate (Mobility reduction through S/S treatment but increase in disposal volumes)
Short-Term Effectiveness	High	High	Moderate	Low
Implementability[b]	Not Applicable	Low	High	High
Cost Present Worth (Non-Discounted)[c]	$0 ($0)	$12,406,557 ($56,604,601)	$55,185,927 ($61,829,592)	$76,410,747 ($83,139,588)

[a]Waste minimization practices proposed under this alternative, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal.
[b]The overall implementability is based on the lower of the rankings for technical and administrative implementability.
[c]Non-discount values do not consider the time value of money. In other words, each dollar earned in the future is assumed to have the same value as each dollar that was invested many years earlier.
$ = Dollar
ARAR = Applicable or Relevant and Appropriate Requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
OU = Operable Unit
S/S = Solidification/Stabilization

Table 4-4. Summary of Comparative Analysis of Remedial Alternatives for OU-2

CERCLA Criteria	Alternative 5: No Action (OU-2)	Alternative 6: Limited Action and Land-Use Controls (OU-2)	Alternative 7: Complete Removal with Off-Site Disposal (OU-2)	Alternative 8: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Overall Protection of Human Health and the Environment	Not Protective	Protective	Protective	Protective
Compliance with ARARs	Not Compliant	Compliant	Compliant	Compliant
Long-Term Effectiveness and Permanence	Low	Moderate	High	High
Reduction of contaminant toxicity, mobility, or volume through treatment	None	None	None[a]	Moderate (Mobility reduction through S/S treatment but increase in disposal volumes)
Short-Term Effectiveness	High	High	Moderate	Low
Implementability[b]	Not Applicable	Low	High	High
Cost Present Worth (Non-Discounted)[c]	$0 ($0)	$2,228,575 ($36,047,405)	$6,617,430 ($6,617,430)	$9,562,520 ($9,562,520)

[a]Waste minimization practices proposed under this alternative, such as radiological scanning and soil sorting, may reduce the volume of contaminated soil requiring disposal.
[b]The overall implementability is based on the lower of the rankings for technical and administrative implementability.
[c]Non-discount values do not consider the time value of money. In other words, each dollar earned in the future is assumed to have the same value as each dollar that was invested many years earlier.
ARAR = Applicable or Relevant and Appropriate Requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
OU = Operable Unit
S/S = Solidification/Stabilization

Table 4-5. Summary of Impacts from Potential Loss of Land-Use Controls

Alternative Number	Alternative Title	Impact of Potential Loss of Land-Use Controls
	OU-1	
1	No Action	Under this alternative, existing land-use controls would not be maintained. Therefore, there would be no impact if land-use controls fail.
2	Limited Action and Land-Use Controls	If land-use controls fail under this alternative, the potential for exposure at unacceptable levels is high.
3	Complete Removal with Off-Site Disposal	Alternative 3 removes soil to meet the release criteria under 10 CFR Part E. Under this alternative, soil would be removed to below dose limit for the critical group, which has been defined as the construction worker. Therefore, no land-use controls are included in this alternative.
4	Complete Removal with Ex-Situ Treatment and Off-Site Disposal	Alternative 4 removes soil to meet the release criteria under 10 CFR Part E. Under this alternative, soil would be removed to below dose limit for the critical group, which has been defined as the construction worker. Therefore, no land-use controls are included in this alternative.
	OU-2	
5	No Action	Under this alternative, existing land-use controls would not be maintained. Therefore, there would be no impact if land-use controls fail.
6	Limited Action and Land-Use Controls	If land-use controls fail under this alternative, the potential for exposure at unacceptable levels is high.
7	Complete Removal with Off-Site Disposal	Alternative 7 removes soil to meet the release criteria under 10 CFR Part E. Under this alternative, soil would be removed to below dose limit for the critical group, which has been defined as the resident adult. Therefore, no land-use controls or five-year reviews are included in this alternative.
8	Complete Removal with Ex-Situ Treatment and Off-Site Disposal	Alternative 8 removes soil to meet the release criteria under 10 CFR Part E. Under this alternative, soil would be removed to below dose limit for the critical group, which has been defined as the resident adult. Therefore, no land-use controls or five-year reviews are included in this alternative.

CFR = Code of Federal Regulations
OU = Operable Unit

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5. REFERENCES

ANL (Argonne National Laboratory) 1984. *Formerly Utilized MED/AEC Sites Remedial Action Program Radiological Survey of the Harshaw Chemical Company, Cleveland, Ohio*. April.

B. Koh and Associates, Inc. 1998. *Site Characterization Report*, Harvard Denison Site.

CWM (Chemical Waste Management) 1992. *The Building C Site Report*. July.

Chevron-BGD 1997. *U.S. Government Responsibility Under FUSRAP for Former Harshaw Chemical Site*. December.

CWRU (Case Western Reserve University) 2004. *The Encyclopedia of Cleveland History*. http://ech.cwru.edu/ech-cgi/article.pl?id=HCC1. Accessed June 2010.

DoD (United States Department of Defense) 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, NUREG-1575, USEPA 402-R-97-016, Revision 1, August.

DOE (United States Department of Energy) 1994. *Decommissioning Handbook*, DOE-EM-0142P, Oak Ridge, TN. March.

Ebbs, S., D. Brady, W. Norvell, and L. Kochian 2001. Uranium Speciation, Plant Uptake, and Phytoremediation, Practice periodical of Hazardous, Toxic, and Radioactive Waste Management. July.

Evanko, Cynthia R. and David A. Dzombak. 1997. *Remediation of Metals-Contaminated Soils and Groundwater*. Technology Evaluation Report TE-97-01. Ground-Water Remediation Technologies Analysis Center, Pittsburgh, PA. October.

FRTR (Federal Remediation Technologies Roundtable) 2009. Remediation Technologies Screening Matrix and Reference Guide, Version 4.0, found at http://www.frtr.gov/.

FRTR 2010. *Remediation Technologies Screening Matrix and Reference Guide, Version 4.0*, http://www.frtr.gov/.

Huang, Jianwei W., Michael J. Blaylock, Yoram Kapulnik, and Burt D. Ensley 1998. *Phytoremediation of Uranium Contaminated Soils: Role of Organic Acids in Triggering Uranium Hyperaccumulation in Plants*. Environmental-Science-and-Technology.

ITRC (Interstate Technology and Regulatory Council) 1999. Phytoremediation Decisions Tree, found at http://clu-in.org/download/partner/phytotree.pdf.

ITRC 2008. *Decontamination and Decommissioning of Radiologically Contaminated Facilities*.

NABIR (Natural and Accelerated Bioremediation Research Program) 1999. *Bioremediation of Metals and Radionuclides*, Office of Biological and Environmental Research, Office of Science, U.S. Department of Energy.

NABIR 2003. *Bioremediation of Metals and Radionuclides: What it is and How it Works*. Second Edition.

Ohio EPA (Ohio Environmental Protection Agency) 2010. Licensed Construction and Demolition Debris Landfill Facilities. http://www.epa.state.oh.us/portals/34/document/facility_lists/lic_cdd.pdf.

Schnoor, J.L. 1997. Phytoremediation. Ground-water Remediation Technology Analysis Center Technology Evaluation Report TE-98-01. Concurrent Technologies Corp., Pittsburgh, Pennsylvania.

USACE (United States Army Corps of Engineers) 1998. *Record of Decision, Soils Operable Unit #1, Iowa Army Ammunition Plant, Middletown, Iowa*, U.S. Army Corps of Engineers, Omaha District, Omaha, NE, Revision 1, September.

USACE 2009. *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1*. October.

USDA (United States Department of Agriculture) 1980. *Soil Survey of Cuyahoga County, Ohio*.

USEPA (United States Environmental Protection Agency) 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. EPA/540/G-89/004, Office of Emergency and Remedial Response, Washington, D.C. October.

USEPA 1990. *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP), *Final Rule*, available from U.S. Government Printing Office, Washington, D.C. March.

USEPA 1991. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)*, OSWER Directive 9285.7-01B, Office of Emergency and Remedial Response, Washington, D.C.

USEPA 1992. *CERCLA/Superfund Orientation Manual*. EPA/542/R-92/005, Office of Solid Waste and Emergency Response, Washington D.C. October.

USEPA 1994. *Engineering Bulletin; In situ Vitrification Treatment*. EPA/540/S-94/504. Office of Emergency and Remedial Response. Washington, D.C. October.

USEPA 1996. *Technology Screening Guide for Radioactively Contaminated Sites*, 402-R-96- 017, Office of Air and Radiation, Office of Solid Waste and Emergency Response, Washington D.C., November.

USEPA 2001. *Use of Bioremediation at Superfund Sites*, EPA 542-R-01-019, Office of Solid Waste and Emergency Response, Washington, D.C., September.

USEPA 2002. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*. OSWER 9285.6-10. December.

USEPA 2006. *Technology Reference Guide for Radiological Contaminated Surfaces*, EPA-402-R-06-003, Office of Air and Radiation, Washington D.C., March.

USEPA 2007. *Technology Reference Guide for Radioactively Contaminated Media*. EPA 402-R-07-004, Office of Radiation and Indoor Air, Washington, D.C.

USEPA 2010. *ProUCL Version 4.1.00 Technical Guide (Draft) Statistical Software for Environmental Applications for Datasets with and without Nondetect Observations*, EPA/600/R-07/041. Accessed May 2010. http://www.epa.gov/osp/hstl/tsc/software.htm

Yim, Man-Sung and Murty, K. Linga 2000. *Materials Issues in Nuclear-Waste Management;* Journal of the Minerals, Metals, and Materials Society (JOM). September.

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APPENDIX A

Ohio Environmental Protection Agency – ARAR List

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Ohio Environmental Protection Agency – ARAR List

ARAR NUMBER	CATEGORY	OHIO REVISED CODE	OHIO ADMINISTRATIVE CODE	PARAGRAPH	CAPTION	TEXT	APPLICATION	TYPE	HARSHAW SITE-SPECIFIC REVIEW RESULTS	
									APPLICABLE	RELEVANT AND APPROPRIATE
Although the following potential ARAR is considered applicable to site conditions, it is superseded by the relevant and appropriate chemical-specific potential ARAR discussed in Section 2.1.1.2 of the FS Report (10 CFR 20 Subpart E):										
NA	ODH		3701: 1-38-22		Decommissioning	This rule applies to the decommissioning of facilities licensed under Chapter 3748 of the Ohio Revised Code. For low-level waste disposal facilities, this rule applies only to ancillary surface facilities that support radioactive waste disposal activities.	Decommissioning with license termination shall be limited to sites considered acceptable for unrestricted release where the residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent (TEDE) to an average member of the critical group that does not exceed 0.25 millisievert (twenty-five millirem) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).	Chemical-Specific	N[1]	N[1]
CERCLA requires that the Government must select a remedy that attains a degree of cleanup of hazardous substances, pollutants and contaminants released into the environment and of control of further release at a minimum which assures protection of human health and the environment. 42 USC 9621(d). With respect to any hazardous substance, pollutant or contaminant that will remain on-site the remedial alternative selected shall require a level or standard of control for such substances which at least attains legally applicable or relevant and appropriate standard, requirement criteria or limitation which are derived from any Federal environmental law or any promulgated standard under a State environmental or facility siting law more stringent than any Federal standard. These standards must be applicable to the release of the hazardous substance, pollutant or contaminant. The following potential ARARs are not chemical-specific and therefore are not considered Applicable or Relevant and Appropriate. However, these will be considered during the development of the remedial design:										
1	ODNR	1518.02			Endangered plant species	Prohibits removal or destruction of endangered plant species (some private property exceptions).	Applies to remediation sites where chemicals may harm endangered species. Clearly establishes that receptor plant species must be considered in risk assessments. This act may require consideration of endangered species in remediation that involves movement or displacement of large volumes of surface soil.	Location-Specific	N[2]	N[2]
2	ODNR	1531.25			Endangered animal species	Prohibits removal or destruction of endangered animal species	Applies to remediation sites where chemicals may harm endangered species. Clearly establishes that receptor animal species must be considered in risk assessments. This act may require consideration of endangered species in remediation that involves movement or displacement of large volumes of surface soil.	Location-Specific	N[2]	N[2]
3	APC	3704.05		A-I	Prohibits violation of air pollution control rules	Prohibits emission of an air contaminant in violation sec. 3704 or any rules, permit, order or variance issued pursuant to that section of the Ohio Revised Code (ORC).	May pertain to any site where emission of an air contaminant occurs, either as a pre-existing condition of the site or as a result of remedial activities. Should be considered for virtually all sites that require the management of solid/hazardous wastes.	Action-Specific	N[2]	N[2]
4	DSIWM	3714.13			Dismantlement debris facilities - violations prohibited	Prohibits violations of any section of chapter 3714 concerning construction and dismantlement debris disposal facilities or any rule or order issued pursuant to it. Disposal of asbestos is specifically prohibited without authorization.	Pertains to construction and dismantlement debris facilities where hazardous waste or hazardous constituents have come to be located. Consider for sites where remedial action will include dismantlement of structures or asbestos has come to be located.	Action-Specific	N[2]	N[2]
5	HW	3734.02		(H)	"Digging" where hazardous or solid waste facility was located	Filling, grading, excavating, building, drilling or mining on land where hazardous waste or solid waste facility was operated is prohibited without prior authorization from the director of the Ohio Environmental Protection Agency (Ohio EPA).	Pertains to any site at which hazardous or solid waste has come to be located. Certain alternatives include excavation activities which may uncover solid and/or hazardous waste. If those activities require the management of solid/hazardous wastes on-site, an exemption for permission and other requirements may be warranted.	Action-Specific	N[2]	N[2]

Ohio Environmental Protection Agency – ARAR List

ARAR NUMBER	CATEGORY	OHIO REVISED CODE	OHIO ADMINISTRATIVE CODE	PARAGRAPH	CAPTION	TEXT	APPLICATION	TYPE	HARSHAW SITE-SPECIFIC REVIEW RESULTS	
									APPLICABLE	RELEVANT AND APPROPRIATE
6	HW APC	3734.02		(I)	Air emissions from hazardous waste facilities	No hazardous waste facility shall emit any particulate matter, dust, fumes, gas, mist, smoke, vapor or odorous substance that interferes with the comfortable enjoyment of life or property or is injurious to public health.	Pertains to any site at which hazardous waste will be managed such that air emissions may occur. Consider for sites that will undergo movement of earth or incineration.	Action-Specific	N[2]	N[2]
7	DSIWM	3734.03			Prohibits open dumping or burning	Prohibits open burning or open dumping of solid waste or treated or untreated infectious waste.	Pertains to any site at which solid waste has come to be located or will be generated during a remedial action.	Action-Specific	N[2]	N[2]
8	APC DSW	3767.13			Prohibition of nuisances	Prohibits noxious exhalations or smells and the obstruction of waterways.	Pertains to any site that may have noxious smells or may obstruct waterways.	Action-Specific	N[2]	N[2]
9	DSW	3767.14			Prohibition of nuisances	Prohibition against throwing refuse, oil, or filth into lakes, streams, or drains.	Pertains to all sites located adjacent to lakes, streams, or drains.	Action-Specific	N[2]	N[2]
10	DERR	5301		.80 to .92	Uniform environmental covenants act	Standards for environmental covenants	Consider for sites with institutional controls or use restrictions	Action-Specific	N[2]	N[2]
11	DSW	6111.04			Acts of pollution prohibited	Pollution of waters of the state is prohibited.	Pertains to any site which has contaminated on-site ground or surface water or will have a discharge to on-site surface or ground water.	Action-Specific	N[2]	N[2]
12	DSW	6111.07		A,C	Water pollution control requirements - duty to comply	Prohibits failure to comply with requirements of sections 6111.01 to 6111.08 or any rules, permit or order issued under those sections.	Pertains to any site which has contaminated ground water or surface water or will have a discharge to on-site surface or ground water.	Action-Specific	N[2]	N[2]
13	HW		3745-270-07	A-E	Testing, tracking, and recordkeeping requirements	Testing, tracking, and recordkeeping requirements for generators, treaters, and disposal facilities.	Consider for sites at which wastes are generated, stored, disposed, or treated	NA[1]	NA[1]	NA[1]
14	HW		3745-270-42	A-D	Treatment standards expressed as specified technologies	Lists specific treatment technologies required for specific wastes.	Consider at all sites generating wastes or with on-site disposal	Action-Specific	N[2]	N[2]
15	HW		3745-270-45	A-D	Treatment standards for hazardous debris	Specifies treatment technologies and performance standards for various debris.	Consider for sites with contamination by debris.	Action-Specific	N[2]	N[2]
16	HW		3745-270-48	A	Universal treatment standards	Gives contaminant chemical specific standards for land disposal.	Consider for sites with waste generation or on-site disposal	Action-Specific	N[2]	N[2]
17	HW	3734.027		A,B	Handling low-level radioactive waste prohibited	A) Prohibits commingling low level radioactive waste with any type of solid waste, hazardous waste, or infectious waste. B) No owner or operator of a solid, infectious or hazardous waste facility shall accept for transfer, storage, treatment or disposal of any radioactive waste.	Pertains to all sites at which low level radioactive waste has come to be located.	Action-Specific	N[2]	N[2]
18	DSW		3745-1-03		Analytical and collection procedures	Specifies analytical methods and collection procedures for surface water discharges.	Pertains to both discharges to surface waters as a result of remediation and any on-site surface waters affected by site conditions.	Action-Specific	N[2]	N[2]
19	DSW		3745-1-04	A,B,C,D,E	The "five freedoms" for surface water	All surface waters of the state shall be free from: A) objectionable suspended solids, B) floating debris, oil and scum, C) materials that create a nuisance, D) toxic, harmful or lethal substances, E) nutrients that create nuisance growth.	Pertains to both discharges to surface waters as a result of remediation and any on-site surface waters affected by site conditions.	Action-Specific	N[2]	N[2]

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20	DSW		3745-1-05	A-C	Anti-degradation policy for surface water	Prevents degradation of surface water quality below designated use or existing water quality. Existing in stream uses shall be maintained and protected. The most stringent controls for treatment shall be required by the director to be employed for all new and existing point source discharges. Prevents any degradation of state resource waters.	Requires that best available technology (BAT) be used to treat surface water discharges. The Ohio EPA Division of Water Quality Planning & Assessment (DWQPA) uses this rule to set standards when existing water quality is better than the designated use.	Action-Specific	N[2]	N[2]
21	DSW		3745-1-06	A,B	Mixing zones for surface water	(A) presents the criteria for establishing non-thermal mixing zones for point source discharges (B) presents the criteria for establishing thermal mixing zones for point source discharges	Applied as a term of discharge permit to install (PTI). Would pertain to an alternative which resulted in a point source discharge.	Action-Specific	N[2]	N[2]
22	DSW		3745-1-07	C	Water quality criteria	Establishes water quality criteria for pollutants which do not have specific numerical or narrative criteria identified in tables 7-1 through 7-15 of this rule.	Pertains to both discharges to surface waters as a result of remedial action and any surface waters affected by site conditions.	Action-Specific	N[2]	N[2]
23	DSW		3745-1-26		Water uses for Cuyahoga River	Establishes water use designations for stream segments within the Cuyahoga River basin.	Pertinent if stream or stream segment is on-site and is either affected by site conditions of if remedy includes direct discharge. Used by the Ohio EPA DSW to establish waste load allocations	Action-Specific	N[2]	N[2]
24	DSW		3745-1-31		Lake Erie standards	Establishes water use designations for Lake Erie.	Pertinent if stream or stream segment is on-site and is either affected by site conditions of if remedy includes direct discharge. Used by the Ohio EPA DSW to establish waste load allocations	Action-Specific	N[2]	N[2]
25	DSW		3745-3-04	A-D	Prohibited discharges	Places restrictions on discharges to Publicly Owned Treatment Works (POTWs) that may harm treatment functions or pass through to receiving stream.	Consider for sites with discharges to POTW.	Action-Specific	N[2]	N[2]
26	DSW		3745-3-05	A-C	Notification of potential problems including slug load	Requires industrial users to notify POTW of discharges that may adversely affect treatment operations, including slug loads	Consider for sites with discharges to POTW.	Action-Specific	N[2]	N[2]
27	GW		3745-9-03	A-C	Monitoring well	Standards for design and closure of wells, compliance with DDAGW guidance.	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975. Would pertain during the Feasibility Study (FS) if new wells are constructed for treatability studies.	Action-Specific	N[2]	N[2]
28	GW		3745-9-04	A,B	Well siting	Mandates that ground water wells be: A) located and maintained so as to prevent contaminants from entering well, B) located so as to be accessible for cleaning and maintenance.	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975. Would pertain during the FS if new wells are constructed for treatability studies.	Action-Specific	N[2]	N[2]
29	GW		3745-9-05	A1,B-H	Well construction	Specifies minimum construction requirements for new ground water wells in regards to casing material, casing depth, potable water, annular spaces, use of drive shoe, openings to allow water entry, contaminant entry.	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975. Would pertain during the FS if new wells are constructed for treatability studies.	Action-Specific	N[2]	N[2]
30	GW		3745-9-06	A	Well construction, specific geologic conditions	Establishes specific requirements for wells in different types of aquifers	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975. Would pertain during the FS if new wells are constructed for treatability studies.	Action-Specific	N[2]	N[2]

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31	GW		3745-9-07	A-C	Well grouting for construction or closure	Establishes specific grouting procedures	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975. Would pertain during the FS if new wells are constructed for treatability studies.	Action-Specific	N[2]	N[2]
32	GW		3745-9-10	A,B,C	Abandoned well sealing	Procedures for closing and sealing wells.	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975.	Action-Specific	N[2]	N[2]
33	ODNR		1501:31-23	01, A-B	List of endangered animal species	List of Ohio animal species considered endangered.	May apply to remediation sites where listed species are threatened by chemical releases. May also apply at sites where remedial activities could disturb existing habitats.	Location-Specific	N[2]	N[2]
34	ODNR		1501-18-1	03, A	List of endangered plant species	Plant species considered endangered in Ohio	May apply at remediation sites where chemical release threatens listed species. Should also be considered where remedial activities may disrupt habitats.	Location-Specific	N[2]	N[2]
35	DSW		3745-1-33	A-E	Water quality criteria for Lake Erie drainage basin	Establishes water quality standards for bodies of water draining into Lake Erie basin. Used by the Ohio EPA DSW to establish discharge limits	Consider for sites with discharges into rivers in the Lake Erie basin	Action-Specific	N[2]	N[2]
36	APC		3745-15-05	A-D	De minimis air contaminant source exemption	Establishes limits below which air discharge permits are not needed	Pertains to any site which utilizes or will utilize air pollution control equipment on-site.	Action-Specific	N[2]	N[2]
37	APC		3745-15-07	A	Air pollution nuisances prohibited	Defines air pollution nuisance as the emission or escape into the air from any sources(s) of smoke, ashes, dust, dirt, grime, acids, fumes, gases, vapors, odors and combinations of the above that endanger health, safety or welfare of the public or cause personal injury or property damage. Such nuisances are prohibited.	Pertains to any site which causes, or may reasonably cause, air pollution nuisances. Consider for sites that will undergo excavation, dismantlement, cap installation, methane production, clearing and grubbing, water treatment, incineration and waste fuel recovery.	Action-Specific	N[2]	N[2]
38	APC		3745-17-08	A1,A2,B,D	Emission restrictions for fugitive dust	All emissions of fugitive dust shall be controlled.	Pertains to sites which may have fugitive emissions (non-stack) of dust. Consider for sites that will undergo grading, loading operations, dismantlement, clearing and grubbing and construction utilize incineration or fuel recovery (waste fuel recovery)	Action-Specific	N[2]	N[2]
39	APC		3745-19-03	A,B,C,D	Open burning standards in restricted areas	Open burning without prior authorization from Ohio EPA is prohibited.	Pertains to sites within a restricted area (within the boundary of a municipality and a zone extending beyond such municipality).	Action-Specific	N[2]	N[2]
40	APC		3745-20-05	A-D	Standards for asbestos waste handling	Specifies procedures for handling asbestos waste generated at a dismantlement site. Sites that will undergo water treatment	Consider for sites at which asbestos containing wastes are present or may be generated.	Action-Specific	N[2]	N[2]
41	APC		3745-25-02		Ambient air quality standards	Establishes standards for particulates, sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone and lead.	Consider for sites with surface excavation, clearing or grubbing and for sites with treatment systems that may emit any of these chemicals.	Action-Specific	N[2]	N[2]
42	HW		3745-270-03	A-D	Dilution prohibited as a substitute for treatment.	Forbids dilution as a means of achieving land disposal restriction levels	Consider for remedial options including land disposal or leaving wastes in-place	Action-Specific	N[2]	N[2]
43	HW		3745-270-09	A-D	Special rules regarding characteristic wastes	Rules applicable to land disposal of characteristic wastes	Consider for sties that generate characteristic wastes	Action-Specific	N[2]	N[2]
44	HW		3745-270-34	A-F	Waste specific prohibitions-toxic metals	Restrictions on land disposal of waste that are toxic characteristic for specified metals	Consider for sites with metallic contamination in wastes	Action-Specific	N[2]	N[2]
45	HW		3745-270-40	A-J	Applicability of treatment standards	Detailed listing of chemical specific land treatment standards or required treatment technologies.	Consider for sites that generate wastes or with wastes disposed on-site	Action-Specific	N[2]	N[2]

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46	HW		3745-270-49	A-E	Land disposal restriction for contaminated soil	Specifies standards for soil treatment	Consider at sites where contaminated soil are generated	Action-Specific	N[2]	N[2]
47	HW		3745-270-50	A-F	Prohibitions on storage of restricted wastes	Rules for storage of wastes that violate LDRs	Consider at sites where remediation includes storage of wastes.	Action-Specific	N[2]	N[2]
48	VAP		3745-300-08	A-E	Generic numerical standards	Voluntary Action Program (VAP) cleanup values for soil, drinking water and surface water	Consider for sites with contaminated soil or water, evaluate risk assumptions of site when considering VAP standards.	NA[2]	NA[2]	NA[2]
49	UIC		3745-34-07		No movement of fluid into underground drinking water	The underground injection of fluid containing any contaminant into an underground source of drinking water is prohibited if the presence of that contaminant may cause a violation of the primary drinking water standards or otherwise adversely affect the health of persons.	Pertains to sites at which materials are to be injected underground. Consider for technologies such as bioremediation and soil flushing.	Action-Specific	N[2]	N[2]
50	UIC		3745-34-34		Mechanical integrity	Requires leak testing to confirm mechanical integrity of underground injection well.	Pertains to sites at which materials are to be injected underground. Consider for technologies such as bioremediation and soil flushing.	Action-Specific	N[2]	N[2]
51	HW		3745-50-44	C4	Additional permit info: hazardous waste storage/treatment in waste piles	Establishes substantive hazardous waste permit requirements necessary for Ohio EPA to determine adequacy of waste piles used to treat or store hazardous waste. Includes information such as waste characteristics, detailed design plans and reports, control of run-on and run-off, closure information, etc.	Pertains to sites at which hazardous waste will be stored or treated in waste piles. Consider for temporary storage also.	NA[2]	NA[2]	NA[2]
52	HW		3745-50-44	A	Permit info required for all hazardous waste facilities	Establishes the substantive hazardous waste permit requirements necessary for Ohio EPA to determine facility compliance. Includes information such as facility description, waste characteristics, equipment descriptions, contingency plan, facility location, topographic map, etc.	Pertains to any site which will have treatment, storage or disposal of hazardous waste occurring on-site or has existing areas of hazardous waste contamination on-site that will be capped in-place. This, along with other paragraphs of this rule, establishes the minimum information required during the remedial design stage. Corrective action for waste management units	NA[2]	NA[2]	NA[2]
53	HW		3745-50-58	E,I,J	Conditions applicable to all permits	Establishes general permit conditions applied to all hazardous waste facilities in Ohio. Includes conditions such as operation and maintenance, site access, monitoring, etc.	Pertains to all alternatives that will incorporate treatment, storage or disposal of hazardous waste.	NA[2]	NA[2]	NA[2]
54	HW		3745-52-11	A-D	Evaluation of wastes	Any person generating a waste must determine if that waste is a hazardous waste (either through listing or by characteristic).	Pertains to sites at which wastes of any type (both solid and hazardous) are located.	NA[2]	NA[2]	NA[2]
55	HW		3745-52-12	A-C	Generator identification number	A generator must not store, treat dispose or transport hazardous wastes without a generator number	Pertains to sites where hazardous waste will be transported off-site for treatment, storage or disposal	NA[2]	NA[2]	NA[2]
56	HW		3745-52-20		Hazardous waste manifest - general requirements	Requires a generator who transports or offers for transportation hazardous waste for off-site treatment, storage or disposal to prepare a uniform hazardous waste manifest	Pertains to sites where hazardous waste will be transported off-site for treatment, storage or disposal	NA[2]	NA[2]	NA[2]
57	HW		3745-52-22		Hazardous waste manifest - number of copies	Specifies the number of manifest copies to be prepared	Pertains to sites where hazardous waste will be transported off-site for treatment, storage or disposal	NA[2]	NA[2]	NA[2]

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58	HW		3745-52-23		Hazardous waste manifest - use	Specifies procedures for the use of hazardous waste manifests including a requirement that they be hand signed by the generator	Pertains to sites where hazardous waste will be transported off-site for treatment, storage or disposal	NA[2]	NA[2]	NA[2]
59	HW		3745-52-30		Hazardous waste packaging	Requires a generator to package hazardous waste in accordance with United States Department of Transportation (DOT) regulations for transportation off-site.	Pertains to any site where hazardous waste will be generated by on-site activities and shipped off-site for treatment and/or disposal.	NA[2]	NA[2]	NA[2]
60	HW		3745-52-31		Hazardous waste labeling	Requires packages of hazardous waste to be labeled in accordance with DOT regulations for off-site transportation.	Pertains to any site where hazardous waste will be generated by on-site activities and shipped off-site for treatment and/or disposal.	NA[2]	NA[2]	NA[2]
61	HW		3745-52-32		Hazardous waste marking	Specifies language for marking packages of hazardous waste prior to off-site transportation	Pertains to any site where hazardous waste will be generated by on-site activities and shipped off-site for treatment and/or disposal.	NA[2]	NA[2]	NA[2]
62	HW		3745-52-33		Hazardous waste placarding	Generator shall placard hazardous waste prior to off-site transportation.	Pertains to any site where hazardous waste will be generated by on-site activities and shipped off-site for treatment and/or disposal.	NA[2]	NA[2]	NA[2]
63	HW		3745-52-34		Accumulation time of hazardous waste	Identifies maximum time periods that a generator may accumulate a hazardous waste without being considered an operator of a storage facility. Also establishes standards for management of hazardous wastes by generators.	Pertains to a site where hazardous waste will be generated as a result of the remedial activities.	NA[2]	NA[2]	NA[2]
64	HW		3745-52-40	A-D	Recordkeeping requirements, three year retention	Specifies records that shall be kept for three years	Consider for sites at which hazardous wastes are generated	NA[1]	NA[1]	NA[1]
65	HW		3745-52-41	A,B	Annual report	Requires generators to prepare annual report to Ohio EPA.	Applicable at sites generating wastes for off-site shipment	NA[1]	NA[1]	NA[1]
66	HW		3745-54-13	A	General analysis of hazardous waste	Prior to any treatment, storage or disposal of hazardous wastes, a representative sample of the waste must be chemically and physically analyzed.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).	NA[2]	NA[2]	NA[2]
67	HW		3745-54-14	A,B,C	Security for hazardous waste facilities	Hazardous waste facilities must be secured so that unauthorized and unknowing entry are minimized or prohibited.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).	NA[2]	NA[2]	NA[2]
68	HW		3745-54-15	A,C	Inspection requirements for hazardous waste facilities	Hazardous waste facilities must be inspected regularly to detect malfunctions, deteriorations, operational errors and discharges. Any malfunctions or deteriorations detected shall be remedied expeditiously.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).	NA[2]	NA[2]	NA[2]
69	HW		3745-54-17	A,B,C	Requirements for ignitable, reactive or incompatible hazardous wastes	Presents general precautions to be taken to prevent accidental ignition or reaction of ignitable, reactive or incompatible wastes.	Pertains to any site at which potentially reactive, ignitable or incompatible wastes are present.	NA[2]	NA[2]	NA[2]
70	HW		3745-54-18	A,B,C	Location standards for hazardous waste treatment, storage, or disposal facilities (TSDFs)	Restricts the siting of hazardous waste facilities in areas of seismic activity or floodplains.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).	Location-Specific	N[2]	N[2]

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71	HW		3745-54-31		Design & operation of hazardous waste facilities	Hazardous waste facilities must be designed, constructed, maintained and operated to minimize the possibility of fire, explosion or unplanned release of hazardous waste or hazardous constituents to the air, soil or surface water which could threaten human health or the environment.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
72	HW		3745-54-32	A,B,C,D	Required equipment for hazardous waste facilities	All hazardous waste facilities must be equipped with emergency equipment, such as an alarm system, fire control equipment and a telephone or radio.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
73	HW		3745-54-33		Testing & maintenance of equipment; hazardous waste facilities	All hazardous waste facilities must test and maintain emergency equipment to assure proper operation.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
74	HW		3745-54-34		Access to communications or alarm system; hazardous waste facilities	Whenever hazardous waste is being handled, all personnel involved shall have immediate access to an internal alarm or emergency communication device.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
75	HW		3745-54-37	A,B	Arrangements/ agreements with local authorities	Arrangements or agreements with local authorities, such as police, fire department and emergency response teams must be made. If local authorities will not cooperate, documentation of that non-cooperation should be provided.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
76	HW		3745-54-52	A-F	Content of contingency plan; hazardous waste facilities	Hazardous waste facilities must have a contingency plan that addresses any unplanned release of hazardous wastes or hazardous constituents into the air, soil or surface water. This rule establishes the minimum required information of such a plan.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
77	HW		3745-54-53	A,B	Copies of contingency plan; hazardous waste facilities	Copies of the contingency plan required by 3745-54-50 must be maintained at the facility and submitted to all local police departments, fire departments, hospitals local emergency response teams and the Ohio EPA.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of)	Action-Specific	N[2]	N[2]
78	HW		3745-54-54	A	Amendment of contingency plan; hazardous waste facilities	The contingency plan must be amended if it fails in an emergency, the facility changes (in its design, construction, maintenance or operation), the list of emergency coordinators change or the list of emergency equipment.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
79	HW		3745-54-55		Emergency coordinator; hazardous waste facilities	At all times there should be at least one employee either on the premises or on call to coordinate all emergency response measures.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
80	HW		3745-54-56	A-I	Emergency procedures; hazardous waste facilities	Specifies the procedures to be followed in the event of an emergency.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).	Action-Specific	N[2]	N[2]
81	HW		3745-54-73	A,B	Operating record	Specifies records to be kept at TSDFs.	Consider for sites with on-site treatment, storage or disposal	NA[1]	NA[1]	NA[1]

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82	HW		3745-54-77	A	Additional reports	Requires facilities to report fires, explosions or other mishaps.	Consider at sites with treatment, storage or disposal on-site	Action-Specific	N[2]	N[2]
83	HW		3745-54-90		Ground water protection; applicability	Establishes circumstances under which an operator of a hazardous waste facility must implement a ground water protection program or a corrective action program.	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
84	HW		3745-54-91	A	Required ground water programs for hazardous waste facilities	Presents the ground water monitoring and response programs required for hazardous waste land-based units.	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
85	HW		3745-54-92		Ground water protection standard; hazardous waste facilities	Compliance must be attained with the conditions specified in the permit to ensure that hazardous constituents (see 3745-54-93) do not exceed the promulgated limits (see 3745-54-94).	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
86	HW		3745-54-95	A,B	Point of compliance for ground water; hazardous waste facilities	Establishes point of compliance at vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the unit(s).	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
87	HW		3745-54-96	A,B,C	Compliance period for ground water; hazardous waste facilities	Compliance period during which the ground water protection standards apply will be specified in the permit. Rule requires that the compliance period for a facility undergoing a corrective action program will extend until it can be demonstrated that the ground water protection standard of Ohio Administrative Code (OAC) 3745-54-92 has not been exceeded for a period of three consecutive years.	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
88	HW		3745-54-97	A-H	General ground water monitoring requirements; hazardous waste facilities	Presents general ground water monitoring program requirements. Includes number, location and depth of wells, casing requirements, sampling and analysis procedures, etc.	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
89	HW		3745-54-98	A-I	Ground water detection monitoring program; hazardous waste facilities	Presents requirements of ground water detection program.	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills) at which hazardous constituents have not been detected in the ground water. This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
90	HW		3745-54-99	A-J	Ground water compliance monitoring program; hazardous waste facilities	Presents requirements of ground water compliance monitoring program.	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills) at which hazardous constituents have been detected. This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]

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91	HW		3745-55-01	A-F	Ground water corrective action program; hazardous waste facilities	Presents the requirements of a ground water corrective action program that prevents hazardous constituents from exceeding their respective concentration limits at the compliance point by either removal or treatment of these hazardous constituents.	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills) at which hazardous constituents have been detected. This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
92	HW		3745-55-011	A,C	Corrective action for waste management units	Requires an applicant for a hazardous waste permit to institute corrective action for all releases of hazardous waste or constituents from any waste management unit, regardless of the time at which waste was placed in such unit.	Pertains to all sites with land-based hazardous waste units (surface impoundments, waste piles, land treatment units, landfills) at which hazardous constituents have been detected. This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
93	HW		3745-55-11	A,B,C	General closure performance standard; hazardous waste facilities	Requires that all hazardous waste facilities be closed in a manner that minimizes the need for further maintenance, controls, minimizes, eliminates or prevents post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off or hazardous waste decomposition products to the ground or surface water or the atmosphere.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been treated, stored or disposed of).	Action-Specific	N[2]	N[2]
94	HW		3745-55-12	B	Content of closure plan; hazardous waste facilities	Specifies the minimum information required in a closure plan for Ohio EPA to determine the adequacy of the plan.	Substantive requirements pertain to any site at which hazardous waste is to be treated, stored or disposed of (or has been treated, stored or disposed of).	Action-Specific	N[2]	N[2]
95	HW		3745-55-14		Disposal/decontamination of equipment, structures & soil	Requires that all contaminated equipment, structures and soil be properly disposed of or decontaminated. Removal of hazardous wastes or constituents from a unit may constitute generation of hazardous wastes.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been treated, stored or disposed of).	Action-Specific	N[2]	N[2]
96	HW		3745-55-17	B	Post-closure care and use of property	Specifies the post-closure care requirements, including maintenance, monitoring and post-closure use of property.	Pertains to all sites with land-based hazardous waste units (landfills and surface impoundments, waste piles, land treatment units and tanks that meet requirements of landfills after closure). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
97	HW		3745-55-18	B	Post-closure plan	Presents the information necessary for Ohio EPA to determine the adequacy of a post-closure plan.	Pertains to all sites with land-based hazardous waste units (landfills and surface impoundments, waste piles, land treatment units and tanks that meet requirements of landfills after closure). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]
98	HW		3745-55-19	B	Notice to local land authority	Requires that a record of the type, location and quantity of hazardous wastes disposed of in each unit be submitted to the local land authority and the director of the Ohio EPA. Also requires that a notation to the deed to the facility property be made indicating that the land was used to manage hazardous wastes and that certain use restrictions may apply to the property.	Pertains to all sites with land-based hazardous waste units (landfills and surface impoundments, waste piles, land treatment units and tanks that meet requirements of landfills after closure). This includes existing land-based areas of contamination.	Action-Specific	N[2]	N[2]

Ohio Environmental Protection Agency – ARAR List

ARAR NUMBER	CATEGORY	OHIO REVISED CODE	OHIO ADMINISTRATIVE CODE	PARAGRAPH	CAPTION	TEXT	APPLICATION	TYPE	HARSHAW SITE-SPECIFIC REVIEW RESULTS	
									APPLICABLE	RELEVANT AND APPROPRIATE
99	HW		3745-56-51	A-F	Design & operating requirements for waste piles	Specifies the design and operation requirements for waste piles. Includes liner system, leachate collection and removal system, wind dispersal prevention and run-on/run-off control.	Pertains to any site at which hazardous waste will be either stored or treated in waste piles.	Action-Specific	N^2	N^2
100	HW		3745-56-54	A,B	Monitoring & inspection of waste piles	Waste piles must be monitored during construction or installation and operation.	Pertains to any site at which hazardous waste will be either stored or treated in waste piles.	Action-Specific	N^2	N^2
101	HW		3745-56-56	A,B	Waste pile requirements for ignitable/ reactive wastes	Presents general precautions to be taken when dealing with potentially ignitable or reactive hazardous wastes that are stored or treated in waste piles.	Pertains to any site at which potentially ignitable or reactive hazardous waste will be either stored or treated in waste piles.	Action-Specific	N^2	N^2
102	HW		3745-56-57	A,B,C	Waste pile requirements for incompatible wastes	Presents general precautions to be taken when dealing with potentially incompatible wastes that are stored or treated in waste piles.	Pertains to any site at which potentially incompatible hazardous waste will be either stored or treated in waste piles.	Action-Specific	N^2	N^2
103	HW		3745-56-58	A,B,C	Closure & post-closure care for waste piles	Specifies closure and post-closure care requirements for waste piles.	Pertains to any site at which hazardous waste will be either stored or treated in waste piles.	Action-Specific	N^2	N^2
104	HW		3745-56-60	A,B	Special requirements for "F" wastes in waste piles	Prohibits the placement of hazardous wastes F020, F021, F022, F023, F026 and F027 in waste piles.	Pertains to any site at which hazardous F-wastes will be either stored or treated in waste piles.	Action-Specific	N^2	N^2
105	HW		3745-66-11	A,B,C	Closure performance standard	Owner shall close facility in manner that minimizes need for further maintenance and reduces or eliminates pollution of ground water, surface water or atmosphere.	Consider for remedial plans that may require extended operation and maintenance of equipment. Consider alternatives with less long-term operation and maintenance (O&M). Applicable for Resource Conservation and Recovery Act (RCRA) facilities, appropriate and relevant for other sites.	Action-Specific	N^2	N^2
106	DW		3745-81-11	A,B,C	Maximum contaminant levels (MCLs) for inorganic chemicals	Presents maximum contaminant levels for inorganics.	Pertains to any site which has contaminated ground or surface water that is either being used, or has the potential for use, as a drinking water source.	Action-Specific	N^2	N^2
107	DW		3745-81-12	A,B,C	MCLs for organic chemicals	Presents MCLs for organics.	Pertains to any site which has contaminated ground or surface water that is either being used, or has the potential for use, as a drinking water source.	Action-Specific	N^2	N^2
108	DW		3745-81-15	A,B	MCLs and best available technologies for radionuclide contaminants.	Presents MCLs for radium-226, radium-228 and gross alpha particle activity.	Pertains to any site which has contaminated ground or surface water that is either being used, or has the potential for use, as a drinking water source.	Action-Specific	N^2	N^2
109	DW		3745-81-25	A-D	Analytical methods for radioactivity	Presents analytical methods for radioactivity.	Pertains to any site which has contaminated ground or surface water that is either being used, or has the potential for use, as a drinking water source.	Action-Specific	N^2	N^2
110	DW		3745-81-27	A-E	Analytical techniques	Presents general analytical techniques for MCLs.	Pertains to any site which has contaminated ground or surface water that is either being used, or has the potential for use, as a drinking water source.	Action-Specific	N^2	N^2

APC = Air Pollution Control
DDAGW = Division of Drinking and Ground Waters
DERR = Division of Environmental
DSIWM = Division of Solid and Infectious Waste Management
DSW = Division of Surface Water
DW = Drinking Water
GW = Ground Water
HW = Hazardous Waste
LDR = Land-disposal Restriction
N^1 = Potential ARAR superseded by 10 CFR 20 Subpart E
N^2 = Potential ARAR not chemical-specific
NA^1 = Not Applicable (Administrative Requirement)
NA^2 = Not Applicable to Site Conditions/Contaminants
ODH = Ohio Department of Health
ODNR = Ohio Department of Natural Resources
UIC = Underground Injection Control
VAP = Voluntary Action Program

APPENDIX C

Detailed Cost Estimates for
Former Harshaw Chemical Company Site – Feasibility Study

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ACRONYMS AND ABBREVIATIONS

DOT	Department of Transportation
FS	Feasibility Study
FUSRAP	Formerly Utilized Sites Remedial Action Program
IH/HP	Industrial Hygiene/Health Physics
LLRW	Low-Level Radioactive Waste
O&M	Operations and Maintenance
S/S	Solidification and Stabilization
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
WAC	Waste Acceptance Criteria

1. INTRODUCTION

This appendix provides information regarding the cost estimate for the detailed analysis of alternatives for the *Former Harshaw Chemical Company Site Feasibility Study Report*, herein referred to as the FS Report. These cost estimates are intended to form a basis for comparing alternatives and support the remedy selection. The costs used in this analysis are based on existing United States Army Corps of Engineers (USACE) contracts, vendor quotes, estimating reference manuals, and engineering estimates. These cost estimates are expected to provide an accuracy of -30% to +50% and are prepared using data available from the *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1* (USACE 2009), herein referred to as the RI Report.

The format for the cost estimate is based on guidance from the United States Environmental Protection Agency (USEPA) and the USACE, *Guide to Developing and Documenting Cost Estimates During a Feasibility Study* (USACE 2000). Section 1.1 provides general organization of the cost estimates, the project schedules, and estimating methodology. Section 1.2 summarizes total 2011 costs for each alternative. Section 1.3 provides the scope of work, detailed assumptions, and basis of estimate for each alternative.

1.1 GENERAL COST INFORMATION

1.1.1 Estimate Scope

The FS Report developed eight alternatives for remediating soil and existing buildings. The No Action alternatives (Alternative 1 and Alternative 5) contain no cost. The alternatives are listed below:

- Alternative 1: No Action (OU-1);
- Alternative 2: Limited Action and Land-Use Controls (OU-1);
- Alternative 3: Complete Removal with Off-Site Disposal (OU-1);
- Alternative 4: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1);
- Alternative 5: No Action (OU-2);
- Alternative 6: Limited Action and Land-Use Controls (OU-2);
- Alternative 7: Complete Removal with and Off-Site Disposal (OU-1); and
- Alternative 8: Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2).

The cost estimates include: (1) capital cost, including both direct and indirect cost; (2) annual operation and maintenance (O&M) costs; and (3) net present value of capital and O&M cost. The detailed estimates provide the key parameters and assumptions used to develop the cost.

1.1.2 Schedule

Remedial action for the site is estimated to be complete within 1 to 2 years, assuming funding is available. O&M activities for alternatives where contaminants are left on-site may require up to a 1,000-year period of analysis due to the long life of contaminants present at the site. For this reason, the period of analysis when contaminants are left on-site will be based on a maximum 1,000-year project life cycle. The duration for each alternative is calculated using productivity factors or engineering judgment. The remedial design, remedial action, post RA documentation, and O&M time periods are estimated in Table C-1.

1.1.3 Estimating Methodology

The primary methodology used is a quantity take-off method whereby costs are calculated based on unit cost multiplied by quantity or other input parameters. Unit cost data used in the relationship is primarily drawn from existing USACE contracts, vendor quotes, *2010 Environmental Remediation Cost Data – Unit Price* (RS Means 2010a), *Cost Works Complete RSMeans Library Online* (RS Means 2010b), and engineering estimates. The primary source of cost data was from existing vendor quotes and cost databases. All together, these provide an estimate with a high degree of certainty, provided the quantities do not change.

Cost elements, such as excavation or building dismantlement, incorporate a productivity adjustment process as part of the estimating methodology. This process is accomplished through the use of factors, which are applied to equipment performance measures in order to account for degradation in the productivity, performance, or output levels of the equipment resulting from site-specific conditions. Productivity factors exist to adjust productivity levels due to safety and procedures associated with the nature of impacted materials.

1.1.4 Cost Elements

Federal construction programs have traditionally distinguished between capital and O&M costs. The remedial action alternatives for this FS Report consist of those activities required to prevent or mitigate the migration of waste into the environment. The remedial action may include activities considered to be O&M in situations where construction alone will not achieve the health and environmental protection criteria.

The remedial action will have a schedule with a defined completion date. The post-closure or O&M phase occurs after the completion of the remedial action and includes activities necessary to confirm closure of the remedial action or activities necessary to monitor and maintain control on releases of hazardous waste into the environment for an indefinite period. In addition, where unlimited use/unrestricted exposure is not achieved, five-year reviews would be conducted to ensure land use has not changed.

1.1.4.1 Capital Costs

Capital costs are those expenditures required to implement a remedial action and consist of both direct and indirect costs. Capital costs do not include the costs required to maintain or operate the action throughout its lifetime.

Direct Capital Costs

Direct capital costs include equipment, labor, and material necessary for implementing the remedial action. These typically include costs for:

- Land-use controls;
- Monitoring, sampling, and analysis during remedial action;
- Site work;
- Surface water and groundwater collection/controls;
- Soil collection/containment;
- Treatment;
- Transportation and disposal; and

- Site restoration.

Indirect Capital Costs

Indirect capital costs consist of engineering, supervision, management, administration, financial, and other services necessary to implement a remedial action. These costs are not incurred as part of actual remedial actions but are ancillary to direct or construction costs. Indirect costs typically include:

- Remedial design;
- Home office overhead, including project management;
- Field office overhead, including construction management; and
- Profit.

1.1.4.2 Operations and Maintenance Costs

O&M costs are those post-remedial action costs necessary for ensuring hazardous waste do not migrate into the environment. These costs typically include:

- Maintaining land-use controls and site database;
- Five-year reviews; and
- Site management/technical support in support of O&M activities.

1.2 REMEDIAL ACTION ALTERNATIVE COST SUMMARIES

Table C-3 provides a cost breakdown of capital cost and O&M cost for each alternative without discounting and with a present value analysis, respectively. The costs have been presented in 2011 dollars. The present value analysis is a method to evaluate expenditures, either capital or O&M, which occur over different time periods. Present value calculations allow for cost comparisons of different remedial alternatives on the basis of a single cost figure for each alternative. This single number, referred to as present value, is the amount needed at an initial point in time (base year) to assure funds will be available in the future. This process involves four basic steps: (1) define the period of analysis; (2) calculate the cash outflow for each year; (3) select a discount rate (i.e., interest rate); and (4) calculate present value using standard economic formulas. The remedial alternatives were evaluated using a 0-1,000 year period of analysis and a 4.125% discount factor based on *Economic Guidance Memorandum, 11-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2011* (USACE 2010). The capital costs have not been discounted due to their relatively short implementation duration. The detailed cost estimates are included in this appendix.

1.3 BASIS OF COST ESTIMATE

1.3.1 Remedial Action Cost Components

1.3.1.1 Land-Use Controls

Land-use controls provide for the development of a long-term management plan and a site information database. The long-term management plan would be developed to address administrative or legal measures to reduce or minimize exposure to contaminants left on-site in Alternatives 2 and 6.

Physical controls include the use of fencing and signs to minimize the potential for unauthorized access.

1.3.1.2 Mobilization and Preparatory Work

This cost component provides for the mobilization of all equipment and preparation of the site for remediation activities. This includes preparing contractor submittals, permitting, and constructing temporary structures and facilities, such as haul road construction, staging and loading areas, and security fencing. A pre-engineered structure has been included to address stockpiling and keeping soil dry to allow maximum efficiency of the waste minimization practice. Office facilities and associated utilities were included under mobilization and preparatory work. In addition, the cost of using security guard during off-hours was included.

1.3.1.3 Remedial Action Monitoring, Sampling, and Analysis

This cost component provides for all work during remedial action associated with air, water, and soil sampling, monitoring, testing, and analysis. This cost component also includes industrial hygiene/health physics (IH/HP) technicians and associated survey equipment required to monitor personnel and equipment, collection and analysis of samples, and the purchase of an on-site mobile laboratory.

Periodic sampling of contaminated media would be conducted during remedial action activities in Alternatives 3, 4, 7, and 8 to monitor levels of contamination. A field duration of less than one year is estimated for the completion of actual excavation, loading, consolidation, waste minimization, and/or treatment activities. Sampling during remedial action activities will be performed by IH/HP technicians and analyzed in the off-site laboratories; however, on-site laboratories could be set-up. For the cost estimate, it was assumed that 20 samples would be collected for every 1,000 yd^3 processed through the waste minimization practice. Also, it was assumed that two samples would be collected every 1,000 ft^2 for final status surveys, with an additional 30% collected for areas requiring further excavation. After all excavation and loading activities have been completed, verification sampling and analysis by an off-site laboratory would be conducted prior to backfill of the site to confirm that cleanup criteria have been met.

1.3.1.4 Site Work

This cost component provides for the preparation of the site and related improvements. This includes clearing and grubbing a portion of the site, surveying, and installing sheet piling along the excavation adjacent to the Cuyahoga River. The total area to be cleared and grubbed is estimated to be 6-8 acres -and includes 2 acres that would require clearing of small diameter trees and shrubs.

1.3.1.5 Surface Water Collection/Control

This cost component provides for the collection and treatment of contact and groundwater that is removed from excavations. Pumps and aboveground holding tanks would be used to collect and contain contact water removed from excavations. After filtering out sediment, contact water would be slowly discharged on-site, in accordance with local regulations. Since the majority of the rainfall occurs in the warmer months, most water requiring collection can be used for moisture conditioning impacted soil.

1.3.1.6 Contaminated Soil Collection/Containment

This cost component provides for excavation of contaminated soil and associated sediment erosion and dust controls. Additionally, the dismantlement of Building G-1, dismantlement of concrete surfaces and foundations to access impacted areas, and the decontamination of the Boiler House, Warehouse, and Garage are included this cost element. These activities result in three waste streams, including soil, concrete building debris, and other debris from dismantlement and decontamination activities. Standard debris listed in the cost tables is defined as materials that are less than 10 inches in one dimension and no longer than 12 ft in any dimension. It is assumed the majority of the concrete and brick generated from the building dismantlement and dismantlement of concrete surfaces and foundations would be crushed, using an impact rock crusher, to a gravel consistency and treated as soil.

Based on the type of excavation, engineering controls would be constructed to prevent surface water from leaving the site without passing through erosion control structures such as a silt fence. The total estimated volume of in-situ soil to be excavated is 29,260 yd^3. A constructability factor of 1.3 and an expansion (swell) factor of 1.25 are applied to the in-situ volume to calculate the ex-situ volume of approximately 47,560 yd^3. Soil would be excavated and transported to an on-site staging area for processing by a waste minimization practice (Alternatives 3, 4, 7, and 8).

The soil and crushed concrete/brick would be processed using a waste minimization practice (Alternatives 3 and 4 and Alternatives 7 and 8 [soil only]). The waste minimization practice would divide the soil into two piles, based on the approved cleanup criteria. Based on USACE input, it was deemed that 50% of the soil would be below approved cleanup criteria, and 50% would be above approved cleanup criteria after the waste minimization practice is complete. The soil below approved criteria would be used as backfill, and the above approved criteria soil would be packaged for transport off-site to a licensed disposal facility (Alternatives 3 and 7) or treated on-site using a solidification technology and packaged for off-site disposal (Alternatives 4 and 8). Based on the history of operations at the site during which metals were used extensively in the commercial process, a portion of the soil processed through the waste minimization process would be assumed to be characteristically hazardous (25% for OU-1 and 10% for OU-2). The main chemical processing activities occurred in OU-1; therefore, a higher percentage is expected there. The soil from the site would be excavated using an excavator with an adjusted output of 660 yd^3 per 8-hour day and would be loaded directly into 22-yd^3 -dump trucks. The waste minimization practice was assumed to process 1,000 tons per hour, based on results from Painesville Formerly Utilized Sites Remedial Action Plan (FUSRAP) Site, adjusted for site specific conditions.

In Alternatives 3 and 7, soil above criteria would be loaded and packaged for off-site transportation and disposal. In Alternatives 4 and 8, soil would be moved to the solidification process area.

A front-end loader would be located at the staging area to assist with loading operations. All equipment would be decontaminated prior to leaving the site. The depth of excavation below the existing grade varies from 0 ft to 19 ft. The areas of contamination below the groundwater table are less than 4% of the total volume; therefore, minimal dewatering would be required.

Building G-1 would be dismantled and segregated by waste streams. It was estimated that 50% of the total building volume (3,200 yd^3) would be concrete and brick that would be reduced in size with an impact rock crusher to allow processing through the waste minimization practice. It is assumed 50% of the material processed through the waste minimization practice would be above the approved cleanup criteria. The material below the criteria would be re-used on-site if it is not characteristically hazardous. The remaining 50% of the building volume would be construction debris (e.g., roofing, vents, windows)

that would be disposed off-site (Alternatives 3, 4, 7, and 8). The structural steel would be decontaminated and recycled.

The Boiler House, Warehouse, and Garage would be decontaminated by wiping and vacuuming surfaces, followed by more aggressive techniques, such as scabbling, or removing impacted surfaces.

1.3.1.7 Solidification/Stabilization Treatment

Treatment of FUSRAP radioactive soil applies to Alternatives 4 and 8. The treatment facility would be located on-site. The soil solidification and stabilization (S/S) process uses chemical reagents that are mixed with waste to make use of complex chemical and physical reactions to improve physical properties and reduce contaminant solubility, toxicity, and/or mobility. This solidification and stabilization process immobilizes contaminants in soil by binding them in a concrete-like, leach-resistant matrix.

Contaminated waste materials would be collected, screened to remove oversized material, and introduced to the batch mixer. The waste material would be mixed with water, chemical reagents/additives, and pozzolanic material (fly ash), kiln dust, or cement. After it is thoroughly mixed, the treated waste would be discharged from the mixer. Treated waste is a solidified mass with significant unconfined compressive strength, high stability, and a rigid texture similar to that of concrete. The cost for soil solidification and stabilization is estimated to add approximately 25% additional volume. The total ex-situ volume of FUSRAP radioactive soil to be treated for OU-1 and OU-2 is approximately 23,800 yd^3. In addition, it was assumed the S/S process would exclude the waste from being eligible for the soil disposal rate since it would be in a solid waste form similar to debris.

1.3.1.8 Transportation and Disposal

Transportation and commercial disposal during the remedial action provides for the shipment and final placement of contaminated soil at a third-party commercial facility that charges a fee to accept waste, depending on a variety of waste acceptance criteria. This item would be applicable to Alternatives 3 and 4 and Alternatives 7 and 8.

Soil to be disposed would be transported to an approved and licensed disposal facility. The soil would be placed in intermodal containers having a 20-ton capacity (approximately 15 yd^3). A truck designed to carry the intermodal containers would transport the soil to a rail transfer facility where it would be loaded for transport to a disposal facility. There is a potential for cost savings if the materials being shipped off-site meet the waste acceptance criteria (WAC) for Subtitle C facilities. There are uncertainties associated with what volume, if any, could be shipped to such facilities; therefore, the cost estimates assume the total volume would be shipped to a radioactive-licensed facility for disposal.

Feasible alternatives to transport waste materials from the Former Harshaw Chemical Company Site to a permitted off-site disposal facility were evaluated as part of this FS Report. The waste materials to be transported to the off-site disposal facility include low-level radioactive waste (LLRW) and mixed waste. LLRW is defined as soil and/or building material at levels above cleanup criteria. Mixed waste is defined as soil and/or building materials containing LLRW and is characteristically hazardous for metals. This assumption is based on the history of operations at the site during which metals were used extensively as part of the commercial process.

The accepted methods for transporting bulk or contained materials are truck, rail, and intermodal containers. All three methods are available to transport waste material from the site, and each method may employ bulk means of transportation, such as gondola cars or dump trucks, or contained means, such

as intermodal containers or flexible (bag) containers, for transporting the waste. Waste haulers must be certified, use appropriate equipment, and follow documented procedures.

The following alternatives were evaluated:

- Alternative A – Truck by Direct Shipment;
- Alternative B – Rail Only, New Siding Track On-Site Loading; and
- Alternative C – Intermodal Transportation, Existing Off-Site Transfer Station, and Major Roads.

1.3.1.8.1 Alternative A – Truck by Direct Shipment

A truck-only alternative was considered for this FS Report. Local access routes to the interstate system are short and easily traversed from the site. The truck-only transportation alternative route begins going west on Harvard Avenue to Jennings Road. From there, the route continues by turning right and going north on Jennings Road. The on-ramp to Interstate 71 is accessed approximately 0.5 miles north of Jennings Road. Trucks can enter the interstate system for the remainder of the haul to the permanent disposal facility.

The advantages of this alternative include:

- Only one method of transport is used, eliminating the costs and logistics of routing railcars;
- Transfer stations are not needed;
- The schedule can be accelerated by increasing the number of trucks;
- Sensitive inner city areas (e.g., schools) are avoided; and
- Trailer-type dump trucks or intermodal container trucks could be used.

The disadvantages of this alternative include:

- The extreme cost for truck hauling soil to the permanent disposal facility. For this FS Report, it was assumed the waste material would be shipped off-site to Utah for disposal. The estimated cost of LLRW shipped off-site was $935/yd^3.

- Restrictions may be placed on waste container loadings in order to meet Department of Transportation (DOT) weight limits on the local highways.

- The route is highly visible to the public and likely to be looked upon with concern or opposed.

- There are greater risks of accidents than rail transportation.

1.3.1.8.2 Alternative B – Rail Only, New Siding Track On-Site Loading

This rail-only alternative re-establishes an old, abandoned rail siding along the north side of the property, using the original siding alignment. Historical maps of the rail siding indicate three siding rails were routed across the north end of the property, with a working siding length of approximately 1,200 ft. The track between on-site siding and the main line requires additional track and a rail switch. A construction quote was obtained for rail installation, using lineal foot costs on prepared base material. An on-site rail spur installed along the former siding alignment is estimated to cost in excess of $200,000, including a switch connection to the current north-south rail line. Additional costs may be necessary for permits,

notifications, and environmental studies. This would delay the schedule in addition to increasing the costs. The estimated cost for this alternative is approximately $535/yd^3.

The advantages of this alternative include:

- May allow for more weight per container thus higher loadings per container;
- Could allow for multiple containers to be shipped on a single railcar;
- Minimizes the overall risks associated with the handling and transport of waste by minimizing the number of times the waste material is handled; and
- Minimizes transportation risks when compared to having several truckloads of waste on the highways for long distances.

The disadvantages of this alternative include:

- Added expense and schedule delay for re-installation of the rail spur.
- Installation of the rail spur may be delayed, and possibly cancelled, due to the rail company completing necessary environmental studies and reviews (e.g., National Environmental Policy Act). If resistance is met during the environmental reviews, the installation of the rail spur could be delayed further or determined to be unacceptable.
- Not all potential disposal facilities have direct rail access.

1.3.1.8.3 Alternative C – Intermodal Transportation, Existing Off-Site Transfer Station, and Major Roads

Intermodal transportation options may include the use of vehicles/containers such as bulk containers, ABC cars, or gondola railcars. This intermodal transportation alternative route begins with trucks traveling west on Harvard Avenue to Jennings Road. From there, the route continues by turning right and going north on Jennings Road. Jennings Road becomes Steelyard Drive after approximately 0.5 miles. The route continues straight on Steelyard Drive for another 0.2 miles before turning right onto Clark Avenue. The route proceeds on North Clark Avenue, crossing over railroad tracks, going north approximately 1.3 miles, and turning left on North Clark Avenue. The route continues on North Clark Avenue to the left and travels 0.08 miles. The route continues by turning left and traveling 0.03 miles on West 3rd Street before turning left onto Clark Avenue and travelling approximately 0.3 miles before turning right into the railcar loading facility. The length of the route is approximately 2.4 miles. The estimated cost for this alternative is $593/yd^3.

The advantages of this alternative include:

- Allows for disposal at any facility regardless if the disposal facility has direct rail access;
- The infrastructure necessary to ship waste off-site using rail transfer stations currently exists and would have no impact on schedule (i.e., no delays to construct supporting infrastructure); and
- No additional project expense is necessary for establishing the waste transportation infrastructure.

The disadvantages of this alternative include:

- May place restrictions on waste container loadings in order to meet DOT weight limits on the local highways;
- Multiple handling of the waste containers slightly increases the overall risk associated with handling and transport of the waste materials to the disposal facility; and
- Transportation of the waste material to the transfer facility would slightly increase the overall risk due to the need to transport the waste containers over the local highways.

1.3.1.8.4 Selection of Transportation Alternative

Alternative C – Intermodal Transportation, Existing Off-Site Transfer Station, and Major Roads was selected as the transportation alternative included in the cost estimate of this FS Report. Alternative C was selected for the following reasons:

- Transportation costs for this alternative were in the middle of the three alternatives.
- Infrastructure currently exists to support this transportation alternative; therefore, no additional project expense is necessary. Also, no schedule delays would be incurred while re-establishing the rail siding at the site.
- The risk of accidents would be minimized as the intermodal containers would only be on the local roadways for a short period of time while en route to the transfer station.

A summary of the transport and disposal volume, transport mode, and transport and disposal price is included in Table C-2.

1.3.1.9 Site Restoration

Site restoration during the remedial action includes backfill, seeding, and restoration of roads and fencing disturbed during site remediation.

Backfill and restoration of the excavation would commence upon verification of the survey unit and would run concurrently with excavation activities. For Alternatives 3, 4, 7, and 8, the majority of the fill material would be provided from the waste minimization process stream of soil that are below criteria, with a small volume imported from off-site sources. The areas would be restored by seeding or resurfacing with crushed stone. Backfill would be compacted to obtain the required soil densities.

1.3.2 Remedial Action O&M Cost Components

1.3.2.1 Land-Use Controls

Land-use controls apply to Alternatives 2 and 6. This item includes maintaining the long-term management plan and a site information database. The long-term management plan would be revised to address administrative or legal measures to reduce exposure to contaminants left on-site. This would include future coordination with stakeholders. Land-use control measures are conducted over a 1,000-year period of analysis due to the long life of metal contaminants present at the site.

Comprehensive Environmental Response, Compensation, and Liability Act five-year reviews and report preparation are also included in Alternatives 2, 3, 4 and 6. Five-year reviews are conducted over a 1,000-year period of analysis due to the long life of contaminants present at the site.

1.3.3 Cost Estimate Markups

1.3.3.1 Design

Remedial design applies to capital and O&M cost and includes services to design the remedial action. Activities that are part of the remedial design include pre-design collection and analysis of field data, engineering survey for design, a treatability study (e.g., pilot-scale), and the various design components such as design analysis, plans, specifications, cost estimate, and schedule at the preliminary, intermediate, and final design phases. A design markup of 10% on capital cost was included and is on the high side of the range for the size of the project but was increased to include additional investigations to further refine impacted areas and for waste profiling. A design markup of 6% on O&M cost was included in the estimates.

1.3.3.2 Home Office Overhead and Project Management

Home office overhead, also known as general and administrative costs, is the contractor's overall cost of doing business, as shared by the project. Project management includes services that are not specific to remedial design or construction management. Project management includes planning and reporting, community relations support during construction or O&M, bid or contract administration, permitting (not already provided by the construction or O&M contractor), and legal services outside of institutional controls (e.g., licensing). Home office overhead and project management has been included as a 5% markup of the total remedial action costs.

1.3.3.3 Field Office Overhead and Remediation Management

Field office overhead can include costs for field supervision and office personnel, temporary facilities and utilities, licenses, travel and per diem, quality control, insurance, bond, and taxes. Remediation management includes services to manage construction or installation of the remedial action, except any similar services provided as part of regular construction activities. Activities include review of submittals, design modifications, construction observation or oversight, engineering survey for construction, preparation of O&M manual, documentation of quality control/quality assurance, and record drawings. A field office overhead and remediation management has been included as a 10% markup of the total remedial action costs.

1.3.3.4 Profit

An 8% profit markup has been applied to the total cost.

1.3.3.5 Contingency

Project risk management includes the processes associated with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project. USACE conducted a review of the cost estimates for each alternative to identify uncertain events or conditions that, if they occur, have a positive or negative effect on a project's objectives.

An abbreviated risk analysis was conducted by USACE in accordance with the USACE Headquarters requirements and guidance provided by the Cost Engineering Directory of Expertise for Civil Works. The abbreviated risk analysis involves a multi-disciplinary team which develops a risk register for each remedial alternative, evaluates risk by likelihood and impact, and produces a contingency percentage to be included in the individual alternative cost estimates.

The abbreviated risk analysis is a qualitative method of evaluating risk that does not specifically account for schedule risks or use formal statistical simulations, such as Monte Carlo risk simulation. The risk analysis results are intended to serve several functions, including the establishment of reasonable contingencies reflective of an 80% confidence level to successfully accomplish the project work within that established contingency amount. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes and tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analyses should be considered an on-going process conducted concurrent to, and iteratively with, other important project processes, such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting, and scheduling.

USACE met to discuss the project scope and review the Basis of the Government Estimate ("Most Likely Cost"). USACE developed potential risk elements, assigned the "likelihood" of occurrence, and assigned the impact level if an occurrence happens. USACE reviewed individual cost categories including:

- Mobilization and site preparation;
- Excavation and dismantlement;
- Consolidation, ex-situ treatment, and disposal;
- O&M;
- Planning, engineering, and design; and
- Construction management.

These cost categories were evaluated for risks in the following areas:

- Organizational;
- Project management;
- Contract acquisition;
- Technical risks;
- Estimates and schedules;
- Lands and damages;
- Regulatory;
- Environmental; and

- Construction.

USACE completed the risk analysis and the recommended project contingency and corresponding confidence levels were incorporated into the cost estimates for each alternative (Table C-3).

1.3.3.6 Program Management or Owner Cost

USACE oversight cost includes Program Management, Project Management, Construction Management, Design Reviews, Quality Assurance, HP Support, Cooperative Agreements with Others, and Engineering During Construction and have not been included in this estimate.

2. REFERENCES

RS Means 2010a. *2010 Environmental Remediation Cost Data – Unit Price.* 9th Edition.2010.

RS Means 2010b. *Cost Works Complete RSMeans Library Online. http://rsmeans.reedconstructiondata.com/66150.aspx*

USACE (United States Army Corps of Engineers) 2000. *Guide to Developing and Documenting Cost Estimates During a Feasibility Study*. July 2000.

USACE 2009. *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1,* Cleveland, Ohio. U.S. Army Corps of Engineers, Buffalo District, Buffalo, NY. December 2009.

USACE 2010. *Economic Guidance Memorandum, 11-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2011.* November 5, 2010.

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TABLES

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Table C-1. Summary of Remedial Alternative Implementation Timelines

Alternatives	Remedial Design (yrs)	Remedial Action (yrs)	Post RA Documentation (yrs)	O & M Period (yrs)
Soil Media Alternatives				
1. No Action (OU-1)	0	0	0	0
2. Limited Action and Land-Use Controls (OU-1)	0.5	<1	1	1,000
3. Complete Removal with Off-Site Disposal (OU-1)	1	<1	1	1,000
4. Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)	1	<1	1	1,000
5. No Action (OU-2)	0	0	0	0
6. Limited Action and Land-Use Controls (OU-2)	0.5	<1	1	1,000
7. Complete Removal with Off-Site Disposal (OU-2)	1	<1	1	0
8. Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)	1	<1	1	0

Table C-2. Summary of Soil Media Waste Transportation and Disposal Information

Waste Stream	Transport & Disposal Volume	Transport Mode	Transport and Disposal Unit Price	Disposal Facility
FUSRAP Radioactive Soil (Alternatives 3 and 7)	15,600 yd^3 and 2,700 yd^3	Intermodal and Rail	\$593/yd^3	Energy Solution's Clive, UT Facility
FUSRAP Radioactive Debris (Alternatives 3 and 7)	4,500 yd^3 and 400 yd^3	Intermodal and Rail	\$946/yd^3	Energy Solution's Clive, UT Facility
FUSRAP Radioactive Mixed Soil (Alternatives 3 and 7)	5,200 yd^3 and 300 yd^3	Intermodal and Rail	\$1193/yd^3	Energy Solution's Clive, UT Facility
FUSRAP Radioactive Soil and Debris (Alternatives 4 and 8)	25,200 yd^3 and 3,600 yd^3	Intermodal and Rail	\$946/yd^3	Energy Solution's Clive, UT Facility
FUSRAP Radioactive Mixed Soil (Alternatives 4 and 8)	6,500 yd^3 and 400 yd^3	Intermodal and Rail	\$1193/yd^3	Energy Solution's Clive, UT Facility

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Table C-3. Key Parameters, Assumptions, and Costs of Alternatives

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Feasibility Study for Former Harshaw Chemical Company Site
Cleveland, Ohio
Summary of Alternatives

Former Harshaw Chemical Company Site Alternatives		Duration	Non Discounted Cost		
			Capital Cost	O&M Cost	Total
1	No Action (OU-1)	0	$0	$0	$0
2	Limited Action and Land-Use Controls (OU-1)	1000 yr	$11,320,378	$45,284,223	$56,604,601
3	Complete Removal with Off-Site Disposal (OU-1)	1000 yr	$55,034,232	$6,795,360	$61,829,592
4	Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)	1000 yr	$76,257,108	$6,882,480	$83,139,588
5	No Action (OU-2)	0	$0	$0	$0
6	Limited Action and Land-Use Controls (OU-2)	1000 yr	$1,400,265	$34,647,140	$36,047,405
7	Complete Removal with Off-Site Disposal (OU-2)	2-3 yr	$6,617,430	$0	$6,617,430
8	Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)	2-3 yr	$9,562,520	$0	$9,562,520

Former Harshaw Chemical Company Site Alternatives		Duration	Discounted Cost (4.125%)		
			Capital Cost	O&M Cost	Total
1	No Action (OU-1)	0	$0	$0	$0
2	Limited Action and Land-Use Controls (OU-1)	1000 yr	$11,320,378	$1,086,179	$12,406,557
3	Complete Removal with Off-Site Disposal (OU-1)	1000 yr	$55,034,232	$151,694	$55,185,927
4	Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)	1000 yr	$76,257,108	$153,639	$76,410,747
5	No Action (OU-2)	0	$0	$0	$0
6	Limited Action and Land-Use Controls (OU-2)	1000 yr	$1,400,265	$828,310	$2,228,575
7	Complete Removal with Off-Site Disposal (OU-2)	2-3 yr	$6,617,430	$0	$6,617,430
8	Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)	2-3 yr	$9,562,520	$0	$9,562,520

Notes:

1. The base year of comparison and cost data will be CY2011. The discounted rates used to calculate present values will be based on Economic Guidance Memorandum, 11-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2011.

2. Costs were estimated for comparison purposes only and are believed to be accurate within a range of -30% to +50%. Use of these costs for other purposes, including but not limited to, budgetary or construction cost estimating is not appropriate.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 2 - Limited Action and Land-Use Controls (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Capital Cost			
Administrative Land Use Controls			
Administrative Land Use Controls	lot	1	Includes planning documents, planning meetings, implementation, and monitoring and enforcement for first year. Estimates are based on the RACER Administrative Land Use Controls Model. Assumed moderate/high level of complexity to implement these controls.
	$/lot	702,000	
Monitoring Plan			
Monitoring Plan	ea	1	Includes monitoring plan for surface soil, sediment, and air monitoring. Estimates are based on the RACER Monitoring Model.
	$/ea	30,000	
Bank Stabilization			
Install Gabion Baskets	lf	200	Gabion retaining wall, sloped backfill, 1.5:1, stepped face, 9' base, 15' high, sandy soil. RSM G20402703300.
	$/lf	1,070	
Geotextile	sf	60,000	
	$/sf	0.22	Stabilization fabric, polypropylene, 6 oz./S.Y. RSM 32112 323 6000.
Rip Rap (24") Layer	cy	4,444	Rip-rap, random, broken stone, machine placed for slope protection. RSM 31371 310 0100.
	$/cy	56.00	
Crushed Stone (6") Choke Course	cy	1,111	Base course drainage layers, aggregate base course, spread & compacted, 3/4" crushed stone, to 6" deep. RSM 32112 323 010.
	$/cy	60.60	
Land Use Controls			
Establish Control Area	day	2	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
	$/day	1,750	
Develop Drawings	hr	40	
	$/hr	80	Develop control drawings.
Signs	sf	44.0	Assume signs on fence every 100 lf. Project signs, high intensity reflectorized, buy, excl. posts. RSM 01581 350 0020.
	$/sf	29.50	
Fence	lf	2,000	Fence, chain link industrial, aluminized steel, 6 ga. wire, 2-1/2" posts @ 10' OC, 8' high, includes excavation, in concrete, excludes barbed wire. RSM 32311 320 0940.
	$/lf	63	
Gate	ea	2	Fence, chain link industrial, double swing gates, 6' high, 20' opening, includes excavation, posts & hardware in concrete. RSM 32311 320 5070.
	$/ea	1,750	
Mobilization/Demobilization			
Submittals/Implementation Plans			
Submittals	ea	5.0	Includes submittals such as Air Monitoring Plan, QCP, Schedule, Materials Handling/Transportation/Disposal Plan, SAP, SSH Plan, Site Security Plan, Site Work Plan, SWPPP, etc. Assume 5 plans and/or appendices to work plan. Based on Engineering Judgment.
	$/ea	15,000	
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor	hr	3,600	This element covers IH/HP technicians for the following areas: 6 to support Building D&D for 3 months. The IH/HP technicians and equipment would be required for a total of 3 months duration at 200 hrs/month. Total hours are 18 months x 200 hrs/mo.
	$/hr	55.55	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 2 - Limited Action and Land-Use Controls (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Equipment	mo $/mo	3 5,500.00	Equipment pricing base on Vendor Quote. The Radiological monitoring equipment includes the following: 1. Model 2929 dual channel scaler (2 @ $300/mo =$600/mo) 2. Alpha Survey Instrument, Model 2360 with 43-89 (5 @ 325/mo = $1,625/mo) 3. Micro R Meter, Model 19 (2 @ $185/mo = $380/mo) 4. Ludlum - M3 - 44-2 - 44-9 Meter 3, NaI Gamma Scintillator, G-M Pancake Detector (3 @ $125/mo = $375/mo) 5. Personal air sampling pumps (3 @ $100/mo = $220/mo) 6. Personal air sampling pump charger (2 @ $70/mo = $140/mo) 7. High volume air samplers (8 @ $180/mo = $1440/mo) 8. Sources (3 @ $50/mo = $150) 9. Dosimetry (20 @ $10/mo = $200) Total = $5,130/month. Use $5,500/mo direct cost to account for other miscellaneous equipment, shipping, or supplies. Assume technicians are local and no per diem or travel is required.
Bioassays	ea $/ea	30 147.32	Bioassays (2/yr x 1 yr x 15 people)
PPE Allowance	set $/set	1,980 8.09	PPE Estimate. Assume average of 20 sets/day for 3 months. Includes Disposable Boot Covers, Coverall, Gloves, and Ear Plugs. ECHO 33010421, 23, 25, and 29.
Buildings and Structures			
Building G-1 Demolition	cf $/cf	336,400 0.48	Building demolition, large urban projects, masonry, includes 20 mile haul, excludes foundation demolition, dump fees. RSM 02411 613 0080. Decreased productivity by 25% to account for rad controls and additional size reduction time required for disposal.
Loading Intermodals	day $/day	14 4,152.00	Includes 3 cy loader, 1 O.E., 1TD, and 2 L.S. as spotters and handling intermodals. Reduced productivity by 50% for loading intermodals and security/S&H requirements. RSMeans Crew B12-S.
Erosion and Sediment Control			
Silt Fence and Straw Bales	lf $/lf	400 8.31	Erosion control, silt fence, polypropylene, 3' high and hay bales, staked. RSM 31251 310 1100 and 1250.
Dust Control			
Water Trucks	mo $/mo	2.0 2,584.00	Rent water tank trailer w/pumped discharge, 5000 gallon capacity. RSM 01543 340 6900.
Offsite Transport and Disposal			
Transport and Disposal (Standard Debris)	cy $/cy	4,800 945.42	Includes transport and disposal to a facility in Utah. Includes intermodal and ABC rail car rental, ABC railcar transport cost with all fuel surcharges, and disposal. Assumes 17 cy/intermodal and 7 intermodals per railcar.
Recycling Credit	ton $/ton	113 -70.00	Assume 15,000 lf of steel. Assume average section is W8 x 15.
Plans and Reports			
Corrective Action Completion Report	hrs	400	Includes Construction QC data and preparing report.
Technical Labor	$/hr	80	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 2 - Limited Action and Land-Use Controls (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Operation and Maintenance			
Administrative Land Use Controls			
Administrative Land Use Controls	annual $/annually	1,000 17,000	Includes monitoring and enforcement of administrative land use controls. Includes annual site inspection visits and periodic notice letters and status reports every two years. Estimates are based on the RACER Administrative Land Use Controls Model.
Bank Stabilization	annual	1,000	Assume riprap and crushed stone is replaced every 50 years or 2% annually.
Rip Rap (24") Layer	cy $/cy	89 56.00	Rip-rap, random, broken stone, machine placed for slope protection. RSM 31371 310 0100.
Crushed Stone (6") Choke Course	cy $/cy	22 60.60	Base course drainage layers, aggregate base course, spread & compacted, 3/4" crushed stone, to 6" deep. RSM 32112 323 010.
Five Year Reviews			
Five Year Reviews	ea $/ea	200 18,000	Includes CERCLA five year reviews. Estimates are based on the RACER Five Year Review Model for a moderately complex site.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 2 - Limited Action and Land-Use Controls (OU-1)
Cost Estimate

CAPITAL COST			$11,320,378
Activity (unit)	Quantity	Unit Cost	Total
Administrative Land Use Controls			
Administrative Land Use Controls (lot)	1	$702,000.00	$702,000
Monitoring Plan			
Monitoring Plan (ea)	1	$30,000.00	$30,000
Bank Stabilization			
Install Gabion Baskets	200	$1,070.00	$214,000
Geotextile	60,000	$0.22	$13,000
Rip Rap (24") Layer	4,444	$56.00	$248,889
Crushed Stone (6") Choke Course	1,111	$60.60	$67,333
Land Use Controls			
Establish Control Area (day)	2	$1,750.00	$3,500
Develop Drawings (hr)	40	$80.00	$3,200
Signs (sf)	44	$29.50	$1,298
Fence (lf)	2,000	$63.00	$126,000
Gate (ea)	2	$1,750.00	$3,500
Mobilization/Demobilization			
Submittals/Implementation Plans			
Submittals (ea)	5	$15,000.00	$75,000
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor (hr)	3,600	$55.55	$199,980
Equipment (mo)	3	$5,500.00	$16,500
Bioassays	30	$147.32	$4,420
PPE Allowance (set)	1,980	$8.09	$16,018
Buildings and Structures			
Building G-1 Demolition (cf)	336,400	$0.48	$161,472
Loading Intermodals (day)	14	$4,152.00	$58,616
Silt Fence and Straw Bales (lf)	400	$8.31	$3,324
Water Trucks (mo)	2	$2,584.00	$5,168
Offsite Transport and Disposal			
Transport and Disposal (Standard Debris) (cy)	4,800	$945.42	$4,538,017
Recycling Credit (ton)	113	($70.00)	-$7,910
Closure Reports			
Corrective Action Completion Report (hr)	400	$80.00	$32,000
Subtotal			$6,515,325
Design		10%	$651,533
Home Office Overhead and Project Management		5%	$325,766
Field Overhead and Remediation Management		10%	$651,533
Subtotal			$8,144,157
Profit		8%	$651,533
Contingency		31%	$2,524,689
Total			$11,320,378

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 2 - Limited Action and Land-Use Controls (OU-1)
Cost Estimate

OPERATION AND MAINTENANCE				$45,284,223
Activity (unit)	Quantity	Unit Cost	Total Cost	Present Value (4.125%)
Administrative Land Use Controls				
Administrative Land Use Controls	1,000	$17,000	$17,000,000	$412,121
Bank Stabilization				
Rip Rap (24") Layer	1,000	$4,978	$4,977,778	$120,673
Crushed Stone (6") Choke Course	1,000	$1,347	$1,346,667	$32,646
Five Year Reviews				
Five Year Reviews	200	$18,000	$3,600,000	$80,364
Subtotal O&M			$26,924,444	$645,805
Design		6%	$1,615,467	$38,748
Home Office Overhead and Project Management		5%	$1,346,222	$32,290
Field Overhead and Remediation Management		10%	$2,692,444	$64,580
Subtotal			$32,578,578	$781,424
Profit		8%	$2,606,286	$62,514
Contingency		31%	$10,099,359	$242,241
Total			$45,284,223	$1,086,179

TOTAL ALTERNATIVE CAPITAL AND O&M COST (Non Discounted Cost)	$56,604,601

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Capital Cost			
Mobilization/Demobilization			
Equipment Mob/Demob.			
Medium Equipment	ea	20	Mob/demob dozer, loader, backhoe or excavator, 70-150 H.P, up to 50 miles. RSM 01543 650 0020. Assume 10 pieces.
	$/ea	251.00	
Large Equipment	ea	20.0	Mob/demob, dozer, loader, backhoe or excavator, above 150 H.P., up to 50 miles. RSM 01543 650 0100. Assume 10 pieces.
	$/ea	470.00	
Small Equipment	ea	60.0	Mob/demob, delivery charge for small equipment, placed in rear of, or towed by pickup. RSM 01543 650 1100. Assume 30 pieces.
	$/ea	70.50	
Submittals/Implementation Plans			
Submittals	ea	15.0	Includes submittals such as Air Monitoring Plan, QCP, Schedule, Materials Handling/Transportation/Disposal Plan, SAP, SSH Plan, Site Security Plan, Site Work Plan, SWPPP, etc. Assume 15 plans and/or appendices to work plan. Based on Engineering Judgment.
	$/ea	15,000	
Permitting			
Permitting	ea	1.0	Local and state permitting not required, but assume work in/adjacent to river will require permitting. Based on Engineering Judgment.
	$/ea	20,000	
Temporary Structures and Facilities			
Haul Roads	sf	5,000	Base course drainage layers, aggregate base course, spread & compacted, 3/4" crushed stone, to 6" deep. RSM 32112 323 0110.
	$/sf	1.29	
Temporary Fencing	lf	375.0	Temporary Fencing, chain link, rented up to 12 months, 6' high, 11 ga, to 1000'. RSM 01562 650 0200.
	$/lf	7.55	
Office Trailers	mo	24.0	Assume 2 trailers. Office Trailer, furnished, rent per month, 50' x 12', excl. hookups with air conditioning. RSM 01521 320 0550 and 0700.
	$/mo	440.00	
Storage Trailers	ea	48	Assume 4 storage boxes. Storage Boxes, rent per month, 40' x 8'. RSM 01521 320 1350.
	$/ea	102.00	
Signs	sf	40.0	Project signs, high intensity reflectorized, buy, excl. posts. RSM 01581 350 0020.
	$/sf	29.50	
Decon Facility	ea	1.0	Based on RACER Decontamination Pad Model for Equipment Decontamination.
	$/ea	28,271	
Electric Generator	mo	12.0	
	$/mo	1,871	Assume 1 electric generator gas engine 10 kW. RSM 01543 340 2300.
Portable Toilets	mo	24	Assume 2 each. Rent portable toilet chemical, recycle, flush type. RSM 01543 340 6420.
	$/mo	253.44	
Waste Volume Reduction Process Staging Area			
Pre-engineered Building	sf	10,000	Assume 100 ft x 100 ft. Pre-Eng Steel Bldg, single post 2-span frame, 30 psf roof & 20 psf wind load, 24 ft high incl. 26 ga. colored ribbed roofing & siding, excl. footings, slab, anchor bolts. RSM 13341 950 3300.
	$/sf	17.55	
Laydown Area	sf	10,000	Base course for roadways, crushed stone base, compacted, crushed 1-1/2" stone base, to 8" deep. RSM 32112 323 0308.
	$/lf	1.29	
Liner	sf	10,000	Liners, membrane lining systems HDPE, 100,000 S.F. or more, 30 mil thick. RSM 33471 353 1100
	$/sf	1.16	
Temporary Utilities and Equipment			
Extend Electric service	ea	1.0	Temporary electrical power equipment (pro-rated per job), overhead feed, 3 uses, 600 amp and temporary electrical power equipment (pro-rated per job), transformers, 3 uses, 75 KVA. RSM 01511 350 0060 and 0230
	$/ea	7,450.00	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Temporary Water Connection	ea	1.0	Assume temporary hydrant or water line connection. Based on Engineering Judgment.
	$/ea	2,500.00	
Monthly Utility and Office Expenses	mo	24.0	Field Office Expense including office equipment rental, office supplies, telephone bill, field office lights & HVAC for 2 office trailers. RSM 01521 340 0120 and 0140 and 0160
	$/mo	346.50	
Trucks	mo	36.0	Assume 3 trucks. Rent truck pickup 3/4 ton 4 wheel drive. RSM 01543 340 7200.
	$/mo	3,062.00	
Security			
Security Guard	hr	3,968.0	Assume 16 hrs/day for 8 months. Watchman, security service, uniformed person, monthly basis, min. RSM 01563 250 0020.
	$/hr	27.50	
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor	hr	12,800	
	$/hr	55.55	This element covers IH/HP technicians for the following areas: 3 at the excavation site to survey personnel, survey additional areas requiring excavation, and obtaining post RA samples for 5 months; 3 at the waste volume reduction process and loading site to survey personnel and transport vehicles for 5 months; 6 to support Building D&D for 3 months, and 2 at the onsite lab to analyze samples/swipes and calibrate equipment for 8 months. The IH/HP technicians and equipment would be required for a total of 64 months duration at 200 hrs/month. Total hours are 64 months x 200 hrs/mo.
Equipment	mo	8	Equipment pricing base on Vendor Quote. The Radiological monitoring equipment includes the following:
	$/mo	5,500.00	1. Model 2929 dual channel scaler (2 @ $300/mo =$600/mo) 2. Alpha Survey Instrument, Model 2360 with 43-89 (5 @ 325/mo = $1,625/mo) 3. Micro R Meter, Model 19 (2 @ $185/mo = $380/mo) 4. Ludlum - M3 - 44-2 - 44-9 Meter 3, NaI Gamma Scintillator, G-M Pancake Detector (3 @ $125/mo = $375/mo) 5. Personal air sampling pumps (3 @ $100/mo = $220/mo) 6. Personal air sampling pump charger (2 @ $70/mo = $140/mo) 7. High volume air samplers (8 @ $180/mo = $1440/mo) 8. Sources (3 @ $50/mo = $150) 9. Dosimetry (20 @ $10/mo = $200) Total = $5,130/month. Use $5,500/mo direct cost to account for other miscellaneous equipment, shipping, or supplies. Assume technicians are local and no per diem or travel is required.
Bioassays	ea	100	
	$/ea	147.32	Bioassays (2/yr x 1 yr x 50 people)
PPE Allowance	set	5,280	PPE Estimate. Assume average of 30 sets/day for 8 months. Includes Disposable Boot Covers, Coverall, Gloves, and Ear Plugs. ECHO 33010421, 23, 25, and 29.
	$/set	8.09	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Rad Soils Sampling/Handling/Packaging			
Rad Offsite Lab Soils Analysis			Confirmatory Sampling Since a MARSSIM analysis has not been performed, assume confirmation samples are obtained every 1,000 sf. The total area is 195,000 sf. Total samples collected are 195. Add 100% additional samples for sidewall samples. Add 30% additional samples for hotspots and QA/QC samples. Total samples = 507 ea Samples will be analyzed for radionuclide's. Assume 10% of rad samples will also have TCLP Test = 51 ea.). Waste Volume Reduction Process Sampling Assume waste volume reduction process piles are sampled at a rate of 20 samples per 1,000 cy. The total volume with swell and constructability is approximately 46,000 cy. Total samples collected = 920. Samples will be analyzed for radionuclide's. Assume 5% of rad samples will also have TCLP Test = 46 ea.)
Thorium Isotopic	ea $/ea	1,427 140.38	Testing, rad analytical vegetation/sediment/soil, alpha spectroscopy, thorium isotopic. ECHOS 33022334.
Lead-210	ea $/ea	1,427 174.13	Testing, rad analytical vegetation/sediment/soil, gamma spectroscopy, lead-210. ECHOS 33022344
Radium 226 and 228	ea $/ea	1,427 142.50	Testing, rad analytical vegetation/sediment/soil, gamma spectroscopy, radium-226, 228. ECHOS 33022346.
Uranium	ea $/ea	1,427 142.45	Testing, rad analytical vegetation/sediment/soil, alpha spectroscopy, uranium isotopic. ECHOS 33022335
TCLP	ea $/ea	97 559.74	Targeted TCLP (Metals, Volatiles, Semi-Volatiles only), Soil Analysis . ECHOS 33021705.
Site Work			
Clearing and Grubbing	acre $/acre	1 6,100	Clearing & grubbing, medium trees, to 12" diameter, cut and chip. RSM 31111 010 0200. Assume wood chip used as mulch onsite.
Surveying			
Establish Site Control/Layout	day $/day	3 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Reestablish Site Control/Layout	day $/day	3 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Volume Surveys	day $/day	3 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Post Restoration Survey	day $/day	3 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Sheetpiling			
Sheetpiling	lf $/lf	310 405	Assume 3100 lf of sheetpiling required along Cuyahoga River. Install Steel sheet piling seawalls, steel sheeting, 12' high, shore driven. RSM 35311 619 0210.
Surface Water Collect & Control Including Dewatering			Assume 100% of water is filtered and used for dust control of soils or discharged according to local regulations.
Excavation Dewatering	day $/day	16 850	Dewatering, pumping, 8 hr., attended 2 hours per day, 2" diaphragm pump, includes 20 L.F. of suction hose and 100 L.F. of discharge hose. RSM 31231 920 0800

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Sump Holes	cf	600	Dewatering, sump hole construction, includes excavation and gravel pit. RSM 31231 920 1600. Assume 20 each @ 30 cf.
	$/cf	2.37	
Storage Tank Delivery	ea	8	Mobilize and demobilize 20,000 gal storage tanks. Based on Engineering Judgment.
	$/ea	500	
Storage Tank Rental	mo	32	Storage tank rental, 20,000 gal. Based on Engineering Judgment. Assume an average of 4 for 8 months each.
	$/mo	1,200	
Water Filtration	ea	1	Water filter, commercial, fully automatic or push button automatic, taste and odor removal, 57 GPM, 2" pipe size. RSM 22321 910 9320
	$/ea	12,400	
Filters	ea	192	Water filter, cartridge style, dirt and rust type, replacement cartridge. RSM 22321 910 1200
	$/ea	39	
Solids Collect And Containment			
Erosion and Sediment Control			
Silt Fence and Straw Bales	lf	1,900	Erosion control, silt fence, polypropylene, 3' high and hay bales, staked. RSM 31251 310 1100 and 1250.
	$/lf	8.31	
Check Dams	cy	40	Rip-rap and rock lining, random, broken stone, machine placed for slope protection. RSM 31371 310 0100.
	$/cy	58.00	
Truck Entrance	cy	40	Base course roadways, crushed stone, compacted, 1-1/2", 8" deep. RSM 32112 323 1522.
	$/cy	47.50	
Dust Control			
Water Trucks	mo	8.0	Rent water tank trailer w/pumped discharge, 5000 gallon capacity. RSM 01543 340 6900.
	$/mo	2,584.00	
Concrete Demolition and Size Reduction			
Bituminous Concrete Demolition	cy	4150	Demolish, remove pavement & curb, concrete, rod reinforced, 7" to 24" thick, remove with backhoe, excludes hauling. RSM 02411 317 5500
	$/cy	153.00	
Asphaltic Concrete Demolition	sy	2222	Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees. RSM 02411 317 5050.
	$/sy	8.80	
Concrete Crushing Plant	hr	60	
	$/hr	516.80	Crusher (200 Tons/Hour). ECHO 17039902.
Soil Excavation and Waste Volume Reduction Process			
Excavate Soils	day	61	Includes 2.5 cy excavator, 3-22 cy off highway trucks, 1 O.E., 3 T.D., 2 L.S. as spotters, dust control, and misc. Reduced productivity by 33% for loading trucks, irregular/precise excavations, and security/S&H requirements. Average 660 cy/day. RSMeans Crew B12-S.
	$/day	7,590.0	
Waste Volume Reduction Process			
Waste Volume Reduction Operation	tons	55,414	The unit rate and production rates are based on the Painesville Site and modified based on vendor discussions. Includes waste volume reduction process and two operators.
	$/ton	35.00	
Waste Volume Reduction Support Crew	day	56	Includes 3 cy loader, 1 O.E., and 1 L.S. as spotters and support to waste volume reduction process, and 1 Sample Tech. RSMeans Crew B12-S. Assumes 1,000 tons/day.
	$/day	3,476.00	
Waste Volume Reduction Support Equipment	mo	4	Includes feed and discharge conveyors, screening plan, and trommel. Based on Painesville Site cost with quotes from screen machine.
	$/mo	30,000.00	
Diesel Generator	mo	4	
	$/mo	15,195.00	Rent electric generator gas engine 250 kW. RSM 01543 340 2800.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Load/Package Contaminated Waste	day $/day	75 4,152.00	Includes 3 cy loader, 1 O.E., 1 TD, and 2 L.S. as spotters and handling intermodals. Reduced productivity by 50% for loading intermodals and security/S&H requirements. RSMeans Crew B12-S.
Bags for Mixed Waste (10 cy)	ea $/ea	613 350.00	Assume mixed waste is placed in 10 cy bags and left onsite. Assume bags are fill to 85% capacity.
Buildings and Structures			
Building G-1 Demolition	cf $/cf	336,400 0.48	Building demolition, large urban projects, masonry, includes 20 mile haul, excludes foundation demolition, dump fees. RSM 02411 613 0080. Decreased productivity by 25% to account for rad controls and additional size reduction time required for disposal.
Loading Intermodals	day $/day	13 4,152.00	Includes 3 cy loader, 1 O.E., 1TD, and 2 L.S. as spotters and handling intermodals. Reduced productivity by 50% for loading intermodals and security/S&H requirements. RSMeans Crew B12-S.
Erosion and Sediment Control			
Silt Fence and Straw Bales	lf $/lf	400 8.31	Erosion control, silt fence, polypropylene, 3' high and hay bales, staked. RSM 31251 310 1100 and 1250.
Dust Control			
Water Trucks	mo $/mo	2.0 2,584.00	Rent water tank trailer w/pumped discharge, 5000 gallon capacity. RSM 01543 340 6900.
Building Decontamination			
Vacuum and Wet Wipe Surfaces	sf $/sf	10,200.00 0.40	Pre-cleaning, HEPA vacuum and wet wipe, flat surfaces. RSM 02821 342 0100
Protect Adjacent Floor Areas	sf $/sf	10,000.00 0.64	Cover surfaces with polyethylene sheeting, floors, each layer, 6 mil, incl. glue & tape. RSM 02821 342 0550
Protect Adjacent Wall Areas	sf $/sf	5,000.00 0.83	Cover surfaces with polyethylene sheeting, walls, each layer, 6 mil, incl. glue & tape. RSM 02821 342 0560
Seal Floor Penetrations	ea $/ea	10.00 10.95	Seal floor penetrations with foam firestop, to 36 sq. in. x 2 in thick. RSM 02821 342 0600
Seal Wall Penetrations	ea $/ea	10.00 11.33	Seal wall penetrations with foam firestop, to 36 sq. in. RSM 02821 342 0620
Shot Blast Floors	sf $/sf	0.00 1.41	Flooring demolition, remove flooring, bead blast, maximum. 09050 520 8100
Shot Blast Walls	sf $/sf	5,100.00 1.76	Flooring demolition, remove flooring, bead blast, maximum. Assume 25% more than floor decon. 09050 520 8100
Remove Roofing	sf $/sf	18,200.00 2.53	Selective demolition, thermal and moisture protection, roofing, built-up, 5-ply, includes gravel. Assume 50% more than traditional roof removal to account for age and contaminated material handling. RSM 070505103720.
DOT Steel Drums	ea $/ea	10.00 118.00	DOT steel drums, 55 gal., open, 17C. ECHOS 33199921
Misc Decon Supplies	sf $/sf	5,100.00 2.36	Miscellaneous Decontamination Supplies. ECHOS 33170425
Offsite Transport and Disposal			
Transport and Disposal (Soils)	cy $/cy	20,829 593.01	Includes transport and disposal to a facility in Utah. Includes intermodal and ABC rail car rental, ABC railcar transport cost with all fuel surcharges, and disposal. Assumes 17 cy/intermodal and 7 intermodals per railcar.
Transport and Disposal (Standard Debris)	cy $/cy	4,540 945.42	Includes transport and disposal to a facility in Utah. Includes intermodal and ABC rail car rental, ABC railcar transport cost with all fuel surcharges, and disposal. Assumes 17 cy/intermodal and 7 intermodals per railcar.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Transport and Disposal (Mixed Waste)	cy	5,207	Assume 25% mixed waste and add $600/cy mixed waste disposal premium for treatment and disposal.
	$/cy	600.00	
Recycling Credit	ton	113	
	$/ton	-70.00	Assume 15,000 lf of steel. Assume average section is W8 x 15.
Restoration			
Backfill Onsite Soils	cy	24,162	Includes loading soils from stockpile and transporting to backfill. Includes spreading and compacting in 8-in lifts. Includes testing.
	$/cy	10.80	
Off-Site Backfill for Balance of Site	cy	21,369	Base course drainage layers, aggregate base course for roadways and large paved areas, alternate method to figure base course, crushed stone, compacted, 1-1/2", 8" deep. RSM 32112 323 0308.
	$/cy	47.50	
Seeding, Vegetative Cover	MSF	90	Seeding with mulch and fertilizer. Assume 2 acres are restored in disturbed areas including equipment damage. RSMeans 329219142200.
	$/MSF	88.00	
Fence and Other Miscellaneous Repairs	lot	1.00	Assume fencing, utility poles, lights, and other structures are removed during remediation and will be replaced.
	$/lot	25,000.00	
Plans and Reports			
Corrective Action Completion Report	hrs	1,000	Includes Construction QC data and preparing report.
Technical Labor	$/hr	80	
Operation and Maintenance			
Five Year Reviews			
Five Year Reviews	ea	200	Includes CERCLA five year reviews. Estimates are based on the RACER Five Year Review Model for a moderately complex site.
	$/ea	18,000	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Cost Estimate

CAPITAL COST			$55,034,232
Activity (unit)	Quantity	Unit Cost	Total
Mobilization/Demobilization			
Equipment Mob/Demob.			
Medium Equipment (ea)	20	$251.00	$5,020
Large Equipment (ea)	20	$470.00	$9,400
Small Equipment (ea)	60	$70.50	$4,230
Submittals/Implementation Plans			
Submittals (ea)	15	$15,000.00	$225,000
Permitting			
Permitting (ea)	1	$20,000.00	$20,000
Temporary Structures and Facilities			
Haul Roads (sf)	5,000	$1.29	$6,450
Temporary Fencing (lf)	375	$7.55	$2,831
Office Trailers (mo)	24	$440.00	$10,560
Storage Trailers (mo)	48	$102.00	$4,896
Signs (sf)	40	$29.50	$1,180
Decon Facility (ea)	1	$28,271.00	$28,271
Electric Generator (mo)	12	$1,871.00	$22,452
Portable Toilets (mo)	24	$253.44	$6,083
Waste Volume Reduction Process Staging Area			
Pre-engineered Building (sf)	10,000	$17.55	$175,500
Laydown Area (sf)	10,000	$1.29	$12,900
Liner (sf)	10,000	$1.16	$11,600
Temporary Utilities and Equipment			
Extend Electric service (ea)	1	$7,450.00	$7,450
Temporary Water Connection (ea)	1	$2,500.00	$2,500
Monthly Utility and Office Expenses (mo)	24	$346.50	$8,316
Trucks (mo)	36	$3,062.00	$110,232
Security			
Security Guard (hr)	3,968	$27.50	$109,120
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor (hr)	12,800	$55.55	$711,040
Equipment (mo)	8	$5,500.00	$44,000
Bioassays	100	$147.32	$14,732
PPE Allowance (set)	5,280	$8.09	$42,715
Rad Offsite Lab Soils Analysis			
Thorium Isotopic (ea)	1,427	$140.38	$200,322
Lead-210 (ea)	1,427	$174.13	$248,484
Radium 226 and 228 (ea)	1,427	$142.50	$203,348
Uranium (ea)	1,427	$142.45	$203,276
TCLP (ea)	97	$559.74	$54,295

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Cost Estimate

Activity (unit)	Quantity	Unit Cost	Total
Site Work			
Clearing and Grubbing (acre)	1	$6,100.00	$6,100
Surveying			
Establish Site Control/Layout (day)	3	$1,750.00	$5,250
Reestablish Site Control/Layout (day)	3	$1,750.00	$5,250
Volume Surveys (day)	3	$1,750.00	$5,250
Post Restoration Survey (day)	3	$1,750.00	$5,250
Sheetpiling			
Sheetpiling (lf)	310	$405.00	$125,550
Surface Water Collect & Control Including Dewatering			
Excavation Dewatering (day)	16	$850.00	$13,600
Sump Holes (cf)	600	$2.37	$1,422
Storage Tank Delivery (ea)	8	$500.00	$4,000
Storage Tank Rental (mo)	32	$1,200.00	$38,400
Water Filtration (ea)	1	$12,400.00	$12,400
Water Filters (ea)	192	$39.00	$7,488
Solids Collect And Containment			
Erosion and Sediment Control			
Silt Fence and Straw Bales (lf)	1,900	$8.31	$15,789
Check Dams (cy)	40	$58.00	$2,320
Truck Entrance (cy)	40	$47.50	$1,900
Dust Control			
Water Trucks (mo)	8	$2,584.00	$20,672
Concrete Demolition and Size Reduction			
Bituminous Concrete Demolition (cy)	4,150	$153.00	$634,893
Asphaltic Concrete Demolition (sy)	2,222	$8.80	$19,556
Concrete Crushing Plant (hr)	60	$516.80	$31,008
Soil Excavation and Waste Volume Reduction Process			
Excavate Soils (day)	61	$7,590.00	$462,990
Waste Volume Reduction Operation (ton)	55,414	$35.00	$1,939,497
Waste Volume Reduction Support Crew (day)	56	$3,476.00	$194,656
Waste Volume Reduction Support Equipment (mo)	4	$30,000.00	$120,000
Diesel Generator (day)	4	$15,195.00	$60,780
Load/Package Contaminated Waste (day)	75	$4,152.00	$309,803
Bags for Mixed Waste (10 cy) (ea)	613	$350.00	$214,550
Buildings and Structures			
Building G-1 Demolition (cf)	336,400	$0.48	$161,472
Loading Intermodals (day)	13	$4,152.00	$55,441
Silt Fence and Straw Bales (lf)	400	$8.31	$3,324
Water Trucks (mo)	2	$2,584.00	$5,168

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Cost Estimate

Activity (unit)	Quantity	Unit Cost	Total
Building Decontamination			
Vacuum and Wet Wipe Surfaces (sf)	10,200	$0.40	$4,080
Protect Adjacent Floor Areas (sf)	10,000	$0.64	$6,400
Protect Adjacent Wall Areas (sf)	5,000	$0.83	$4,150
Seal Floor Penetrations (ea)	10	$10.95	$110
Seal Wall Penetrations (ea)	10	$11.33	$113
Shot Blast Floors (sf)	0	$1.41	$0
Shot Blast Walls (sf)	5,100	$1.76	$8,989
Roof Removal (sf)	18,200	$2.53	$46,046
DOT Steel Drums (ea)	10	$118.00	$1,180
Misc Decon Supplies (sf)	5,100	$2.36	$12,036
Offsite Transport and Disposal			
Transport and Disposal (Soils) (cy)	20,829	$593.01	$12,351,920
Transport and Disposal (Standard Debris) (cy)	4,540	$945.42	$4,292,208
Transport and Disposal (Mixed Waste) (cy)	5,207	$600.00	$3,124,388
Recycling Credit (ton)	113	($70.00)	-$7,910
Restoration			
Backfill Onsite Soils (cy)	24,162	$10.80	$261,033
Off-Site Backfill for Balance of Site (cy)	21,369	$47.50	$1,015,039
Seeding, Vegetative Cover (msf)	90	$88.00	$7,920
Fence and Other Miscellaneous Repairs (lot)	1	$25,000.00	$25,000
Closure Reports			
Corrective Action Completion Report (hr)	1,000	$80.00	$80,000
Subtotal			$28,222,683
Design		10%	$2,822,268
Home Office Overhead and Project Management		5%	$1,411,134
Field Overhead and Remediation Management		10%	$2,822,268
Subtotal			$35,278,354
Profit		8%	$2,822,268
Contingency		48%	$16,933,610
Total			$55,034,232

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 3 - Complete Removal with Off-Site Disposal (OU-1)
Cost Estimate

OPERATION AND MAINTENANCE **$6,795,360**

Activity (unit)	Quantity	Unit Cost	Total Cost	Present Value (4.125%)
Five Year Reviews				
Five Year Reviews	200	$18,000	$3,600,000	$80,364
Subtotal O&M			$3,600,000	$80,364
Design		6%	$216,000	$4,822
Home Office Overhead and Project Management		5%	$180,000	$4,018
Field Overhead and Remediation Management		10%	$360,000	$8,036
Subtotal			$4,356,000	$97,240
Profit		8%	$348,480	$7,779
Contingency		48%	$2,090,880	$46,675
Total			$6,795,360	$151,694

TOTAL ALTERNATIVE CAPITAL AND O&M COST (Non Discounted Cost) **$61,829,592**

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Capital Cost			
Mobilization/Demobilization			
Equipment Mob/Demob.			
Medium Equipment	ea	20	Mob/demob dozer, loader, backhoe or excavator, 70-150 H.P, up to 50 miles. RSM 01543 650 0020. Assume 10 pieces.
	$/ea	251.00	
Large Equipment	ea	20.0	Mob/demob, dozer, loader, backhoe or excavator, above 150 H.P., up to 50 miles. RSM 01543 650 0100. Assume 10 pieces.
	$/ea	470.00	
Small Equipment	ea	60.0	Mob/demob, delivery charge for small equipment, placed in rear of, or towed by pickup. RSM 01543 650 1100. Assume 30 pieces.
	$/ea	70.50	
Submittals/Implementation Plans			
Submittals	ea	15.0	Includes submittals such as Air Monitoring Plan, QCP, Schedule, Materials Handling/Transportation/Disposal Plan, SAP, SSH Plan, Site Security Plan, Site Work Plan, SWPPP, etc. Assume 15 plans and/or appendices to work plan. Based on Engineering Judgment.
	$/ea	15,000	
Permitting			
Permitting	ea	1.0	Local and state permitting not required, but assume work in/adjacent to river will require permitting. Based on Engineering Judgment.
	$/ea	20,000	
Temporary Structures and Facilities			
Haul Roads	sf	5,000	Base course drainage layers, aggregate base course, spread & compacted, 3/4" crushed stone, to 6" deep. RSM 32112 323 0110.
	$/sf	1.29	
Temporary Fencing	lf	375.0	Temporary Fencing, chain link, rented up to 12 months, 6' high, 11 ga, to 1000'. RSM 01562 650 0200.
	$/lf	7.55	
Office Trailers	mo	24.0	Assume 2 trailers. Office Trailer, furnished, rent per month, 50' x 12', excl. hookups with air conditioning. RSM 01521 320 0550 and 0700.
	$/mo	440.00	
Storage Trailers	ea	48	Assume 4 storage boxes. Storage Boxes, rent per month, 40' x 8'. RSM 01521 320 1350.
	$/ea	102.00	
Signs	sf	40.0	Project signs, high intensity reflectorized, buy, excl. posts. RSM 01581 350 0020.
	$/sf	29.50	
Decon Facility	ea	1.0	Based on RACER Decontamination Pad Model for Equipment Decontamination.
	$/ea	28,271	
Electric Generator	mo	12.0	
	$/mo	1,871	Assume 1 electric generator gas engine 10 kW. RSM 01543 340 2300.
Portable Toilets	mo	24	Assume 2 each. Rent portable toilet chemical, recycle, flush type. RSM 01543 340 6420.
	$/mo	253.44	
Waste Volume Reduction Staging Area			
Pre-engineered Building	sf	10,000	Assume 100 ft x 100 ft. Pre-Eng Steel Bldg, single post 2-span frame, 30 psf roof & 20 psf wind load, 24 ft high incl. 26 ga. colored ribbed roofing & siding, excl. footings, slab, anchor bolts. RSM 13341 950 3300.
	$/sf	17.55	
Laydown Area	sf	10,000	Base course for roadways, crushed stone base, compacted, crushed 1-1/2" stone base, to 8" deep. RSM 32112 323 0308.
	$/lf	1.29	
Liner	sf	10,000	Liners, membrane lining systems HDPE, 100,000 S.F. or more, 30 mil thick. RSM 33471 353 1100
	$/sf	1.16	
Temporary Utilities and Equipment			
Extend Electric service	ea	1.0	Temporary electrical power equipment (pro-rated per job), overhead feed, 3 uses, 600 amp and temporary electrical power equipment (pro-rated per job), transformers, 3 uses, 75 KVA. RSM 01511 350 0060 and 0230
	$/ea	7,450.00	
Temporary Water Connection	ea	1.0	Assume temporary hydrant or water line connection. Based on Engineering Judgment.
	$/ea	2,500.00	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Monthly Utility and Office Expenses	mo $/mo	24.0 346.50	Field Office Expense including office equipment rental, office supplies, telephone bill, field office lights & HVAC for 2 office trailers. RSM 01521 340 0120 and 0140 and 0160
Trucks	mo $/mo	36.0 3,062.00	Assume 3 trucks. Rent truck pickup 3/4 ton 4 wheel drive. RSM 01543 340 7200.
Security			
Security Guard	hr $/hr	3,968.0 27.50	Assume 16 hrs/day for 8 months. Watchman, security service, uniformed person, monthly basis, min. RSM 01563 250 0020.
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor	hr $/hr	12,800 55.55	This element covers IH/HP technicians for the following areas: 3 at the excavation site to survey personnel, survey additional areas requiring excavation, and obtaining post RA samples for 5 months; 3 at the waste volume reduction process and loading site to survey personnel and transport vehicles for 5 months; 6 to support Building D&D for 3 months, and 2 at the onsite lab to analyze samples/swipes and calibrate equipment for 8 months. The IH/HP technicians and equipment would be required for a total of 64 months duration at 200 hrs/month. Total hours are 64 months x 200 hrs/mo.
Equipment	mo $/mo	8 5,500.00	Equipment pricing base on Vendor Quote. The radiological monitoring equipment includes the following: 1. Model 2929 dual channel scaler (2 @ $300/mo =$600/mo) 2. Alpha Survey Instrument, Model 2360 with 43-89 (5 @ 325/mo = $1,625/mo) 3. Micro R Meter, Model 19 (2 @ $185/mo = $380/mo) 4. Ludlum - M3 - 44-2 - 44-9 Meter 3, NaI Gamma Scintillator, G-M Pancake Detector (3 @ $125/mo = $375/mo) 5. Personal air sampling pumps (3 @ $100/mo = $220/mo) 6. Personal air sampling pump charger (2 @ $70/mo = $140/mo) 7. High volume air samplers (8 @ $180/mo = $1440/mo) 8. Sources (3 @ $50/mo = $150) 9. Dosimetry (20 @ $10/mo = $200) Total = $5,130/month. Use $5,500/mo direct cost to account for other miscellaneous equipment, shipping, or supplies. Assume technicians are local and no per diem or travel is required.
Bioassays	ea $/ea	100 147.32	Bioassays (2/yr x 1 yr x 50 people)
PPE Allowance	set $/set	5,280 8.09	PPE Estimate. Assume average of 30 sets/day for 8 months. Includes Disposable Boot Covers, Coverall, Gloves, and Ear Plugs. ECHO 33010421, 23, 25, and 29.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Rad Soils Sampling/Handling/Packaging			
Rad Offsite Lab Soils Analysis			Confirmatory Sampling Since a MARSSIM analysis has not been performed, assume confirmation samples are obtained every 1,000 sf. The total area is 195,000 sf. Total samples collected are 195. Add 100% additional samples for sidewall samples. Add 30% additional samples for hotspots and QA/QC samples. Total samples = 507 ea Samples will be analyzed for radionuclide's. Assume 10% of rad samples will also have TCLP Test = 51 ea. Waste Volume Reduction Process Sampling Assume waste volume reduction process piles are sampled at a rate of 20 samples per 1,000 cy. The total volume with swell and constructability is approximately 46,000 cy. Total samples collected = 920. Samples will be analyzed for radionuclide's. Assume 5% of rad samples will also have TCLP Test = 46 ea.
Thorium Isotopic	ea $/ea	1,427 140.38	Testing, rad analytical vegetation/sediment/soil, alpha spectroscopy, thorium isotopic. ECHOS 33022334.
Lead-210	ea $/ea	1,427 174.13	Testing, rad analytical vegetation/sediment/soil, gamma spectroscopy, lead-210. ECHOS 33022344
Radium 226 and 228	ea $/ea	1,427 142.50	Testing, rad analytical vegetation/sediment/soil, gamma spectroscopy, radium-226, 228. ECHOS 33022346.
Uranium	ea $/ea	1,427 142.45	Testing, rad analytical vegetation/sediment/soil, alpha spectroscopy, uranium isotopic. ECHOS 33022335
TCLP	ea $/ea	97 559.74	Targeted TCLP (Metals, Volatiles, Semi-Volatiles only), Soil Analysis . ECHOS 33021705.
Site Work			
Clearing and Grubbing	acre $/acre	1 6,100	Clearing & grubbing, medium trees, to 12" diameter, cut and chip. RSM 31111 010 0200. Assume wood chip used as mulch onsite.
Surveying			
Establish Site Control/Layout	day $/day	3 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Reestablish Site Control/Layout	day $/day	3 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Volume Surveys	day $/day	3 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Post Restoration Survey	day $/day	3 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Sheetpiling			
Sheetpiling	lf $/lf	310 405	Assume 3100 lf of sheetpiling required along Cuyahoga River. Install Steel sheet piling seawalls, steel sheeting, 12' high, shore driven. RSM 35311 619 0210.
Surface Water Collect & Control Including Dewatering			Assume 100% of water is filtered and used for dust control of soils or discharged according to local regulations.
Excavation Dewatering	day $/day	16 850	Dewatering, pumping, 8 hr., attended 2 hours per day, 2" diaphragm pump, includes 20 L.F. of suction hose and 100 L.F. of discharge hose. RSM 31231 920 0800

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Sump Holes	cf	600	Dewatering, sump hole construction, includes excavation and gravel pit. RSM 31231 920 1600. Assume 20 each @ 30 cf.
	$/cf	2.37	
Storage Tank Delivery	ea	8	Mobilize and demobilize 20,000 gal storage tanks. Based on Engineering Judgment.
	$/ea	500	
Storage Tank Rental	mo	32	Storage tank rental, 20,000 gal. Based on Engineering Judgment. Assume an average of 4 for 8 months each.
	$/mo	1,200	
Water Filtration	ea	1	Water filter, commercial, fully automatic or push button automatic, taste and odor removal, 57 GPM, 2" pipe size. RSM 22321 910 9320
	$/ea	12,400	
Filters	ea	192	Water filter, cartridge style, dirt and rust type, replacement cartridge. RSM 22321 910 1200
	$/ea	39	
Solids Collect And Containment			
Soils Media			
Erosion and Sediment Control			
Silt Fence and Straw Bales	lf	1,900	Erosion control, silt fence, polypropylene, 3' high and hay bales, staked. RSM 31251 310 1100 and 1250.
	$/lf	8.31	
Check Dams	cy	40	Rip-rap and rock lining, random, broken stone, machine placed for slope protection. RSM 31371 310 0100.
	$/cy	58.00	
Truck Entrance	cy	40	Base course roadways, crushed stone, compacted, 1-1/2", 8" deep. RSM 32112 323 1522.
	$/cy	47.50	
Dust Control			
Water Trucks	mo	8.0	Rent water tank trailer w/pumped discharge, 5000 gallon capacity. RSM 01543 340 6900.
	$/mo	2,584.00	
Concrete Demolition and Size Reduction			
Bituminous Concrete Demolition	cy	4150	Demolish, remove pavement & curb, concrete, rod reinforced, 7" to 24" thick, remove with backhoe, excludes hauling. RSM 02411 317 5500
	$/cy	153.00	
Asphaltic Concrete Demolition	sy	2222	Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees. RSM 02411 317 5050.
	$/sy	8.80	
Concrete Crushing Plant	hr	60	
	$/hr	516.80	Crusher (200 Tons/Hour). ECHO 17039902.
Soil Excavation and Waste Volume Reduction Process			
Excavate Soils	day	61	Includes 2.5 cy excavator, 3-22 cy off highway trucks, 1 O.E., 3 T.D., 2 L.S. as spotters, dust control, and misc. Reduced productivity by 33% for loading trucks, irregular/precise excavations, and security/S&H requirements. Average 660 cy/day. RSMeans Crew B12-S.
	$/day	7,590.0	
Waste Volume Reduction and Waste Stream Handling			
Waste Volume Reduction Operation	tons	55,414	The unit rate and production rates are based on the Painesville Site and modified based on vendor discussions. Includes waste volume reduction process and two operators.
	$/ton	35.00	
Waste Volume Reduction Process Support Crew	day	56	Includes 3 cy loader, 1 O.E., and 1 L.S. as spotters and support to waste volume reduction process, and 1 Sample Tech. RSMeans Crew B12-S. Assumes 1,000 tons/day.
	$/day	3,476.00	
Waste Volume Reduction Support Equipment	mo	4	Includes feed and discharge conveyors, screening plan, and trommel. Based on Painesville Site cost with quotes from screen machine.
	$/mo	30,000.00	
Diesel Generator	mo	4	
	$/mo	15,195.00	Rent electric generator gas engine 250 kW. RSM 01543 340 2800.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Load/Package Contaminated Waste	day $/day	93 4,152.00	Includes 3 cy loader, 1 O.E., 1 TD, and 2 L.S. as spotters and handling intermodals. Reduced productivity by 50% for loading intermodals and security/S&H requirements. RSMeans Crew B12-S.
Bags for Mixed Waste (10 cy)	ea $/ea	613 350.00	Assume mixed waste is placed in 10 cy bags and left onsite. Assume bags are fill to 85% capacity.
Buildings and Structures			
Building G-1 Demolition	cf $/cf	336,400 0.48	Building demolition, large urban projects, masonry, includes 20 mile haul, excludes foundation demolition, dump fees. RSM 02411 613 0080. Decreased productivity by 25% to account for rad controls and additional size reduction time required for disposal.
Erosion and Sediment Control			
Silt Fence and Straw Bales	lf $/lf	400 8.31	Erosion control, silt fence, polypropylene, 3' high and hay bales, staked. RSM 31251 310 1100 and 1250.
Dust Control			
Water Trucks	mo $/mo	2.0 2,584.00	Rent water tank trailer w/pumped discharge, 5000 gallon capacity. RSM 01543 340 6900.
Loading Intermodals/Bags	day $/day	17 4,152.00	Includes 3 cy loader, 1 O.E., 1TD, and 2 L.S. as spotters and handling intermodals. Reduced productivity by 50% for loading intermodals and security/S&H requirements. RSMeans Crew B12-S.
Building Decontamination			
Vacuum and Wet Wipe Surfaces	sf $/sf	10,200.00 0.40	Pre-cleaning, HEPA vacuum and wet wipe, flat surfaces. RSM 02821 342 0100
Protect Adjacent Floor Areas	sf $/sf	10,000.00 0.64	Cover surfaces with polyethylene sheeting, floors, each layer, 6 mil, incl. glue & tape. RSM 02821 342 0550
Protect Adjacent Wall Areas	sf $/sf	5,000.00 0.83	Cover surfaces with polyethylene sheeting, walls, each layer, 6 mil, incl. glue & tape. RSM 02821 342 0560
Seal Floor Penetrations	ea $/ea	10.00 10.95	Seal floor penetrations with foam firestop, to 36 sq. in. x 2 in thick. RSM 02821 342 0600
Seal Wall Penetrations	ea $/ea	10.00 11.33	Seal wall penetrations with foam firestop, to 36 sq. in. RSM 02821 342 0620
Shot Blast Floors	sf $/sf	0.00 1.41	Flooring demolition, remove flooring, bead blast, maximum. 09050 520 8100
Shot Blast Walls	sf $/sf	5,100.00 1.76	Flooring demolition, remove flooring, bead blast, maximum. Assume 25% more than floor decon. 09050 520 8100
Remove Roofing	sf $/sf	18,200.00 2.53	Selective demolition, thermal and moisture protection, roofing, built-up, 5-ply, includes gravel. Assume 50% more than traditional roof removal to account for age and contaminated material handling. RSM 070505103720.
DOT Steel Drums	ea $/ea	10.00 118.00	DOT steel drums, 55 gal., open, 17C. ECHOS 33199921
Misc Decon Supplies	sf $/sf	5,100.00 2.36	Miscellaneous Decontamination Supplies. ECHOS 33170425

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Ex Situ Treatment			Includes the treatment of above criteria soils processed through the waste volume reduction process. Includes treatment of hazardous waste. Based on RACER parametric model for Solidification. Assumes 100 lb/cf and mixed in 15 cy batches.
Treatment Volume	cy	23,089	
Loader	hr	2	910, 1.25 CY, Wheel Loader. ECHOS 17030220
	$/hr	144.06	
Truck	hr	52	12 CY, Dump Truck. ECHOS 17030285
	$/hr	153.22	
Holding Tank	mo	1	Wastewater holding tanks, above ground, ss, DOT approved, monthly rental, 550 gal. ECHOS 19040401
	$/mo	496.47	
Holding Tank	mo	1	Wastewater holding tanks, above ground, steel, open, stationary, monthly rental, 21,000 gal. ECHOS 19040408
	$/mo	1,701.04	
Portland Cement	ton	470	Portland Cement Type I (Bulk). ECHOS 33150405
	$/ton	144.57	
Treatment Additive	ton	32	Urrichem by Soliditech. ECHOS 33150408
	$/ton	2,982.02	
Plywood Boxes	ea	18	1 CY Plywood Boxes. ECHOS 33150418
	$/ea	100.17	
Operations Labor	hr	104	Operational Labor for Process Equipment. ECHOS 33150420
	$/hr	62.99	
Chemical Transport	ea	26	Bulk Chemical Transport (40,000 Lb Truckload). ECHOS 33150421
	$/ea	2,829.31	
Mixer	mo	1	15 CY Waste Mixer. ECHOS 33150434
	$/mo	16,213.00	
Solidification/Stabilization Ancillary Equipme	ea	1	Solidification/Stabilization Ancillary Equipment. ECHOS 33150435
	$/ea	16,175.50	
Maintenance of Solidification Unit	yr	0.1	Maintenance of Solidification/Stabilization Unit. ECHOS 33150437
	$/yr	9,825.81	
Drums	ea	3	DOT steel drums, 55 gal., open, 17C. ECHOS 33199921
	$/ea	141.93	
Fuel	gal	207	Diesel Fuel. ECHOS 33420201
	$/gal	4.31	
Process Water	kgal	46	Process Water, Supplied by Tanker Truck. ECHOS 33420301
	$/kgal	17.01	
Offsite Transport and Disposal			
Transport and Disposal (Standard Debris)	cy	31,712	Includes transport and disposal to a facility in Utah. Includes intermodal and ABC rail car rental, ABC railcar transport cost with all fuel surcharges, and disposal. Assumes 17 cy/intermodal and 7 intermodals per railcar. Volumes include 25% increase due to solidification process.
	$/cy	945.42	
Transport and Disposal (Mixed Waste)	cy	0	Assume 25% mixed waste but since it has undergone treatment, it can be disposed as nonhazardous.
	$/cy	600.00	
Recycling Credit	ton	113	
	$/ton	-70.00	Assume 15,000 lf of steel. Assume average section is W8 x 15.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Restoration			
Backfill Onsite Soils	cy $/cy	24,162 10.80	Includes loading soils from stockpile and transporting to backfill. Includes spreading and compacting in 8-in lifts. Includes testing.
Off-Site Backfill for Balance of Site	cy $/cy	21,369 47.50	Base course drainage layers, aggregate base course for roadways and large paved areas, alternate method to figure base course, crushed stone, compacted, 1-1/2", 8" deep. RSM 32112 323 0308.
Seeding, Vegetative Cover	MSF $/MSF	90 88.00	Seeding with mulch and fertilizer. Assume 2 acres are restored in disturbed areas including equipment damage. RSMeans 329219142200.
Fence and Other Miscellaneous Repairs	lot $/lot	1.00 25,000.00	Assume fencing, utility poles, lights, and other structures are removed during remediation and will be replaced.
Plans and Reports			
Corrective Action Completion Report	hrs	1,200	Includes Construction QC data and preparing report.
Technical Labor	$/hr	80	
Operation and Maintenance			
Five Year Reviews			
Five Year Reviews	ea $/ea	200 18,000	Includes CERCLA five year reviews. Estimates are based on the RACER Five Year Review Model for a moderately complex site.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Cost Estimate

CAPITAL COST			$76,257,108
Activity (unit)	Quantity	Unit Cost	Total
Mobilization/Demobilization			
Equipment Mob/Demob.			
Medium Equipment (ea)	20	$251.00	$5,020
Large Equipment (ea)	20	$470.00	$9,400
Small Equipment (ea)	60	$70.50	$4,230
Submittals/Implementation Plans			
Submittals (ea)	15	$15,000.00	$225,000
Permitting			
Permitting (ea)	1	$20,000.00	$20,000
Temporary Structures and Facilities			
Haul Roads (sf)	5,000	$1.29	$6,450
Temporary Fencing (lf)	375	$7.55	$2,831
Office Trailers (mo)	24	$440.00	$10,560
Storage Trailers (mo)	48	$102.00	$4,896
Signs (sf)	40	$29.50	$1,180
Decon Facility (ea)	1	$28,271.00	$28,271
Electric Generator (mo)	12	$1,871.00	$22,452
Portable Toilets (mo)	24	$253.44	$6,083
Waste Volume Reduction Process Staging Area			
Pre-engineered Building (sf)	10,000	$17.55	$175,500
Laydown Area (sf)	10,000	$1.29	$12,900
Liner (sf)	10,000	$1.16	$11,600
Temporary Utilities and Equipment			
Extend Electric service (ea)	1	$7,450.00	$7,450
Temporary Water Connection (ea)	1	$2,500.00	$2,500
Monthly Utility and Office Expenses (mo)	24	$346.50	$8,316
Trucks (mo)	36	$3,062.00	$110,232
Security			
Security Guard (hr)	3,968	$27.50	$109,120
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor (hr)	12,800	$55.55	$711,040
Equipment (mo)	8	$5,500.00	$44,000
Bioassays	100	$147.32	$14,732
PPE Allowance (set)	5,280	$8.09	$42,715
Rad Offsite Lab Soils Analysis			
Thorium Isotopic (ea)	1,427	$140.38	$200,322
Lead-210 (ea)	1,427	$174.13	$248,484
Radium 226 and 228 (ea)	1,427	$142.50	$203,348
Uranium (ea)	1,427	$142.45	$203,276
TCLP (ea)	97	$559.74	$54,295

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Cost Estimate

Activity (unit)	Quantity	Unit Cost	Total
Site Work			
Clearing and Grubbing (acre)	1	$6,100.00	$6,100
Surveying			
Establish Site Control/Layout (day)	3	$1,750.00	$5,250
Reestablish Site Control/Layout (day)	3	$1,750.00	$5,250
Volume Surveys (day)	3	$1,750.00	$5,250
Post Restoration Survey (day)	3	$1,750.00	$5,250
Sheetpiling			
Sheetpiling (lf)	310	$405.00	$125,550
Surface Water Collect & Control Including Dewatering			
Excavation Dewatering (day)	16	$850.00	$13,600
Sump Holes (cf)	600	$2.37	$1,422
Storage Tank Delivery (ea)	8	$500.00	$4,000
Storage Tank Rental (mo)	32	$1,200.00	$38,400
Water Filtration (ea)	1	$12,400.00	$12,400
Water Filters (ea)	192	$39.00	$7,488
Solids Collect And Containment			
Erosion and Sediment Control			
Silt Fence and Straw Bales (lf)	1,900	$8.31	$15,789
Check Dams (cy)	40	$58.00	$2,320
Truck Entrance (cy)	40	$47.50	$1,900
Dust Control			
Water Trucks (mo)	8	$2,584.00	$20,672
Concrete Demolition and Size Reduction			
Bituminous Concrete Demolition (cy)	4,150	$153.00	$634,893
Asphaltic Concrete Demolition (sy)	2,222	$8.80	$19,556
Concrete Crushing Plant (hr)	60	$516.80	$31,008
Soil Excavation and Waste Volume Reduction Process			
Excavate Soils (day)	61	$7,590.00	$462,990
Waste Volume Reduction Process Operation (ton)	55,414	$35.00	$1,939,497
Waste Volume Reduction Support Crew (day)	56	$3,476.00	$194,656
Waste Volume Reduction Support Equipment (mo)	4	$30,000.00	$120,000
Diesel Generator (day)	4	$15,195.00	$60,780
Load/Package Contaminated Waste (day)	93	$4,152.00	$387,254
Bags for Mixed Waste (10 cy) (ea)	613	$350.00	$214,550
Buildings and Structures			
Building G-1 Demolition (cf)	336,400	$0.48	$161,472
Loading Intermodals (day)	17	$4,152.00	$69,302
Silt Fence and Straw Bales (lf)	400	$8.31	$3,324
Water Trucks (mo)	2	$2,584.00	$5,168

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Cost Estimate

Activity (unit)	Quantity	Unit Cost	Total
Building Decontamination			
Vacuum and Wet Wipe Surfaces (sf)	10,200	$0.40	$4,080
Protect Adjacent Floor Areas (sf)	10,000	$0.64	$6,400
Protect Adjacent Wall Areas (sf)	5,000	$0.83	$4,150
Seal Floor Penetrations (ea)	10	$10.95	$110
Seal Wall Penetrations (ea)	10	$11.33	$113
Shot Blast Floors (sf)	0	$1.41	$0
Shot Blast Walls (sf)	5,100	$1.76	$8,989
Roof Removal (sf)	18,200	$2.53	$46,046
DOT Steel Drums (ea)	10	$118.00	$1,180
Misc Decon Supplies (sf)	5,100	$2.36	$12,036
Ex Situ Treatment			
Loader (hr)	16	$144.06	$2,305
Truck (hr)	16	$153.22	$2,452
Holding Tank (mo)	1	$496.47	$496
Holding Tank (mo)	1	$1,701.04	$1,701
Portland Cement (ton)	42	$144.57	$6,072
Treatment Additive (ton)	3	$2,982.02	$8,946
Plywood Boxes (ea)	6	$100.17	$601
Operations Labor (hr)	32	$62.99	$2,016
Chemical Transport (ea)	4	$2,829.31	$11,317
Mixer (mo)	1.0	$16,213.00	$16,213
Solidification/Stabilization Ancillary Equipment (ea)	1.0	$16,175.50	$16,176
Maintenance of Solidification Unit (yr)	0.01	$9,825.81	$98
Drums (ea)	2.0	$141.93	$284
Fuel (gal)	47	$4.31	$203
Process Water (kgal)	5	$17.01	$85
Offsite Transport and Disposal			
Transport and Disposal (Standard Debris) (cy)	31,712	$945.42	$29,980,751
Transport and Disposal (Mixed Waste) (cy)	0	$600.00	$0
Recycling Credit (ton)	113	($70.00)	-$7,910
Restoration			
Backfill Onsite Soils (cy)	24,162	$10.80	$261,033
Off-Site Backfill for Balance of Site (cy)	21,369	$47.50	$1,015,039
Seeding, Vegetative Cover (msf)	90	$88.00	$7,920
Fence and Other Miscellaneous Repairs (lot)	1	$25,000.00	$25,000
Closure Reports			
Corrective Action Completion Report (hr)	1,200	$80.00	$96,000
Subtotal			$38,611,194
Design		10%	$3,861,119
Home Office Overhead and Project Management		5%	$1,930,560
Field Overhead and Remediation Management		10%	$3,861,119
Subtotal			$48,263,992
Profit		8%	$3,861,119
Contingency		50%	$24,131,996
Total			$76,257,108

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 4 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1)
Cost Estimate

OPERATION AND MAINTENANCE **$6,882,480**

Activity (unit)	Quantity	Unit Cost	Total Cost	Present Value (4.125%)
Five Year Reviews				
Five Year Reviews	200	$18,000	$3,600,000	$80,364
Subtotal O&M			$3,600,000	$80,364
Design		6%	$216,000	$4,822
Home Office Overhead and Project Management		5%	$180,000	$4,018
Field Overhead and Remediation Management		10%	$360,000	$8,036
Subtotal			$4,356,000	$97,240
Profit		8%	$348,480	$7,779
Contingency		50%	$2,178,000	$48,620
Total			$6,882,480	$153,639

TOTAL ALTERNATIVE CAPITAL AND O&M COST (Non Discounted Cost) **$83,139,588**

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 6 - Limited Action and Land-Use Controls (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Capital Cost			
Administrative Land Use Controls			
Administrative Land Use Controls	lot	1	Includes planning documents, planning meetings, implementation, and monitoring and enforcement for first year. Estimates are based on the RACER Administrative Land Use Controls Model. Assumed moderate/high level of complexity to implement these controls.
	$/lot	702,000	
Monitoring Plan			
Monitoring Plan	ea	1	Includes monitoring plan for surface soil, sediment, and air monitoring. Estimates are based on the RACER Monitoring Model.
	$/ea	30,000	
Land Use Controls			
Establish Control Area	day	2	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
	$/day	1,750	
Develop Drawings	hr	40	
	$/hr	80	Develop control drawings.
Signs	sf	24.0	Assume signs on fence every 100 lf. Project signs, high intensity reflectorized, buy, excl. posts. RSM 01581 350 0020.
	$/sf	29.50	
Fence	lf	1,000	Fence, chain link industrial, aluminized steel, 6 ga. wire, 2-1/2" posts @ 10' OC, 8' high, includes excavation, in concrete, excludes barbed wire. RSM 32311 320 0940.
	$/lf	63	
Gate	ea	2	Fence, chain link industrial, double swing gates, 6' high, 20' opening, includes excavation, posts & hardware in concrete. RSM 32311 320 5070.
	$/ea	1,750	
Operation and Maintenance			
Administrative Land Use Controls			
Administrative Land Use Controls	annual	1,000	Includes monitoring and enforcement of administrative land use controls. Includes annual site inspection visits and periodic notice letters and status reports every two years. Estimates are based on the RACER Administrative Land Use Controls Model.
	$/annually	17,000	
Five Year Reviews			
Five Year Reviews	ea	200	Includes CERCLA five year reviews. Estimates are based on the RACER Five Year Review Model for a moderately complex site.
	$/ea	18,000	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 6 - Limited Action and Land-Use Controls (OU-2)
Cost Estimate

CAPITAL COST **$1,400,265**

Activity (unit)	Quantity	Unit Cost	Total
Administrative Land Use Controls			
Administrative Land Use Controls (lot)	1	$702,000.00	$702,000
Monitoring Plan			
Monitoring Plan (ea)	1	$30,000.00	$30,000
Land Use Controls			
Establish Control Area (day)	2	$1,750.00	$3,500
Develop Drawings (hr)	40	$80.00	$3,200
Signs (sf)	24	$29.50	$708
Fence (lf)	1,000	$63.00	$63,000
Gate (ea)	2	$1,750.00	$3,500
Subtotal			$805,908
Design		10%	$80,591
Home Office Overhead and Project Management		5%	$40,295
Field Overhead and Remediation Management		10%	$80,591
Subtotal			$1,007,385
Profit		8%	$80,591
Contingency		31%	$312,289
Total			$1,400,265

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 6 - Limited Action and Land-Use Controls (OU-2)
Cost Estimate

OPERATION AND MAINTENANCE **$34,647,140**

Activity (unit)	Quantity	Unit Cost	Total Cost	Present Value (4.125%)
Administrative Land Use Controls				
Administrative Land Use Controls	1,000	$17,000	$17,000,000	$412,121
Five Year Reviews				
Five Year Reviews	200	$18,000	$3,600,000	$80,364
Subtotal O&M			$20,600,000	$492,485
Design		6%	$1,236,000	$29,549
Home Office Overhead and Project Management		5%	$1,030,000	$24,624
Field Overhead and Remediation Management		10%	$2,060,000	$49,248
Subtotal			$24,926,000	$595,907
Profit		8%	$1,994,080	$47,673
Contingency		31%	$7,727,060	$184,731
Total			$34,647,140	$828,310

TOTAL ALTERNATIVE CAPITAL AND O&M COST (Non Discounted Cost) **$36,047,405**

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Capital Cost			
Mobilization/Demobilization			
Equipment Mob/Demob.			
Medium Equipment	ea	10	Mob/demob dozer, loader, backhoe or excavator, 70-150 H.P, up to 50 miles. RSM 01543 650 0020. Assume 10 pieces.
	$/ea	251.00	
Large Equipment	ea	10.0	Mob/demob, dozer, loader, backhoe or excavator, above 150 H.P., up to 50 miles. RSM 01543 650 0100. Assume 10 pieces.
	$/ea	470.00	
Small Equipment	ea	20.0	Mob/demob, delivery charge for small equipment, placed in rear of, or towed by pickup. RSM 01543 650 1100. Assume 30 pieces.
	$/ea	70.50	
Submittals/Implementation Plans			
Submittals	ea	15.0	Includes submittals such as Air Monitoring Plan, QCP, Schedule, Materials Handling/Transportation/Disposal Plan, SAP, SSH Plan, Site Security Plan, Site Work Plan, SWPPP, etc. Assume 15 plans and/or appendices to work plan. Based on Engineering Judgment.
	$/ea	15,000	
Permitting			
Permitting	ea	0.0	Local and state permitting not required, but assume work in/adjacent to river will require permitting. Based on Engineering Judgment.
	$/ea	20,000	
Temporary Structures and Facilities			
Haul Roads	sf	2,000	Base course drainage layers, aggregate base course, spread & compacted, 3/4" crushed stone, to 6" deep. RSM 32112 323 0110.
	$/sf	1.29	
Temporary Fencing	lf	375.0	Temporary Fencing, chain link, rented up to 12 months, 6' high, 11 ga, to 1000'. RSM 01562 650 0200.
	$/lf	7.55	
Office Trailers	mo	8.0	Assume 2 trailers. Office Trailer, furnished, rent per month, 50' x 12', excl. hookups with air conditioning. RSM 01521 320 0550 and 0700.
	$/mo	440.00	
Storage Trailers	ea	16	Assume 4 storage boxes. Storage Boxes, rent per month, 40' x 8'. RSM 01521 320 1350.
	$/ea	102.00	
Signs	sf	20.0	Project Signs, sign, high intensity reflectorized, buy, excl. posts. RSM 01581 350 0020.
	$/sf	29.50	
Decon Facility	ea	1.0	Based on RACER Decontamination Pad Model for Equipment Decontamination.
	$/ea	28,271	
Electric Generator	mo	4.0	
	$/mo	1,871	Assume 1 electric generator gas engine 10 kW. RSM 01543 340 2300.
Portable Toilets	mo	8	Assume 2 each. Rent portable toilet chemical, recycle, flush type. RSM 01543 340 6420.
	$/mo	253.44	
Waste Volume Reduction Process Staging Area			
Pre-engineered Building	sf	2,500	Assume 50 ft x 50 ft. Pre-Eng Steel Bldg, single post 2-span frame, 30 psf roof & 20 psf wind load, 24 ft high incl. 26 ga. colored ribbed roofing & siding, excl. footings, slab, anchor bolts. RSM 13341 950 3300.
	$/sf	17.55	
Laydown Area	sf	2,500	Base course for roadways, crushed stone base, compacted, crushed 1-1/2" stone base, to 8" deep. RSM 32112 323 0308.
	$/lf	1.29	
Liner	sf	2,500	Pond and Reservoir Liners, membrane lining systems HDPE, 100,000 S.F. or more, 30 mil thick. RSM 33471 353 1100
	$/sf	1.16	
Temporary Utilities and Equipment			
Extend Electric service	ea	1.0	Temporary electrical power equipment (pro-rated per job), overhead feed, 3 uses, 600 amp and temporary electrical power equipment (pro-rated per job), transformers, 3 uses, 75 KVA. RSM 01511 350 0060 and 0230
	$/ea	7,450.00	
Temporary Water Connection	ea	1.0	Assume temporary hydrant or water line connection. Based on Engineering Judgment.
	$/ea	2,500.00	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Monthly Utility and Office Expenses	mo $/mo	8.0 346.50	Field Office Expense including office equipment rental, office supplies, telephone bill, field office lights & HVAC for 2 office trailers. RSM 01521 340 0120 and 0140 and 0160
Trucks	mo $/mo	8.0 3,062.00	Assume 2 trucks. Rent truck pickup 3/4 ton 4 wheel drive. RSM 01543 340 7200.
Security			
Security Guard	hr $/hr	992.0 27.50	Assume 16 hrs/day for 2 months. Watchman, security service, uniformed person, monthly basis, min. RSM 01563 250 0020.
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor	hr $/hr	800 55.55	This element covers IH/HP technicians for the following areas: 3 at the excavation site to survey personnel, survey additional areas requiring excavation, and obtaining post RA samples for 0.5 months; 3 at the waste volume reduction process and loading site to survey personnel and transport vehicles for 0.5 months; and 2 at the onsite lab to analyze samples/swipes and calibrate equipment for 0.5 months. The IH/HP technicians and equipment would be required for a total of 4 months duration at 200 hrs/month. Total hours are 4 months x 200 hrs/mo.
Equipment	mo $/mo	1 5,500.00	Equipment pricing base on Vendor Quote. The radiological monitoring equipment includes the following: 1. Model 2929 dual channel scaler (2 @ $300/mo =$600/mo) 2. Alpha Survey Instrument, Model 2360 with 43-89 (5 @ 325/mo = $1,625/mo) 3. Micro R Meter, Model 19 (2 @ $185/mo = $380/mo) 4. Ludlum - M3 - 44-2 - 44-9 Meter 3, NaI Gamma Scintillator, G-M Pancake Detector (3 @ $125/mo = $375/mo) 5. Personal air sampling pumps (3 @ $100/mo = $220/mo) 6. Personal air sampling pump charger (2 @ $70/mo = $140/mo) 7. High volume air samplers (8 @ $180/mo = $1440/mo) 8. Sources (3 @ $50/mo = $150) 9. Dosimetry (20 @ $10/mo = $200) Total = $5,130/month. Use $5,500/mo direct cost to account for other miscellaneous equipment, shipping, or supplies. Assume technicians are local and no per diem or travel is required.
Bioassays	ea $/ea	60 147.32	Bioassays (2/yr x 1 yr x 30 people)
PPE Allowance	set $/set	1,320 3.00	PPE Estimate. Assume average of 30 sets/day for 2 months. Includes Disposable Boot Covers, Coverall, Gloves, and Ear Plugs. ECHO 33010421, 23, 25, and 29.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Rad Soils Sampling/Handling/Packaging			Confirmatory Sampling
Rad Offsite Lab Soils Analysis			Since a MARSSIM analysis has not been performed, assume confirmation samples are obtained every 1,000 sf. The total area is 55,000 sf. Total samples collected are 55. Add 100% additional samples for sidewall samples. Add 30% additional samples for hotspots and QA/QC samples. Total samples = 143 ea Samples will be analyzed for radionuclide's. Assume 10% of rad samples will also have TCLP Test = 15 ea. Waste Volume Reduction Process Sampling Assume waste volume reduction process piles are sampled at a rate of 20 samples per 1,000 cy. The total volume with swell and constructability is approximately 6,500 cy. Total samples collected = 130. Samples will be analyzed for radionuclide's. Assume 5% of rad samples will also have TCLP Test = 13 ea.
Thorium Isotopic	ea $/ea	286 140.38	Testing, rad analytical vegetation/sediment/soil, alpha spectroscopy, thorium isotopic. ECHOS 33022334.
Lead-210	ea $/ea	286 174.13	Testing, rad analytical vegetation/sediment/soil, gamma spectroscopy, lead-210. ECHOS 33022344
Radium 226 and 228	ea $/ea	286 142.50	Testing, rad analytical vegetation/sediment/soil, gamma spectroscopy, radium-226, 228. ECHOS 33022346.
Uranium	ea $/ea	286 142.45	Testing, rad analytical vegetation/sediment/soil, alpha spectroscopy, uranium isotopic. ECHOS 33022335
TCLP	ea $/ea	28 559.74	Targeted TCLP (Metals, Volatiles, Semi-Volatiles only), Soil Analysis . ECHOS 33021705.
Site Work			
Clearing and Grubbing	acre $/acre	1 6,100	Clearing & grubbing, medium trees, to 12" diameter, cut and chip. RSM 31111 010 0200. Assume wood chip used as mulch onsite.
Surveying			
Establish Site Control/Layout	day $/day	1 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Reestablish Site Control/Layout	day $/day	1 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Volume Surveys	day $/day	1 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Post Restoration Survey	day $/day	1 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Surface Water Collect & Control Including Dewatering			Assume 100% of water is filtered and used for dust control of soils or discharged according to local regulations.
Excavation Dewatering	day $/day	2 850	Dewatering, 8 hr., attended 2 hours/day, 2" diaphragm pump, includes 20 L.F. of suction hose and 100 L.F. of discharge hose. RSM 312319200800
Sump Holes	cf $/cf	100 2.37	Dewatering, sump hole construction, includes excavation and gravel pit. RSM 31231 920 1600. Assume 20 each @ 30 cf.
Storage Tank Delivery	ea $/ea	1 500	Mobilize and demobilize 20,000 gal storage tanks. Based on Engineering Judgment.
Storage Tank Rental	mo $/mo	1 1,200	Storage tank rental, 20,000 gal. Based on Engineering Judgment. Assume 1 tank for 1 month.
Water Filtration	ea	0	Included in Alternative 5. Assume concurrent operation with Alternative 5.
Filters	ea $/ea	24 39	Water filter, cartridge style, dirt and rust type, replacement cartridge. RSM 22321 910 1200

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Solids Collect And Containment			
Erosion and Sediment Control			
Silt Fence and Straw Bales	lf	240	Erosion control, silt fence, polypropylene, 3' high and hay bales, staked. RSM 31251 310 1100 and 1250.
	$/lf	8.31	
Check Dams	cy	10	Rip-rap and rock lining, random, broken stone, machine placed for slope protection. RSM 31371 310 0100.
	$/cy	58.00	
Truck Entrance	cy	20	Base course roadways, crushed stone, compacted, 1-1/2", 8" deep. RSM 32112 323 1522.
	$/cy	47.50	
Dust Control			
Water Trucks	mo	1.0	Rent water tank trailer w/pumped discharge, 5000 gallon capacity. RSM 01543 340 6900.
	$/mo	2,584.00	
Concrete Demolition and Size Reduction			
Bituminous Concrete Demolition	cy	0	Demolish, remove pavement & curb, concrete, rod reinforced, 7" to 24" thick, remove with backhoe, excludes hauling. RSM 02411 317 5500
	$/cy	153.00	
Asphaltic Concrete Demolition	sy	1611	Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees. RSM 02411 317 5050.
	$/sy	8.80	
Concrete Crushing Plant	hr	8	
	$/hr	516.80	Crusher (200 Tons/Hour). ECHO 17039902.
Soil Excavation and Waste Volume Reduction Process			
Excavate Soils	day	8	Includes 2.5 cy excavator, 3-22 cy off highway trucks, 1 O.E., 3 T.D., 2 L.S. as spotters, dust control, and misc. Reduced productivity by 33% for loading trucks, irregular/precise excavations, and security/S&H requirements. Average 660 cy/day. RSMeans Crew B12-S.
	$/day	7,590.0	
Waste Volume Reduction Process			
Waste Volume Reduction Operation	tons	7,796	The unit rate and production rates are based on the Painesville Site and modified based on vendor discussions. Includes waste volume reduction process and two operators.
	$/ton	35.00	
Waste Volume Reduction Support Crew	day	8	Includes 3 cy loader, 1 O.E., and 1 L.S. as spotters and support to waste volume reduction process, and 1 Sample Tech. RSMeans Crew B12-S. Assumes 1,000 tons/day.
	$/day	3,476.00	
Waste Volume Reduction Support Equipment	mo	0.5	Includes feed and discharge conveyors, screening plan, and trommel. Based on Painesville Site cost with quotes from screen machine.
	$/mo	30,000.00	
Diesel Generator	mo	0.5	
	$/mo	15,195.00	Rent electric generator gas engine 250 kW. RSM 01543 340 2800.
Load/Package Contaminated Waste	day	10	Includes 3 cy loader, 1 O.E., 1 TD, and 2 L.S. as spotters and handling intermodals. Reduced productivity by 50% for loading intermodals and security/S&H requirements. RSMeans Crew B12-S.
	$/day	4,152.00	
Bags for Mixed Waste (10 cy)	ea	35	Assume mixed waste is placed in 10 cy bags and left onsite. Assume bags are fill to 85% capacity.
	$/ea	350.00	
Offsite Transport and Disposal			
Transport and Disposal (Soils)	cy	2,945	Includes transport and disposal to a facility in Utah. Includes intermodal and ABC rail car rental, ABC railcar transport cost with all fuel surcharges, and disposal. Assumes 17 cy/intermodal and 7 intermodals per railcar.
	$/cy	593.01	
Transport & Disposal (Standard Debris)	cy	371	Includes transport and disposal to a facility in Utah. Includes intermodal and ABC rail car rental, ABC railcar transport cost with all fuel surcharges, and disposal. Assumes 17 cy/intermodal and 7 intermodals per railcar.
	$/cy	945.42	
Transport and Disposal (Mixed Waste)	cy	294	Assume 10% mixed waste and add $600/cy mixed waste disposal premium for treatment and disposal.
	$/cy	600.00	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Restoration			
Backfill Onsite Soils	cy $/cy	3,248 10.80	Includes loading soils from stockpile and transporting to backfill. Includes spreading and compacting in 8-in lifts. Includes testing.
Off-Site Backfill for Balance of Site	cy $/cy	3,316 47.50	Base course drainage layers, aggregate base course for roadways and large paved areas, alternate method to figure base course, crushed stone, compacted, 1-1/2", 8" deep. RSM 32112 323 0308.
Seeding, Vegetative Cover	MSF $/MSF	45 88.00	Seeding with mulch and fertilizer. Assume 1 acre is restored in disturbed areas including equipment damage. RSMeans 329219142200.
Fence and Other Miscellaneous Repairs	lot $/lot	1.00 10,000.00	Assume fencing, utility poles, lights, and other structures are removed during remediation and will be replaced.
Plans and Reports			
Corrective Action Completion Report	hrs	600	Includes Construction QC data and preparing report.
Technical Labor	$/hr	80	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)
Cost Estimate

CAPITAL COST			$6,617,430
Activity (unit)	Quantity	Unit Cost	Total
Mobilization/Demobilization			
Equipment Mob/Demob.			
Medium Equipment (ea)	10	$251.00	$2,510
Large Equipment (ea)	10	$470.00	$4,700
Small Equipment (ea)	20	$70.50	$1,410
Submittals/Implementation Plans			
Submittals (ea)	15	$15,000.00	$225,000
Permitting			
Permitting (ea)	0	$20,000.00	$0
Temporary Structures and Facilities			
Haul Roads (sf)	2,000	$1.29	$2,580
Temporary Fencing (lf)	375	$7.55	$2,831
Office Trailers (mo)	8	$440.00	$3,520
Storage Trailers (mo)	16	$102.00	$1,632
Signs (sf)	20	$29.50	$590
Decon Facility (ea)	1	$28,271.00	$28,271
Electric Generator (mo)	4	$1,871.00	$7,484
Portable Toilets (mo)	8	$253.44	$2,028
Waste Volume Reduction Staging Area			
Pre-engineered Building (sf)	2,500	$17.55	$43,875
Laydown Area (sf)	2,500	$1.29	$3,225
Liner (sf)	2,500	$1.16	$2,900
Temporary Utilities and Equipment			
Extend Electric service (ea)	1	$7,450.00	$7,450
Temporary Water Connection (ea)	1	$2,500.00	$2,500
Monthly Utility and Office Expenses (mo)	8	$346.50	$2,772
Trucks (mo)	8	$3,062.00	$24,496
Security			
Security Guard (hr)	992	$27.50	$27,280
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor (hr)	800	$55.55	$44,440
Equipment (mo)	1	$5,500.00	$5,500
Bioassays	60	$147.32	$8,839
PPE Allowance (set)	1,320	$3.00	$3,960
Rad Offsite Lab Soils Analysis			
Thorium Isotopic (ea)	286	$140.38	$40,149
Lead-210 (ea)	286	$174.13	$49,801
Radium 226 and 228 (ea)	286	$142.50	$40,755
Uranium (ea)	286	$142.45	$40,741
TCLP (ea)	28	$559.74	$15,673

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)
Cost Estimate

Activity (unit)	Quantity	Unit Cost	Total
Site Work			
Clearing and Grubbing (acre)	1	$6,100.00	$3,050
Surveying			
Establish Site Control/Layout (day)	1	$1,750.00	$1,750
Reestablish Site Control/Layout (day)	1	$1,750.00	$1,750
Volume Surveys (day)	1	$1,750.00	$1,750
Post Restoration Survey (day)	1	$1,750.00	$1,750
Surface Water Collect & Control Including Dewatering			
Excavation Dewatering (day)	2	$850.00	$1,700
Sump Holes (cf)	100	$2.37	$237
Storage Tank Delivery (ea)	1	$500.00	$500
Storage Tank Rental (mo)	1	$1,200.00	$1,200
Water Filters (ea)	24	$39.00	$936
Solids Collect And Containment			
Erosion and Sediment Control			
Silt Fence and Straw Bales (lf)	240	$8.31	$1,994
Check Dams (cy)	10	$58.00	$580
Truck Entrance (cy)	20	$47.50	$950
Dust Control			
Water Trucks (mo)	1	$2,584.00	$2,584
Concrete Demolition and Size Reduction			
Bituminous Concrete Demolition (cy)	0	$153.00	$0
Asphaltic Concrete Demolition (sy)	1,611	$8.80	$14,178
Concrete Crushing Plant (hr)	8	$516.80	$4,134
Soil Excavation and Waste Volume Reduction Process			
Excavate Soils (day)	8	$7,590.00	$60,720
Waste Volume Reduction Operation (ton)	7,796	$35.00	$272,853
Waste Volume Reduction Support Crew (day)	8	$3,476.00	$27,808
Waste Volume Reduction Support Equipment (mo)	0.5	$30,000.00	$15,000
Diesel Generator (day)	0.5	$15,195.00	$7,598
Load/Package Contaminated Waste (day)	9.8	$4,152.00	$40,491
Bags for Mixed Waste (10 cy) (ea)	35	$350.00	$12,250
Offsite Transport and Disposal			
Transport and Disposal (Soils) (cy)	2,945	$593.01	$1,746,113
Transport and Disposal (Standard Debris) (cy)	371	$945.42	$350,987
Transport and Disposal (Mixed Waste) (cy)	294	$600.00	$176,670
Restoration			
Backfill Onsite Soils (cy)	3,248	$10.80	$35,093
Off-Site Backfill for Balance of Site (cy)	3,316	$47.50	$157,498
Seeding, Vegetative Cover (msf)	45	$88.00	$3,960
Fence and Other Miscellaneous Repairs (lot)	1	$10,000.00	$10,000

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 7 - Complete Removal with Off-Site Disposal (OU-2)
Cost Estimate

Activity (unit)	Quantity	Unit Cost	Total
Closure Reports			
Corrective Action Completion Report (hr)	600	$80.00	$48,000
Subtotal			$3,650,996
Design		10%	$365,100
Home Office Overhead and Project Management		5%	$182,550
Field Overhead and Remediation Management		10%	$365,100
Subtotal			$4,563,745
Profit		8%	$365,100
Contingency		37%	$1,688,586
Total			$6,617,430

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Capital Cost			
Mobilization/Demobilization			
Equipment Mob/Demob.			
Medium Equipment	ea	10	Mob/demob dozer, loader, backhoe or excavator, 70-150 H.P, up to 50 miles. RSM 01543 650 0020. Assume 10 pieces.
	$/ea	251.00	
Large Equipment	ea	10.0	Mob/demob, dozer, loader, backhoe or excavator, above 150 H.P., up to 50 miles. RSM 01543 650 0100. Assume 10 pieces.
	$/ea	470.00	
Small Equipment	ea	20.0	Mob/demob, delivery charge for small equipment, placed in rear of, or towed by pickup. RSM 01543 650 1100. Assume 30 pieces.
	$/ea	70.50	
Submittals/Implementation Plans			
Submittals	ea	15.0	Includes submittals such as Air Monitoring Plan, QCP, Schedule, Materials Handling/Transportation/Disposal Plan, SAP, SSH Plan, Site Security Plan, Site Work Plan, SWPPP, etc. Assume 15 plans and/or appendices to work plan. Based on Engineering Judgment.
	$/ea	15,000	
Permitting			
Permitting	ea	0.0	Local and state permitting not required, but assume work in/adjacent to river will require permitting. Based on Engineering Judgment.
	$/ea	20,000	
Temporary Structures and Facilities			
Haul Roads	sf	2,000	Base course drainage layers, aggregate base course, spread & compacted, 3/4" crushed stone, to 6" deep. RSM 32112 323 0110.
	$/sf	1.29	
Temporary Fencing	lf	375.0	Temporary Fencing, chain link, rented up to 12 months, 6' high, 11 ga, to 1000'. RSM 01562 650 0200.
	$/lf	7.55	
Office Trailers	mo	8.0	Assume 2 trailers. Office Trailer, furnished, rent per month, 50' x 12', excl. hookups with air conditioning. RSM 01521 320 0550 and 0700.
	$/mo	440.00	
Storage Trailers	ea	16	Assume 4 storage boxes. Storage Boxes, rent per month, 40' x 8'. RSM 01521 320 1350.
	$/ea	102.00	
Signs	sf	20.0	Project Signs, sign, high intensity reflectorized, buy, excl. posts. RSM 01581 350 0020.
	$/sf	29.50	
Decon Facility	ea	1.0	Based on RACER Decontamination Pad Model for Equipment Decontamination.
	$/ea	28,271	
Electric Generator	mo	4.0	
	$/mo	1,871	Assume 1 electric generator gas engine 10 kW. RSM 01543 340 2300.
Portable Toilets	mo	8	Assume 2 each. Rent portable toilet chemical, recycle, flush type. RSM 01543 340 6420.
	$/mo	253.44	
Waste Volume Reduction Process Staging Area			
Pre-engineered Building	sf	2,500	Assume 50 ft x 50 ft. Pre-Eng Steel Bldg, single post 2-span frame, 30 psf roof & 20 psf wind load, 24 ft high incl. 26 ga. colored ribbed roofing & siding, excl. footings, slab, anchor bolts. RSM 13341 950 3300.
	$/sf	17.55	
Laydown Area	sf	2,500	Base course for roadways, crushed stone base, compacted, crushed 1-1/2" stone base, to 8" deep. RSM 32112 323 0308.
	$/lf	1.29	
Liner	sf	2,500	Pond and Reservoir Liners, membrane lining systems HDPE, 100,000 S.F. or more, 30 mil thick. RSM 33471 353 1100
	$/sf	1.16	
Temporary Utilities and Equipment			
Extend Electric service	ea	1.0	Temporary electrical power equipment (pro-rated per job), overhead feed, 3 uses, 600 amp and temporary electrical power equipment (pro-rated per job), transformers, 3 uses, 75 KVA. RSM 01511 350 0060 and 0230
	$/ea	7,450.00	
Temporary Water Connection	ea	1.0	Assume temporary hydrant or water line connection. Based on Engineering Judgment.
	$/ea	2,500.00	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Monthly Utility and Office Expenses	mo $/mo	8.0 346.50	Field Office Expense including office equipment rental, office supplies, telephone bill, field office lights & HVAC for 2 office trailers. RSM 01521 340 0120 and 0140 and 0160
Trucks	mo $/mo	8.0 3,062.00	Assume 2 trucks. Rent truck pickup 3/4 ton 4 wheel drive. RSM 01543 340 7200.
Security			
Security Guard	hr $/hr	992.0 27.50	Assume 16 hrs/day for 2 months. Watchman, security service, uniformed person, monthly basis, min. RSM 01563 250 0020.
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor	hr $/hr	800 55.55	This element covers IH/HP technicians for the following areas: 3 at the excavation site to survey personnel, survey additional areas requiring excavation, and obtaining post RA samples for 0.5 months; 3 at the waste volume reduction process and loading site to survey personnel and transport vehicles for 0.5 months; and 2 at the onsite lab to analyze samples/swipes and calibrate equipment for 0.5 months. The IH/HP technicians and equipment would be required for a total of 4 months duration at 200 hrs/month. Total hours are 4 months x 200 hrs/mo.
Equipment	mo $/mo	1 5,500.00	Equipment pricing base on Vendor Quote. The radiological monitoring equipment includes the following: 1. Model 2929 dual channel scaler (2 @ $300/mo =$600/mo) 2. Alpha Survey Instrument, Model 2360 with 43-89 (5 @ 325/mo = $1,625/mo) 3. Micro R Meter, Model 19 (2 @ $185/mo = $380/mo) 4. Ludlum - M3 - 44-2 - 44-9 Meter 3, NaI Gamma Scintillator, G-M Pancake Detector (3 @ $125/mo = $375/mo) 5. Personal air sampling pumps (3 @ $100/mo = $220/mo) 6. Personal air sampling pump charger (2 @ $70/mo = $140/mo) 7. High volume air samplers (8 @ $180/mo = $1440/mo) 8. Sources (3 @ $50/mo = $150) 9. Dosimetry (20 @ $10/mo = $200) Total = $5,130/month. Use $5,500/mo direct cost to account for other miscellaneous equipment, shipping, or supplies. Assume technicians are local and no per diem or travel is required.
Bioassays	ea $/ea	60 147.32	Bioassays (2/yr x 1 yr x 30 people)
PPE Allowance	set $/set	1,320 3.00	PPE Estimate. Assume average of 30 sets/day for 2 months. Includes Disposable Boot Covers, Coverall, Gloves, and Ear Plugs. ECHO 33010421, 23, 25, and 29.

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Rad Soils Sampling/Handling/Packaging			Confirmatory Sampling
Rad Offsite Lab Soils Analysis			Since a MARSSIM analysis has not been performed, assume confirmation samples are obtained every 1,000 sf. The total area is 55,000 sf. Total samples collected are 55. Add 100% additional samples for sidewall samples. Add 30% additional samples for hotspots and QA/QC samples. Total samples = 143 ea Samples will be analyzed for radionuclide's. Assume 10% of rad samples will also have TCLP Test = 15 ea. Waste Volume Reduction Process Sampling Assume waste volume reduction process piles are sampled at a rate of 20 samples per 1,000 cy. The total volume with swell and constructability is approximately 6,500 cy. Total samples collected = 130. Samples will be analyzed for radionuclide's. Assume 5% of rad samples will also have TCLP Test = 13 ea.
Thorium Isotopic	ea $/ea	286 140.38	Testing, rad analytical vegetation/sediment/soil, alpha spectroscopy, thorium isotopic. ECHOS 33022334.
Lead-210	ea $/ea	286 174.13	Testing, rad analytical vegetation/sediment/soil, gamma spectroscopy, lead-210. ECHOS 33022344
Radium 226 and 228	ea $/ea	286 142.50	Testing, rad analytical vegetation/sediment/soil, gamma spectroscopy, radium-226, 228. ECHOS 33022346.
Uranium	ea $/ea	286 142.45	Testing, rad analytical vegetation/sediment/soil, alpha spectroscopy, uranium isotopic. ECHOS 33022335
TCLP	ea $/ea	28 559.74	Targeted TCLP (Metals, Volatiles, Semi-Volatiles only), Soil Analysis . ECHOS 33021705.
Site Work			
Clearing and Grubbing	acre $/acre	1 6,100	Clearing & grubbing, medium trees, to 12" diameter, cut and chip. RSM 31111 010 0200. Assume wood chip used as mulch onsite.
Surveying			
Establish Site Control/Layout	day $/day	1 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Reestablish Site Control/Layout	day $/day	1 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Volume Surveys	day $/day	1 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Post Restoration Survey	day $/day	1 1,750	Boundary & survey markers, crew for building layout, 3 person crew. RSM 01712 313 1200.
Surface Water Collect & Control Including Dewatering			Assume 100% of water is filtered and used for dust control of soils or discharged according to local regulations.
Excavation Dewatering	day $/day	2 850	Dewatering, pumping, 8 hr., attended 2 hours per day, 2" diaphragm pump, includes 20 L.F. of suction hose and 100 L.F. of discharge hose. RSM 31231 920 0800
Sump Holes	cf $/cf	100 2.37	Dewatering, sump hole construction, includes excavation and gravel pit. RSM 31231 920 1600. Assume 20 each @ 30 cf.
Storage Tank Delivery	ea $/ea	1 500	Mobilize and demobilize 20,000 gal storage tanks. Based on Engineering Judgment.
Storage Tank Rental	mo $/mo	1 1,200	Storage tank rental, 20,000 gal. Based on Engineering Judgment. Assume 1 tank for 1 month.
Water Filtration	ea	0	Included in Alternative 4. Assume concurrent operation with Alternative 4.
Filters	ea $/ea	24 39	Water filter, cartridge style, dirt and rust type, replacement cartridge. RSM 22321 910 1200

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Solids Collect And Containment			
Erosion and Sediment Control			
Silt Fence and Straw Bales	lf	240	Erosion control, silt fence, polypropylene, 3' high and hay bales, staked. RSM 31251 310 1100 and 1250.
	$/lf	8.31	
Check Dams	cy	10	Rip-rap and rock lining, random, broken stone, machine placed for slope protection. RSM 31371 310 0100.
	$/cy	58.00	
Truck Entrance	cy	20	Base course roadways, crushed stone, compacted, 1-1/2", 8" deep. RSM 32112 323 1522.
	$/cy	47.50	
Dust Control			
Water Trucks	mo	1.0	Rent water tank trailer w/pumped discharge, 5000 gallon capacity. RSM 01543 340 6900.
	$/mo	2,584.00	
Concrete Demolition and Size Reduction			
Bituminous Concrete Demolition	cy	0	Demolish, remove pavement & curb, concrete, rod reinforced, 7" to 24" thick, remove with backhoe, excludes hauling. RSM 02411 317 5500
	$/cy	153.00	
Asphaltic Concrete Demolition	sy	1611	Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees. RSM 02411 317 5050.
	$/sy	8.80	
Concrete Crushing Plant	hr	8	
	$/hr	516.80	Crusher (200 Tons/Hour). ECHO 17039902.
Soil Excavation and Waste Volume Reduction Process			
Excavate Soils	day	8	Includes 2.5 cy excavator, 3-22 cy off highway trucks, 1 O.E., 3 T.D., 2 L.S. as spotters, dust control, and misc. Reduced productivity by 33% for loading trucks, irregular/precise excavations, and security/S&H requirements. Average 660 cy/day. RSMeans Crew B12-S.
	$/day	7,590.0	
Waste Volume Reduction Process			
Waste Volume Reduction Operation	tons	7,796	The unit rate and production rates are based on the Painesville Site and modified based on vendor discussions. Includes waste volume reduction process and two operators.
	$/ton	35.00	
Waste Volume Reduction Support Crew	day	8	Includes 3 cy loader, 1 O.E., and 1 L.S. as spotters and support to waste volume reduction process, and 1 Sample Tech. RSMeans Crew B12-S. Assumes 1,000 tons/day.
	$/day	3,476.00	
	mo	0.5	Includes feed and discharge conveyors, screening plan, and trommel. Based on Painesville Site cost with quotes from screen machine.
Waste Volume Reduction Support Equipment	$/mo	30,000.00	
Diesel Generator	mo	0.5	
	$/mo	15,195.00	Rent electric generator gas engine 250 kW. RSM 01543 340 2800.
Load/Package Contaminated Waste	day	12	Includes 3 cy loader, 1 O.E., 1 TD, and 2 L.S. as spotters and handling intermodals. Reduced productivity by 50% for loading intermodals and security/S&H requirements. RSMeans Crew B12-S.
	$/day	4,152.00	
Bags for Mixed Waste (10 cy)	ea	35	Assume mixed waste is placed in 10 cy bags and left onsite. Assume bags are fill to 85% capacity.
	$/ea	350.00	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Ex Situ Treatment			Includes the treatment of above criteria soils processed through the waste volume reduction process. Based on RACER parametric model for Solidification. Assumes 100 lb/cf and mixed in 5 cy batches.
Treatment Volume	cy	3,248	
Loader	hr	16	910, 1.25 CY, Wheel Loader. ECHOS 17030220
	$/hr	144.06	
Truck	hr	16	12 CY, Dump Truck. ECHOS 17030285
	$/hr	153.22	
Holding Tank	mo	1	Wastewater holding tanks, above ground, ss, DOT approved, monthly rental, 550 gal. ECHOS 19040401
	$/mo	496.47	
Holding Tank	mo	1	Wastewater holding tanks, above ground, steel, open, stationary, monthly rental, 21,000 gal. ECHOS 19040408
	$/mo	1,701.04	
Portland Cement	ton	42	Portland Cement Type I (Bulk). ECHOS 33150405
	$/ton	144.57	
Treatment Additive	ton	3	Urrichem by Soliditech. ECHOS 33150408
	$/ton	2,982.02	
Plywood Boxes	ea	6	1 CY Plywood Boxes. ECHOS 33150418
	$/ea	100.17	
Operations Labor	hr	32	Operational Labor for Process Equipment. ECHOS 33150420
	$/hr	62.99	
Chemical Transport	ea	4	Bulk Chemical Transport (40,000 Lb Truckload). ECHOS 33150421
	$/ea	2,829.31	
Mixer	mo	1	15 CY Waste Mixer. ECHOS 33150434
	$/mo	16,213.00	
Solidification/Stabilization Ancillary Equipment	ea	1	Solidification/Stabilization Ancillary Equipment. ECHOS 33150435
	$/ea	16,175.50	
Maintenance of Solidification Unit	yr	0.01	Maintenance of Solidification/Stabilization Unit. ECHOS 33150437
	$/yr	9,825.81	
Drums	ea	2	DOT steel drums, 55 gal., open, 17C. ECHOS 33199921
	$/ea	141.93	
Fuel	gal	47	Diesel Fuel. ECHOS 33420201
	$/gal	4.31	
Process Water	kgal	5	Process Water, Supplied by Tanker Truck. ECHOS 33420301
	$/kgal	17.01	
Offsite Transport and Disposal			
Transport and Disposal (Standard Debris)	cy	3,927	Includes transport and disposal to a facility in Utah. Includes intermodal and ABC rail car rental, ABC railcar transport cost with all fuel surcharges, and disposal. Assumes 17 cy/intermodal and 7 intermodals per railcar.
	$/cy	945.42	
Transport and Disposal (Mixed Waste)	cy	0	Assume 25% mixed waste but since it has undergone treatment, it can be disposed as nonhazardous.
	$/cy	600.00	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Key Parameters and Assumptions

Key Parameters and Assumptions:

Item	Unit	Value	Notes
Restoration			
Backfill Onsite Soils	cy $/cy	3,188 10.80	Includes loading soils from stockpile and transporting to backfill. Includes spreading and compacting in 8-in lifts. Includes testing.
Off-Site Backfill for Balance of Site	cy $/cy	3,377 47.50	Base course drainage layers, aggregate base course for roadways and large paved areas, alternate method to figure base course, crushed stone, compacted, 1-1/2", 8" deep. RSM 32112 323 0308.
Seeding, Vegetative Cover	MSF $/MSF	45 88.00	Seeding with mulch and fertilizer. Assume 1 acre is restored in disturbed areas including equipment damage. RSMeans 329219142200.
Fence and Other Miscellaneous Repairs	lot $/lot	1.00 10,000.00	Assume fencing, utility poles, lights, and other structures are removed during remediation and will be replaced.
Plans and Reports			
Corrective Action Completion Report	hrs	600	Includes Construction QC data and preparing report.
Technical Labor	$/hr	80	

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Cost Estimate

CAPITAL COST			$9,562,520
Activity (unit)	Quantity	Unit Cost	Total
Mobilization/Demobilization			
Equipment Mob/Demob.			
Medium Equipment (ea)	10	$251.00	$2,510
Large Equipment (ea)	10	$470.00	$4,700
Small Equipment (ea)	20	$70.50	$1,410
Submittals/Implementation Plans			
Submittals (ea)	15	$15,000.00	$225,000
Permitting			
Permitting (ea)	0	$20,000.00	$0
Temporary Structures and Facilities			
Haul Roads (sf)	2,000	$1.29	$2,580
Temporary Fencing (lf)	375	$7.55	$2,831
Office Trailers (mo)	8	$440.00	$3,520
Storage Trailers (mo)	16	$102.00	$1,632
Signs (sf)	20	$29.50	$590
Decon Facility (ea)	1	$28,271.00	$28,271
Electric Generator (mo)	4	$1,871.00	$7,484
Portable Toilets (mo)	8	$253.44	$2,028
Waste Volume Reduction Process Staging Area			
Pre-engineered Building (sf)	2,500	$17.55	$43,875
Laydown Area (sf)	2,500	$1.29	$3,225
Liner (sf)	2,500	$1.16	$2,900
Temporary Utilities and Equipment			
Extend Electric service (ea)	1	$7,450.00	$7,450
Temporary Water Connection (ea)	1	$2,500.00	$2,500
Monthly Utility and Office Expenses (mo)	8	$346.50	$2,772
Trucks (mo)	8	$3,062.00	$24,496
Security			
Security Guard (hr)	992	$27.50	$27,280
Sampling Radioactive Contaminated Media			
Rad Monitoring			
Labor (hr)	800	$55.55	$44,440
Equipment (mo)	1	$5,500.00	$5,500
Bioassays	60	$147.32	$8,839
PPE Allowance (set)	1,320	$3.00	$3,960
Rad Offsite Lab Soils Analysis			
Thorium Isotopic (ea)	286	$140.38	$40,149
Lead-210 (ea)	286	$174.13	$49,801
Radium 226 and 228 (ea)	286	$142.50	$40,755
Uranium (ea)	286	$142.45	$40,741
TCLP (ea)	28	$559.74	$15,673

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Cost Estimate

Activity (unit)	Quantity	Unit Cost	Total
Site Work			
Clearing and Grubbing (acre)	1	$6,100.00	$3,050
Surveying			
Establish Site Control/Layout (day)	1	$1,750.00	$1,750
Reestablish Site Control/Layout (day)	1	$1,750.00	$1,750
Volume Surveys (day)	1	$1,750.00	$1,750
Post Restoration Survey (day)	1	$1,750.00	$1,750
Surface Water Collect & Control Including Dewatering			
Excavation Dewatering (day)	2	$850.00	$1,700
Sump Holes (cf)	100	$2.37	$237
Storage Tank Delivery (ea)	1	$500.00	$500
Storage Tank Rental (mo)	1	$1,200.00	$1,200
Water Filters (ea)	24	$39.00	$936
Solids Collect And Containment			
Erosion and Sediment Control			
Silt Fence and Straw Bales (lf)	240	$8.31	$1,994
Check Dams (cy)	10	$58.00	$580
Truck Entrance (cy)	20	$47.50	$950
Dust Control			
Water Trucks (mo)	1	$2,584.00	$2,584
Concrete Demolition and Size Reduction			
Bituminous Concrete Demolition (cy)	0	$153.00	$0
Asphaltic Concrete Demolition (sy)	1,611	$8.80	$14,178
Concrete Crushing Plant (hr)	8	$516.80	$4,134
Soil Excavation and Waste Volume Reduction Process			
Excavate Soils (day)	8	$7,590.00	$60,720
Waste Volume Reduction Operation (ton)	7,796	$35.00	$272,853
Waste Volume Reduction Support Crew (day)	8	$3,476.00	$27,808
Waste Volume Reduction Support Equipment (mo)	1	$30,000.00	$15,000
Diesel Generator (day)	1	$15,195.00	$7,598
Load/Package Contaminated Waste (day)	12	$4,152.00	$47,960
Bags for Mixed Waste (10 cy) (ea)	35	$350.00	$12,250
Ex Situ Treatment			
Loader (hr)	16	$144.06	$2,305
Truck (hr)	16	$153.22	$2,452
Holding Tank (mo)	1	$496.47	$496
Holding Tank (mo)	1	$1,701.04	$1,701
Portland Cement (ton)	42	$144.57	$6,072
Treatment Additive (ton)	3	$2,982.02	$8,946
Plywood Boxes (ea)	6	$100.17	$601
Operations Labor (hr)	32	$62.99	$2,016

Feasibility Study for Former Harshaw Chemical Company Site
Alternative 8 - Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-2)
Cost Estimate

Activity (unit)	Quantity	Unit Cost	Total
Chemical Transport (ea)	4	$2,829.31	$11,317
Mixer (mo)	1.0	$16,213.00	$16,213
Solidification/Stabilization Ancillary Equipment (ea)	1.0	$16,175.50	$16,176
Maintenance of Solidification Unit (yr)	0.01	$9,825.81	$98
Drums (ea)	2.0	$141.93	$284
Fuel (gal)	47	$4.31	$203
Process Water (kgal)	5	$17.01	$85
Offsite Transport and Disposal			
Transport and Disposal (Standard Debris) (cy)	3,927	$945.42	$3,713,042
Transport and Disposal (Mixed Waste) (cy)	0	$600.00	$0
Restoration			
Backfill Onsite Soils (cy)	3,188	$10.80	$34,436
Off-Site Backfill for Balance of Site (cy)	3,377	$47.50	$160,384
Seeding, Vegetative Cover (msf)	45	$88.00	$3,960
Fence and Other Miscellaneous Repairs (lot)	1	$10,000.00	$10,000
Closure Reports			
Corrective Action Completion Report (hr)	600	$80.00	$48,000
Subtotal			$5,168,930
Design		10%	$516,893
Home Office Overhead and Project Management		5%	$258,446
Field Overhead and Remediation Management		10%	$516,893
Subtotal			$6,461,162
Profit		8%	$516,893
Contingency		40%	$2,584,465
Total			$9,562,520

APPENDIX D

Groundwater Flow and Contaminant Transport Modeling
Former Harshaw Chemical Company Site – Feasibility Study

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LIST OF ATTACHMENTS

Attachment 1 Equilibrium Distribution Coefficients for Predictive Modeling
Attachment 2 Development and Application of FEHM Leaching Model

ACRONYMS AND ABBREVIATIONS

%	Percent
Δt	Time-step Size
Δx	Grid Spacing in the x-direction
ρ_b	Dry Bulk Density
µg	Micrograms
µg/L	Micrograms Per Liter
2D	Two-dimensional
3D	Three-dimensional
AEC	Atomic Energy Commission
amsl	above mean sea level
ASTM	American Society for Testing and Materials
BGS	below ground surface
CO_2	Carbon Dioxide
COC	Contaminant of Concern
Cou	Courant Number
DEM	Digital Elevation Model
DOE	United States Department of Energy
ft	feet
ft/day	Feet Per Day
ft^3/day	Cubic Feet Per Day
FEHM	Finite Element Heat and Mass Transfer Code
FS	Feasibility Study
g/cm^3	Grams Per Cubic Centimeter
gpm	Gallons Per Minute
HELP	Hydrologic Evaluation of Landfill Performance
IA	Investigative Area
in/yr	Inches Per Year
K	Hydraulic Conductivity
K_d	Equilibrium Distribution Coefficient
Kh	Horizontal Hydraulic Conductivity
Kz	Vertical Hydraulic Conductivity
LIDAR	Light Detection and Ranging
mL/g	Milliliters Per Gram
MCL	Maximum Contaminant Level
MED	Manhattan Engineer District
η_e	Effective Porosity
n	Number of Measurements
OGRIP	Ohio Geographically Referenced Information Program
OU-1	Operable Unit 1
OU-2	Operable Unit 2
pCi	picoCuries
pCi/µg	picoCuries per microgram
pCi/L	picoCuries per liter
R^2	Correlation Coefficient
Ra-226	Radium-226
Rf	Retardation Factor
RI	Remedial Investigation

ACRONYMS AND ABBREVIATIONS (CONTINUED)

RMSE	Root Mean Square Error
SAIC	Science Applications International Corporation
SESOIL	Seasonal Soil Compartment Model
Ss	Specific Storage
Sy	Specific yield
Th-230	Thorium-230
Th-232	Thorium-232
TVD	Total Variation Diminishing
U-234	Uranium-234
U-235	Uranium-235
U-238	Uranium-238
UCl_4	Uranium Tetrachloride
UF_4	Uranium Tetrafluoride
UF_6	Uranium Hexafluoride
USGS	United States Geologic Survey
v_x	Contaminant Velocity in the x-direction

GLOSSARY OF TERMS

Advection	Bulk transport of the mass of discrete chemical or biological constituents by fluid flow within a receiving water. Advection describes the mass transport due to the velocity, or flow, of the water body.
Aquifer	A water-bearing layer of rock (including gravel and sand) that will yield water in usable quantity to a well or spring.
Attenuation	The process by which a compound is reduced in concentration over time, through absorption, adsorption, degradation, dilution, and/or transformation.
Bedrock	Bedrock is the rock that underlies the soil; it can be permeable or non-permeable.
Bulk Density	The amount of mass of a soil per unit volume of soil; where mass is measured after all water has been extracted and total volume includes the volume of the soil itself and the volume of air space (voids) between the soil grains.
Cleanup	Actions taken to deal with a release or threat of release of a hazardous substance that could affect humans and/or the environment.
Contaminants of Concern	Chemicals that are potentially site-related and whose data are of sufficient quality for use in a quantitative risk assessment.
Correlation Coefficient	A numerical value that identifies the strength of relationship between variables.
Diffusion	The movement of suspended or dissolved particles (or molecules) from a more concentrated to a less concentrated area.
Dispersion	The spreading and mixing of chemical constituents in ground water.
Distribution Coefficient (K_d)	Distribution coefficient is an experimentally derived physical constant that expresses the ratio of the amount of chemical.
Downgradient	The direction that groundwater flows; similar to "downstream" for surface water.
Extraction Well	A discharge well used to remove groundwater or air.
Heterogeneous	Varying in structure or composition at different locations in space.
Homogeneous	Uniform in structure or composition at all locations in space.
Hydraulic Conductivity	A coefficient of proportionality describing the rate at which water can move through a permeable medium.

Hydraulic Gradient	The change in total potentiometric head between two points divided by the horizontal distance separating the two points.
Hydraulic Head	Height above a datum plane (such as mean sea level) of the column of water that can be supported by the hydraulic pressure at a given point in a groundwater system. Equal to the distance between the water level in a well and the datum plane.
Hydrogeology	The study of the interaction of groundwater and the surrounding soil and rock.
MCL	The maximum level of certain contaminants permitted in drinking water supplied by a public water system as set by USEPA under the federal Safe Drinking Water Act.
Permeability	The rate at which liquids pass through soil or other material in a specified direction.
Plume	A concentration of contaminants in air, soil, or water usually extending from a distinct source.
Recharge	Process by which rain water (precipitation) seeps into the ground-water system.
Release	Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment of a hazardous or toxic chemical, or extremely hazardous substance.
Remediation	Cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site.
Residual Saturation	Saturation level below which fluid drainage will not occur.
Retardation	Preferential retention of contaminant movement in the subsurface resulting from adsorptive processes or solubility differences.
Saturation Zone	The soil or rock located below the top of the groundwater table.
Soil Boring	A process by which a soil sample is extracted from the ground for analytical testing.
Solute	A substance dissolved in another substance, usually, the component of a solution present in the lesser amount.
Sorption	Refers to processes that remove solutes from the fluid phase and concentrate them on the solid phase of a medium.
Source	A reservoir of contamination existing in a separate phase from water.

Specific Storage	The volume of water that an aquifer system releases or takes into storage per unit volume per unit change in head.
Specific Yield	The amount of water a unit volume of saturated permeable rock will yield when drained by gravity.

Sources:

1. USEPA Terminology Services, http://iaspub.epa.gov/sor_internet/registry/termreg/searchandretrieve/termsandacronyms/search.do
2. National Academies Press, Alternatives for Groundwater Cleanup (1994), http://books.nap.edu/openbook.php?record_id=2311&page=287
3. USGS, Land Subsidence in the United States, Glossary, http://pubs.usgs.gov/circ/circ1182/pdf/17Glossary.pdf

1. INTRODUCTION

The Former Harshaw Chemical Company Site (Figure D-1) is located at 1000 Harvard Avenue in Cleveland, Ohio, approximately 3 miles south of downtown Cleveland. The site is located within an industrialized area adjacent to the Cuyahoga River and Big Creek. The site consists of several developed and undeveloped land parcels located near the intersection of Harvard Avenue and Jennings Road. Developed site parcels include former production areas with remaining facility buildings, former production area foundations, parking areas associated with previously demolished buildings, and re-developed privately-owned commercial properties.

The Former Harshaw Chemical Company Site was initially purchased by the Harshaw, Fuller & Goodwin Company in 1905 and commercially manufactured chemical solvents, metal salts, fluorides, hydrofluoric acids, and other chemical products at the Harvard Avenue location. The Harshaw Chemical Company began production activities for the Manhattan Engineer District (MED) in late 1942 in support of the United States' early atomic weapons program. The primary process conducted by the Harshaw Chemical Company at the Harvard Avenue location consisted of the refining of uranium oxide to produce several uranium-bearing materials, including uranium hexafluoride (UF_6), uranium tetrafluoride (UF_4), and uranium tetrachloride (UCl_4). The Harshaw Chemical Company also conducted numerous additional chemical and radiological research and production activities for the MED and later for the Atomic Energy Commission (AEC). Groundwater and soil contamination resulting from these activities is characterized in the *Former Harshaw Chemical Site Remedial Investigation Report* (USACE 2009).

The Former Harshaw Chemical Company Site Remedial Investigation (RI) included the development of a groundwater flow and contaminant transport model to assist in site decision-making. The model area included Operable Unit 1 (OU-1) and off-site areas to the north and west (Figure D-1). The model focused on OU-1 because the RI identified no groundwater contamination in other areas of the Former Harshaw Chemical Company Site. The model was used in the RI to predict baseline fate and transport of total uranium in OU-1 groundwater. Further, the model was constructed to support the Feasibility Study (FS) evaluation of the impact of soil remediation upon future contaminant fate and transport in OU-1 groundwater.

This appendix documents updates to: (1) the RI groundwater flow and transport model; and (2) supporting models. The latter includes the site geologic model, which provides the geologic framework for the flow and transport model, and the vadose zone leaching modeling, which guides source term specification for the flow and transport model.

This appendix also evaluates the impact of OU-1 FS soil remedial alternatives on future post-remediation groundwater conditions for OU-1 soil contaminants of concern (COCs). Since there is no groundwater pathway in the assumed industrial future land use for OU-1, there are no COCs for OU-1 groundwater and groundwater remedial actions are not considered in the FS. Therefore, the groundwater evaluation herein is not intended to demonstrate compliance with Maximum Contaminant Levels (MCLs) or any other groundwater standard. Rather, it is intended to demonstrate that significant further degradation of groundwater will not occur after implementation of the OU-1 FS soil remedial alternatives. MCLs are used in this groundwater evaluation solely as a benchmark to compare current to predicted future groundwater conditions after implementation of the OU-1 FS soil alternatives.

Consistent with the preceding discussion, only the two soil COCs for OU-1, total uranium and thorium, are considered in this groundwater evaluation for OU-1. Transport of total uranium in OU-1 groundwater is evaluated quantitatively herein using the groundwater flow and transport model. Transport of thorium in OU-1 groundwater is evaluated qualitatively herein, taking into consideration quantitative total uranium transport predictions and relative mobility, plume footprint, and continuing sources for thorium

versus total uranium. These evaluations consider the current versus predicted future contaminant extent above the MCL (as a point of comparison, rather than as a groundwater standard). Results are judged in terms of no significant impact, significant positive impact (i.e., significantly decreased extent of contamination above the MCL), or significant negative impact (i.e., significantly increased extent of contamination above the MCL). The results of the groundwater analysis are not a criterion in the selection of the preferred OU-1 soil remedial alternative, but may be considered as appropriate during the selection process.

Rather than simply supplementing the previous model documentation in the RI report, this appendix provides complete documentation of the current flow and transport model, as extensive updates were made. The model documentation in this appendix is organized consistent with the recommendations in American Society for Testing and Materials (ASTM) Standard Guide D5447 (ASTM 2004).

2. PURPOSE AND SCOPE

The purpose of this task is to: (1) update the existing RI groundwater flow and contaminant transport model for OU-1; (2) update related models (including the geologic framework model and vadose zone leaching models); and (3) predict transport of total uranium and thorium in OU-1 groundwater, under the conditions of the various OU-1 FS soil remedial alternatives. To accomplish this task, Science Applications International Corporation (SAIC) evaluated and synthesized site-specific geologic, hydrogeologic, and geochemical (contaminant migration) characteristics in the study area, along with relevant literature data.

The scope of this analysis includes the following actions:

- Update and refine the site conceptual flow and transport model, including incorporating boring logs, groundwater quality data, and water level data collected subsequent to original model development during the RI;
- Translate the updated site conceptual model into a numerical flow and transport model;
- Use the numerical model to predict transport of total uranium in OU-1 groundwater under the conditions of the various OU-1 FS soil remedial alternatives;
- Perform appropriate sensitivity/uncertainty simulations for total uranium transport in OU-1 groundwater with the numerical model;
- Evaluate potential thorium transport in OU-1 groundwater qualitatively, taking into consideration quantitative total uranium transport predictions and relative mobility, plume footprint, and continuing sources for thorium versus total uranium; and
- Evaluate whether the OU-1 and OU-2 proposed soil cleanup criteria for total uranium, thorium-230, thorium-232, and radium-226 are protective of groundwater. Because it includes only OU-1, the model was only indirectly used to evaluate the Operable Unit 2 (OU-2) criteria.

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3. CONCEPTUAL GROUNDWATER FLOW AND CONTAMINANT TRANSPORT MODEL

A conceptual model is a qualitative understanding of the site groundwater flow and solute transport system. Its purpose is to organize and integrate available data regarding the system and to serve as the foundation from which to build the numerical groundwater flow and contaminant transport model. The conceptual model includes: (1) a description of the model area; (2) a detailed discussion of the geology, hydrogeology, and contamination in the model area; and (3) a conceptual model summary.

The detailed geology/hydrogeology discussions focus on the conceptual model layer structure. The rationale for the selected structure and the delineation of the structure (e.g., layer top and bottom elevation maps, layer isopach maps, and potentiometric maps) is presented. Hydrologic boundaries, hydraulic properties, and water budget are also addressed. The contaminant discussion focuses on characterization of the current extent of groundwater contamination, sources of that contamination, and transport mechanisms (both source and aqueous-phase). The conceptual model section concludes with a summary describing the understanding of groundwater flow and contaminant fate and transport.

3.1 DESCRIPTION OF AREA

The Former Harshaw Chemical Company Site (Figure D-1) is located at 1000 Harvard Avenue in Cleveland, Ohio, approximately 3 miles south of downtown Cleveland. The site is located within an industrialized area adjacent to the Cuyahoga River and Big Creek. The site consists of several developed and undeveloped land parcels located near the intersection of Harvard Avenue and Jennings Road. Developed site parcels include former production areas with remaining facility buildings, former production area foundations, parking areas associated with previously demolished buildings, and re-developed privately-owned commercial properties. The site includes areas of pavement, broken pavement, and non-paved (vegetated, dirt, or gravel) surfaces.

The model area includes OU-1 and off-site areas to the north and west (Figure D-1). Processing and handling of uranium compounds occurred primarily within OU-1 in Building G-1 and the surrounding area, including the former rail yard adjacent to Building G-1, and the former foundry, Building F-1 (Figure D-1). The model focused on OU-1 because the RI identified no groundwater contamination in other operable units of the Former Harshaw Chemical Company Site.

Other anthropogenic features within the model domain include Chemical Solvents, Inc. to the north, a CSX Transportation Inc. railroad line along the north and west sides, small manufacturing shops along Jennings Road, a shipping business to the west, and C&D Trucking to the southwest.

3.2 PHYSIOGRAPHY

The model area is located at the confluence of the Cuyahoga River and Big Creek floodplains (Figure D-1). The model area is bounded on the east by the Cuyahoga River, on the south by Big Creek, and on the west by uplands that rise above the floodplain. The model area is relatively flat, with a slope of less than 1 % toward the east (Cuyahoga River) and to the south (Big Creek). The land surface elevation in the model area ranges from approximately 600 ft above mean sea level (amsl) at the toe of the western uplands to about 590 ft amsl at the top of the banks of Big Creek and the Cuyahoga River to about 575 ft amsl at the Cuyahoga River. The relatively level floodplain in the model area was leveled with both recent and older anthropogenic fill in order to develop the site. The surrounding areas above the floodplain are developed land with relatively low relief at an approximate elevation of 675 ft amsl.

3.3 GEOLOGY

The following sections describe the regional and site-specific geology.

3.3.1 Regional Geology

Cuyahoga County is situated within the Appalachian Plateau and the lower-lying Central Lowland physiographic provinces. The two provinces are separated by the Portage Escarpment, which runs northeast through the south-central portion of the county. The glacial soil of the Portage Escarpment is cut by valleys associated with rivers and tributary systems. Alluvial deposits in these valleys, including the Cuyahoga River valley, vary and are composed of silty clays, sands, and gravels.

Unconsolidated deposits in Cuyahoga County consist of madeland (fill), glacial tills, lacustrine soil from glacial stages of Lake Erie, and fluvial deposits. Lacustrine soil, consisting of lake clays and beach ridges, is present along the Cuyahoga River valley as far as 15 miles south of the present shoreline but is generally restricted to the northern part of the county [within 3 miles of Lake Erie]. This soil is often covered with anthropogenic fill associated with industrial and residential development, especially in low-lying areas. Glacial soil in the county is Wisconsinan age tills of the Killbuck and Cuyahoga Lobes. The majority of the tills in the county are Killbuck (Hiram and Hayesville tills) and Cuyahoga (Lavery till). The tills are primarily composed of silty clays with varying percentages of sands and gravels. Lenses of sand and gravel within the tills are usually present as relatively thin layers of limited horizontal continuity. Fluvial deposits are associated with the Rocky River, Cuyahoga River, and Chagrin River systems. These rivers flow north to Lake Erie.

Cuyahoga County lies on the eastern flank of the Findlay Arch, an extension of the Cincinnati Arch bedrock anticline. Bedrock underlying the county consists of eastward-dipping rocks of the Pennsylvanian (310-265 million years), Mississippian (355-310 million years), and Devonian (410-355 million years) periods. Rocks from these periods are represented by the Pennsylvanian Allegheny and Conemaugh Formations and the Pottsville Group, the Mississippian Cuyahoga Shale and Berea Sandstone, and the Devonian Bedford and Ohio shales. The Allegheny and Conemaugh formations consist of interbedded shales, sandstones, limestones, and coals. The Pottsville Group consists of sandstones and conglomerates, including the Sharon Conglomerate. The underlying Cuyahoga Formation consists of interbedded shales and sandstones, and the Berea Sandstone is composed of fine-to-medium quartz sandstone. The Devonian Bedford Shale consists of interbedded shales and sandstones. The Ohio Shale occurs as a gray, medium-to-thick bedded shale with siltstone or sandstone interbeds (Chagrin Shale Member) and dark-gray-to-black, thin-bedded shale (Cleveland Member). The Berea and Sharon Formations are locally important sources of groundwater.

Bedrock elevations in Cuyahoga County range from 0 to 1,200 ft amsl. Lower elevations occur in pre-glacial bedrock valleys. The largest of these extends from the Cleveland lakeshore east of downtown and south to the Summit County line. Other lesser valleys extend south from Rocky River to Middleburg Heights, from Middleburg Heights east to Independence, and from Maple Heights southeast to the Summit County line. Another significant bedrock valley runs from south to north near the Geauga County line in eastern Cuyahoga County. The valleys are filled with glacial deposits of varying grain size. Portions of these buried valleys contain sand and gravel deposits, which may be important sources of groundwater in some areas.

3.3.2 Site-specific Geology

During the RI, a three-dimensional (3D) geologic model of the Former Harshaw Chemical Company Site was developed to support RI/FS activities. For this groundwater modeling effort, the following revisions were made to the 3D geologic model:

- Update the geologic model with lithologic picks (elevations that correspond to transitions between distinct lithologies) from 14 new OU-1 and OU-2 groundwater monitoring wells installed in 2008 and soil borings on the Milan Trucking property in OU-2.
- Re-evaluate previous lithologic picks for existing OU-1 borings to ensure consistency and quality in the geologic model.
- Incorporate recent topography data derived from Light Detection and Ranging (LIDAR) data.
- Extend the top of bedrock surface to the west and north using regional bedrock data to match the extent of the bedrock surface within the groundwater model.
- Revise location coordinates for historical (those with "DM" prefix) groundwater monitoring wells.
- Include the weathered bedrock zone as a distinct unit in the geologic model for consistency with the groundwater model.

This updated geologic model provides the framework for the updated groundwater flow and transport model discussed in this report. Contour maps, cross-sections and 3D images from this updated geologic model are provided in this section.

The geologic units of interest in the model area consist of the unconsolidated anthropogenic fill layers (Old Fill and New Fill), the poorly sorted and variably textured floodplain and fluvial deposits (Native Sediment), and a thin weathered zone in the basal Ohio Shale (weathered bedrock). These units are illustrated in Figure D-2, a perspective view of the 3D geologic model looking to the northwest, and Figure D-3, a section through the 3D geologic model at Building G-1. This 3D geologic model was developed from LIDAR-derived topographic data, regional bedrock maps, site-specific ground surface survey data, site-specific lithologic picks from borings and monitoring wells, and control points specified to produce realistic interpretations in areas lacking data. The site-specific lithologic pick data used to develop the geologic model are presented in Table D-1.

A comprehensive discussion of the geologic units in the 3D geologic model is provided in Section 2.3.2.2 of the RI Report (USACE 2009), and a summary discussion is provided here.

3.3.2.1 Overburden

The overburden in the model area consists (in descending order) of New Fill, Old Fill, and Native Sediment. The Native Sediment was covered by reworked sediment and other construction-related fill material during what appear to be two major stages of development: the deposition of Old Fill during the initial major development of the site after 1903, and the deposition of New Fill during construction and operation of the Former Harshaw Chemical Company Site. The elevation of the top of the overburden (i.e., the topography) is shown in Figure D-4, with overburden units present at land surface noted. The topography presented in Figure D-4 was developed from LIDAR-derived Digital Elevation Models (DEMs) (OGRIP 2006) that were corrected using available site-specific ground surface survey data. The

overburden thickness is shown in Figure D-5 and is generated from the difference between the topography (Figure D-4) and the top of weathered bedrock (discussed subsequently in Section 3.3.2.2). The combined overburden on the Former Harshaw Chemical Company Site varies from less than 5 ft (1.5 m) thick to nearly 40 ft (12.2 m) thick. The overburden is thinnest over the bedrock high below Building G-1and the Boiler House buildings, and it is thickest near the Cuyahoga River bank, where fill was used to elevate the ground level above the natural floodplain. This topographic difference between natural floodplain and anthropogenic fill elevations can be observed by comparing the riverbank elevations in Investigative Area (IA)-06 to those along OU-1.

The New Fill is predominantly heterogeneous in composition and grain size. It contains a significantly higher percentage of fine-grained material than the underlying Old Fill. The grain sizes range from clay to silty-clay with some sand. In many locations the New Fill contains construction debris such as bricks, glass, plastic, and various stained, granular materials (thought to be chemical process wastes) as noted by field geologists on soil boring logs. Figure D-6 presents the elevation of the top of the New Fill, which corresponds to the topography where the New Fill is present. Figure D-7 presents the thickness of the New Fill, which is generated from the difference between the top of the New Fill (Figure D-6) and the top of the underlying materials (which vary depending upon location at the site).

The Old Fill consists of re-worked fluvial material and was likely deposited during the initial major development of the area after 1903, but prior to construction of the Harshaw Chemical Company. During this period, the site was characterized by a topographic high formed by the underlying bedrock with approximately 100 ft of relief. This bedrock high was leveled during historical site development, and the area apparently was back-filled with what generally appears to be a mixture of foundry sand and re-worked fluvial sediment. This Old Fill unit is distinguished primarily by the yellow-orange and brown soil colors and secondarily by compositions recorded on soil boring logs. The Old Fill generally contains a higher percentage of sand and shaley angular gravel than the New Fill above it. The Old Fill also contains layers of silt and clay and is predominantly heterogeneous. The Old Fill is nearly continuous across the site but is observed to pinch out in some areas. Old Fill appears to be absent along river banks in areas that have been built up using New Fill. The elevation of the top of the Old Fill is shown in Figure D-8, and the thickness is shown in Figure D-9. The thickness is generated from the difference between the top of the Old Fill (Figure D-8) and the top of the underlying materials (which vary depending upon location at the site).

The Native Sediment that underlies the fill ranges from 1 ft to more than 30 ft in thickness on the Former Harshaw Chemical Company Site. These fine-grained floodplain and coarse-grained fluvial sediment contain varying percentages of clay, silt, fine-to-medium sand, and fine-to-medium gravel, although more gravelly deposits have been found at the site. The color ranges from dark olive brown to dark gray, and geotechnical analyses classified most soil samples as silty clay or gravelly sand with clayey gravel. In general, finer-grained alluvial deposits are located west and north of Building G-1, consistent with a low-energy floodplain environment. Coarser-grained deposits occur in the eastern portion of the site near the Cuyahoga River, consistent with higher-energy fluvial channel deposits. The regional glacial moraine deposits common to the surrounding areas are not seen at the site, but are presumed to be present in adjacent highlands to the west. The dynamic nature of the post-glacial environment in the Cuyahoga River valley left little glacial till material deposits. The elevation of the top of the Native Sediment is shown in Figure D-10 and the thickness is shown in Figure D-11. The thickness is generated from the difference between the top of the Native Sediment (Figure D-10) and the top of the weathered bedrock (discussed in the following section).

3.3.2.2 Bedrock

The uppermost bedrock at the site is the Chagrin Member of the Ohio Shale – a fissile and fine-textured, bluish-gray, and poorly fossiliferous Upper Devonian formation. The Ohio Shale normally exhibits dense, small-scale (short lengths), tight (small aperture) fracturing that creates moderate-to-low porosity and low bulk permeability. A thin, weathered zone occurs at the top of the bedrock. Figure D-12 presents the elevation of the top of weathered bedrock. Relative to the top of bedrock developed previously for the RI, the top of bedrock presented in Figure D-12 is extended laterally to match the extent of the groundwater flow model. Regional bedrock maps produced by the Ohio Division of Geological Survey (2003) were used to supplement site-specific weathered bedrock picks in order to accomplish this extension.

The top of weathered bedrock ranges from about 520 to 590 ft amsl in the model area, generally declining from west to east toward the Cuyahoga River (Figure D-12). Building G-1 and the Boiler House buildings sit atop a bedrock high, where elevations are as high as about 590 ft, based on Geoprobe soil borings installed through the floor of Building G-1. The bedrock high abruptly declines to the east along a northeast-southwest trending structural feature created by past Cuyahoga River erosion. The weathered bedrock is assumed to be 5 ft thick for the purposes of this modeling effort.

3.4 HYDROGEOLOGY

Regional hydrogeologic conditions are summarized below, followed by a more detailed description of local hydrogeologic conditions.

3.4.1 Regional Hydrogeology

In general, Cuyahoga County does not possess extensive high-yield aquifers. The *Ground Water Resources of Cuyahoga County* (Crowell 1979) indicates the majority of the county overlies areas of poor groundwater production, where yields of 10 gallons per minute (gpm) or less may be developed from groundwater wells. Higher production rates in some areas can be obtained from sandstone bedrock and in other areas from unconsolidated buried valley deposits.

Groundwater in most areas is produced from Mississippian or Devonian shale bedrock and the overlying unconsolidated deposits, which are predominantly clays. Wells completed in the shale bedrock may produce 3 to 10 gpm (11.4 to 37.9 L/minute), with lesser yields from the overlying clays. Brackish water and dry holes are common in the overburden.

Yields of 10 to 40 gpm may be obtained from the Berea Sandstone and the Sharon Sandstone in somewhat extensive but isolated areas in the southern half of Cuyahoga County. Berea Sandstone wells may be drilled in the Olmstead, Middleburg/Parma Heights, and Independence areas, and along the Geauga County line to the east. The Sharon Sandstone can be tapped in the extreme south-central portion of the county, and in an area in the eastern part of Cuyahoga County.

A buried bedrock valley aquifer system extends from the lakeshore in the Cleveland area, south to the Summit County line, then west across the south-central portion of Cuyahoga County to Middleburg Heights. Production from the northern portion of the system averages 3 to 10 gpm, except for a small portion in the center of the valley where up to 250 gpm may be produced. Production from the remainder of the system averages 10 to 25 gpm. Additional buried valley deposits in the eastern part of the county generally produce 3 to 25 gpm, with the exception of a small area northwest of Maple Heights where yields of up to 1,500 gpm can be obtained. Yields of 3 to 25 gpm can also be obtained from buried valley deposits under the eastern portion of the county, near the Geauga County line.

3.4.2 Site-specific Hydrogeology

The hydrogeologic zones of interest at the Former Harshaw Chemical Company Site include the overburden units and, to a lesser extent, the underlying weathered shale bedrock. Seventy-one monitoring wells and piezometers are currently present at the Former Harshaw Chemical Company Site. All are completed in the overburden, with the exception of one well (RMW-38) screened in the weathered bedrock immediately below the overburden. Of the 71 current groundwater monitoring points, 29 were installed prior to the RI, 28 were installed during the RI, and 14 were installed subsequent to the RI. Sixty of the 71 monitoring points are located within the model area, with the remaining 11 located in OU-2 (south of Big Creek). A number of additional wells were installed at various times prior to the RI, but these have been plugged and abandoned or are otherwise unavailable for continued use.

Table D-2 presents the water level data collected from June 2003 through July 2010, along with per-well summary statistics (count, mean, and range), for the 60 monitoring wells and piezometers that currently exist within the model area. In the right-hand portion of Table D-2, for each measurement, the difference from the mean water level for that well is provided. At the bottom of these difference columns, both the measurement count and the mean of the differences for a given event are provided. The May 2004, August 24, 2004, October 2004, December 2004, and May 2005 events include water level measurements for all or nearly all of the 57 wells installed at that time (three IA10 wells were not installed until 2008), while the remaining eight events include significantly fewer water level measurements. The former five events were therefore considered for mapping water levels. Of these five events, the May 2004 event is much higher than average (mean difference of 4 ft, as shown at the bottom of Table D-2), the August 24, 2004, and October 2004 events are lower than average (mean differences of -1.4 ft and -2.1 ft, respectively), and the December 2004 and May 2005 events are near average (mean differences of -0.3 ft and 1.1 ft, respectively).

Potentiometric surface maps were constructed for a higher-than-average event (May 2004), a lower-than-average event (October 2004), and a near-average event (May 2005). These maps are presented in Figures D-13 through D-15. Data from Table D-2 were used to construct these contour maps, including the data for RMW-38 which is completed in the weathered bedrock. Data from this well are consistent with surrounding water levels in the overburden, supporting the hypothesis that water levels and flow patterns in the weathered bedrock are similar to and controlled by those in the overburden. The IA04-TP0001 May 2004 water level is anomalously high and was therefore not used in developing the May 2004 potentiometric surface.

As shown under a range of water level conditions in Figures D-13 through D-15, flow is generally from the western uplands toward the surface water bodies: to the east toward the Cuyahoga River and to a lesser degree to the south toward Big Creek. The May 2004 potentiometric surface suggests flow from the Cuyahoga River and Big Creek into the overburden; this short-term flow pattern is attributable to the flood-stage conditions in the Cuyahoga River during this measurement event. In all three potentiometric surfaces, a potentiometric high exists under and to the south of Building G-1, mimicking the bedrock structural high.

As a standard practice, calibration targets for a steady-state flow model are drawn from a water level event that is very close to mean water levels. As noted above, of the events that include water level data for nearly all of the monitoring wells on site, the December 2004 and May 2005 events are closest to mean water levels (mean differences of -0.3 ft and 1.1 ft, respectively). While the December 2004 event is slightly closer to mean water levels, the May 2005 event reflects an overall higher horizontal hydraulic gradient from the Building G-1 area to the Cuyahoga River. Calibration of the model to this condition will therefore be more conservative in terms of transport from the Building G-1 area toward the Cuyahoga

River. Consequently, water level data from the May 2005 event were selected as the calibration targets for the steady-state flow model.

In addition, the May 2005 event was not influenced by high surface-water conditions. The United States Geologic Survey (USGS) Independence, Ohio, gauge on the Cuyahoga River recorded a daily mean of 1,840 ft^3/s, which is a low to moderate flow condition (Figure D-16). A comparison of site groundwater levels with water elevations in Big Creek and the Cuyahoga River indicate the water bodies are receiving groundwater from the Former Harshaw Chemical Company Site under the May 2005 condition. Groundwater flow gradients from the overburden to the Cuyahoga River and Big Creek along the site vary between 0.004 and 0.03 ft/ft. Coincident with this May 2005 water level monitoring event, river stage data were recorded from three gauges adjacent to the model area. At the confluence of the Cuyahoga River and Big Creek, the stage was 574.75 ft. Approximately 1,800 ft downstream at a gauge by the Harvard-Denison Bridge, the stage was 574.61 ft. Upstream on Big Creek at the rail bridge south of IA05, the observed stage was 575.51 ft.

Groundwater level data were evaluated to determine whether vertical gradients exist across the overburden units (New Fill, Old Fill, and Native Sediment) that could necessitate representing the overburden with more than one layer in the numerical model. The presence of vertical gradients cannot be directly evaluated from co-located well pairs screened in different overburden units at the Former Harshaw Chemical Company Site, as no such pairs exist. In fact, only ten wells are screened entirely in one overburden unit (all ten in the Native Sediment). Vertical gradients, if present, would be expected to be downward, driven by recharge in concert with sufficiently low vertical hydraulic conductivity (Kz) in one or more of the overburden units. This would result in potentiometric lows in the Native Sediment, which is the lowermost overburden unit. Of the ten wells screened entirely in the Native Sediment, seven have water levels consistent with water levels for nearby wells, while three exhibit minor potentiometric highs. Thus, these data do not suggest that conductivity variations with depth are inducing downward vertical gradients.

Additionally, overall flow patterns based on mapping all wells together are generally smooth (Figures D-13 through D-15). Perturbations are attributable to pumping, structural features (e.g., bedrock high), and anomalous measurements. Based on these observations, vertical gradients across the overburden units are not apparent. Therefore, the overburden units are represented in the numerical groundwater flow model as a single layer (model layer 1). The weathered bedrock is represented as a second layer (layer 2).

To assess the impact of the groundwater extraction system associated with the on-site sanitary sewer line (see Section 3.7.4 for a description of this system), groundwater levels were taken on August 24, 2004, when the system was off-line, and on August 27, 2004, when the system was operational. These water levels are presented in Table D-2. The observed zone of influence extended up to 125 ft to the west (upgradient), and up to 70 ft east (downgradient) of the line sink. The average head differential of 0.37 ft from 15 nearby wells is based on a range of 3.5 ft in DM-1 (located 5 ft from a pumping well) to 0.06 ft in IA03-TW0003 (located about 75 ft away from the sewer line). Water levels were monitored three days apart during the dry season, during which a natural decline of 0.06 ft (lowest drawdown value) may have occurred in the absence of pumping. If DM-1 is removed from the dataset, the average drawdown becomes 0.14 ft, with a range of 0.06 to 0.25 ft. Overall, the data indicate localized hydraulic effects in the immediate vicinity of the extraction system and sanitary sewer line; wider impacts upon the flow system in the model area as a whole are not evident.

3.4.3 Surface Water

As noted above, groundwater in the model area discharges to the Cuyahoga River and to a lesser extent to Big Creek. The Cuyahoga River lies along the eastern boundary of the model area and seasonally varies

up to 10 ft in stage based on visual observations during two RI phases. Big Creek lies along the southern boundary of the model area.

Groundwater discharge rates to these surface water bodies are a function of seasonal water level and creek stage (both variable), as well as the conductivity of the river bed and adjacent aquifer materials. The alluvium adjacent to and beneath the creek and river beds varies in thickness and allows the discharge of groundwater to the channels. The banks along the river and creek also exhibit thicker coarse-textured fill with higher conductivity values. Observed water levels in monitoring wells respond to river-stage fluctuations, verifying good hydraulic connection.

Streamflow data from the Cuyahoga River USGS gauging station in Independence, Ohio, (about four miles upstream of the model area) are presented in Figure D-16. Based on these data, the river conditions during the May 2005 water level monitoring event selected as the calibration target dataset were receding and nearly returned to baseflow. Coincident with this May 2005 water level monitoring event, river stage data were recorded from three gauges adjacent to the model area. At the confluence of the Cuyahoga River and Big Creek, the stage was 574.75 ft. Approximately 1,800 ft downstream at a gauge by the Harvard-Denison Bridge, the stage was 574.61 ft. Upstream on Big Creek at the rail bridge south of IA05, the observed stage was 575.51 ft.

3.4.4 Recharge

The term recharge in this document refers to the net flux from precipitation reaching the saturated zone. The amount of precipitation that infiltrates to the groundwater is limited by surface runoff, by evapotranspiration, and by the geologic material comprising the vadose zone.

Recharge estimates for a similar depth to water table and soil type in Cuyahoga County are from 4 to 7 inches/yr (Barber 1994). Consistent with this regional information, site-specific Hydrologic Evaluation of Landfill Performance (HELP) model simulations performed during the RI yielded recharge estimates of 5.5 to 6.1 inches/yr (assuming slight slope of 0.5%, promoting some runoff, and no paving) (USACE 2009). Similarly, site-specific Seasonal Soil Compartment (SESOIL) model simulations performed during the RI yielded recharge estimates of 8.6 in/yr for an unpaved area (USACE 2009).

Large portions of the model area are covered by intact pavement and buildings (Figure D-17), which reduce recharge substantially.

Other portions of the model area are covered by cracked pavement without vegetation (Figure D-17). In these areas, infiltration is reduced but so too is evapotranspiration due to the lack of vegetation. HELP simulations conducted for the RI suggest recharge ranging from about 10 to 17 in/yr in these areas, depending upon runoff area and slope length (USACE 2009).

An area of highly fragmented pavement is present between Building G-1 and the Cuyahoga River (Figure D-17). This area is thoroughly vegetated, and similar recharge is expected here as in unpaved, vegetated areas.

The existing stormwater management system at the site does not promote runoff and reduce recharge to groundwater to the extent that it otherwise might, due to clogs and sediment accumulation in the sewer lines. This is discussed in greater detail in Section 3.7.3.

3.5 HYDROLOGIC BOUNDARIES

The flow model domain includes three types of natural hydrologic boundaries: rivers, a recharge zone along the western uplands, lateral no-flow boundaries along flow lines, and a lower no-flow boundary at the base of the weathered bedrock. The river boundaries (Figure D-18) are discussed in detail in Section 3.4.3, and the remaining boundaries are discussed here.

Along the border of the uplands to the west of the site (Figure D-18), recharge into the model area occurs from both (1) throughflow in the adjacent unconsolidated zone and weathered bedrock and (2) surface water run-off from the upland slope during storm events.

Although insufficient monitoring well data are available to define the potentiometric surface in the extreme western and extreme northern portions of the model area (i.e., west of Jennings Freeway and north of the Harvard-Denison Bridge, respectively), flow in these areas is expected to be generally from the western uplands to Big Creek and Cuyahoga River. Consequently the extreme western and northern edges of the model area are expected to be along flow lines and are therefore no-flow boundaries (Figure D-18).

A no-flow boundary is used at the base of the weathered bedrock, as the conductivity of the competent Ohio Shale is expected to be at least two orders of magnitude lower than that of the weathered shale.

3.6 HYDRAULIC PROPERTIES

3.6.1 Hydraulic Conductivity

Single-well slug tests conducted on 22 monitoring wells produced hydraulic conductivity values ranging from 0.31 to 154 ft/day (0.09 to 46.9 m/day) in the fill [number of measurements (n) = 4], from 0.03 to 85 ft/day in the Native Sediment (n = 40), and from 0.14 to 0.17 ft/day in the weathered bedrock at well RMW-38 (n = 2). Table 6-45 of the RI (USACE 2009) summarizes the slug test results and geologic material tested in each well. For both the overburden and shale, the measured hydraulic conductivities are within the range of published literature values for these respective lithologies (Fetter 1988). The low hydraulic conductivity values from weathered bedrock well RWM-38 do not indicate that secondary features (joints, fractures, and faults) greatly enhance the hydraulic conductivity.

The slug test results are presented spatially in Figure D-19. Posted hydraulic conductivity values represent the average of the rising and falling head tests for each well. The higher slug test results generally occur nearer the Cuyahoga River and Big Creek, consistent with the depositional environment and hydrogeologic setting discussed in preceding sections.

The wide conductivity range is expected because slug tests evaluate an extremely small portion of a given water-bearing zone and therefore are strongly impacted by lithologic heterogeneity. In addition, significant uncertainty is inherently associated with slug test results because they can be strongly influenced by skin effects in wells and data may be easily misinterpreted. Any or all of these factors may account for cases such as the low conductivity values near the Cuyahoga River at DM-28 and IA04-TP0004 (0.43 and 0.04 ft/day, respectively), where the depositional suggests that higher conductivity values should generally prevail.

For these reasons, the slug test data are best used to establish a realistic hydraulic conductivity *range* for the model area, rather than being used to establish a continuous conductivity distribution across the model area by, for example, interpolating (whether geostatistically or not) between these measured data values.

3.6.2 Effective Porosity

Effective porosity is the ratio of the volume of interconnected pore space through which groundwater can flow to the total volume of the geologic material (Porges and Hammer 2001). Because effective porosity only accounts for pore space available for groundwater flow, the value of effective porosity is less than total porosity. For groundwater modeling applications, effective porosity is used.

Site-specific effective porosity data are not available; however, total porosity data collected for the RI provide an upper bound for the effective porosity. Total porosity values summarized in Table 6-10 of the RI (USACE 2009) for three native soil samples range from 0.38 to 0.51, with an average of 0.43.

Average effective porosity values in literature for clay, silt, and medium sand are 0.06, 0.20, and 0.32, respectively (McWhorter and Sunada 1977). The fill and native soil in the model area generally have a higher proportion of fines than sands, and so the effective porosity in the model area is expected to be roughly in the 0.15 to 0.20 range. This substantial reduction with respect to the site-specific measured total porosity values is typical of fines, where total porosity is generally high but effective porosity is generally low.

McWhorter and Sunada (1977) do not provide effective porosity values for shale but provide values for clay ranging from 0.01 to 0.18, with a median value of 0.06. Somewhat higher effective porosity values would be expected for weathered shale.

3.6.3 Specific Yield

Specific yield (Sy) is the volume of water released or taken into storage per unit surface area of aquifer per unit change in the level of the water table. The upper limit for Sy is the effective porosity, but the value for Sy is generally much less than the effective porosity because some water is retained by the soil matrix (specific retention) during drainage.

The Sy is relevant only for transient flow simulations. Since only steady-state flow simulations were conducted, Sy data were not developed for this model.

3.6.4 Specific Storage

Specific storage (Ss) is the volume of water released from or taken into storage by an aquifer per volume of aquifer, per unit change in hydraulic head (Porges and Hammer 2001).

As with Sy, Ss is relevant only for transient flow simulations. Because only steady-state flow simulations were conducted, Ss were not developed for this model.

3.7 WATER SOURCES AND SINKS

3.7.1 Recharge

Recharge from precipitation is a significant source of water to the flow system. Details on recharge are presented in Section 3.4.4.

3.7.2 Rivers

Groundwater in the model area discharges primarily to the Cuyahoga River and Big Creek. Additional details on these surface water features are provided in Section 3.4.3.

3.7.3 Drainage

Surface water drainage features at the Former Harshaw Chemical Company Site include several stormwater outfalls, storm sewers, and minimal drainage ditches, which are detailed in Section 2.3.4.3 of the RI Report (USACE 2009). Surface drainage to catch basins may not be transmitted to operating storm sewers that discharge to the Big Creek or the Cuyahoga River due to clogs or sediment accumulation. Many stormwater outflows do not pass water during or after precipitation events, and thus drainage is less efficient than originally designed for the site. No significant drainage ditches occur on-site, and groundwater in the fill and alluvium occurs at elevations beneath the bottom of topographic depressions. The degraded stormwater management system promotes more infiltration to groundwater than would be expected if the sewer lines were fully transmissive. The only outfall that routinely discharges to the Cuyahoga River is near well DM-27R, where discharge may be both surface and groundwater due to its invert depth at the day-light point on the bank (i.e., it falls at or below the local groundwater level, and it is the primary trunk line from several catch basins near Building G-1, several of which are in poor condition). This outflow is the primary discharge for stormwater from IA03 and IA04, and it does not appear to be fully operating during storm events.

3.7.4 Pumping

An extraction well system is operated in the model area to limit infiltration of a nickel groundwater plume into and along the bedding of a sewer line running from Chemical Solvents, Inc. to a Harvard Avenue trunk line. The subject sanitary sewer line is oriented north-south and runs along the west side of Building G-1. Personnel at Engelhard (the system operator) claim the system averages approximately 5 gpm (18.9 L/minute) while operating. Operation is not continuous, and so the 5 gpm estimate is regarded as a rough ceiling on the long-term average extraction rate for the system as a whole. Six extraction wells are located directly along the sanitary sewer line, and two more are located to the east, roughly between the foundry and the warehouse. No information is available on per-well extraction rates.

3.8 CONTAMINANT CHARACTERIZATION

This section presents a discussion of sources and the current extent of total uranium contamination in groundwater in the study area. Although thorium is also a COC in groundwater in the model area, the extent of thorium contamination is less than that of total uranium, and thorium is generally less mobile than uranium. Consequently, this contaminant characterization section focuses on total uranium. Ultimately, potential thorium transport in OU-1 is evaluated qualitatively in this modeling report, taking into consideration quantitative total uranium transport predictions in OU-1 and relative mobility, plume footprint, and continuing sources for thorium versus total uranium.

Characterization of total uranium contamination is discussed in detail in the RI (USACE 2009), and a summary discussion is presented here.

3.8.1 Contaminant Sources

Total uranium contamination in soil and groundwater in the model area resulted from a wide variety of past activities at Harshaw Chemical, including:

- Releases to surface soil from air stacks, dusts, and spills around Building G-1;
- Releases to surface soil in MED material laydown yards;
- Releases to soil and groundwater via burial of contaminated soil and waste;

- Releases to soil and groundwater via use of contaminated soil and waste as fill; and
- Releases to soil and groundwater via leaky building drains (e.g., in Building G-1) and leaky sewer systems in general.

Although a gross removal of MED materials was conducted during historical site operations, residuals remain. Remaining total uranium contamination in soil can potentially serve as a long-term source for groundwater contamination via leaching.

3.8.2 Groundwater Contamination

Figure D-20 presents the interpreted total uranium plume in OU-1 groundwater. At each monitoring location, the maximum of all of the unfiltered total uranium results (which potentially span the period from 2004 through 2011) is conservatively used. Unfiltered and filtered total uranium results for Harshaw groundwater samples are generally very similar.

The outermost contour in Figure D-20 is the total uranium MCL of 30 µg/L. As discussed in Section 1, the MCL is used here as a point of comparison and not as a groundwater compliance standard since groundwater is not a medium of concern in the Harshaw FS. Total uranium results above the MCL are generally confined to the immediate vicinity of Building G-1, a primary source area. Impacts to wells north/northeast of Building G-1 are coincident with Building G-2 and the associated high-security storage yard (MED material laydown areas) to the north (between the building and railroad tracks). Analysis of aerial photos for the RI suggests the prior presence in these areas of significant quantities of MED material, which were likely more highly contaminated than what is currently observed on-site. Although a gross removal of those materials was conducted during historical site operations, soil and groundwater residuals help to explain the current contaminant distribution.

The above-background results along the Cuyahoga River are consistent with the use of contaminated fill along the river bank. In addition to being attributable to the use of contaminated fill, the above MCL result at DM-27R may also have originated from known past discharge of Engelhard treatment facility water (treated for lead; untreated for total uranium) to the storm sewer. Bank collapses at the Cuyahoga River in this area prompted replacement of well DM-27 with well DM-27R and may have promoted leaks in this sewer line that caused localized groundwater impacts.

3.9 TRANSPORT PROPERTIES

3.9.1 Dry Bulk Density

Site-specific dry bulk density (ρ_b) data were not collected. Wet bulk density data for three native soil samples (presented in Table 6-10 of the RI; USACE 2009) range from 2.16 to 2.44 g/cm^3, with a mean of 2.32 g/cm^3. These data provide an upper limit on the dry bulk density of the site overburden.

Literature dry bulk density values for unconsolidated soil range from about 1.1 g/cm^3 for clay to 1.6 g/cm^3 for sand (Argonne National Lab 2011). Literature dry bulk density values for shale range from 2.2 to 2.7 g/cm^3 (Morris and Johnson 1967).

3.9.2 Sorption

Sorption of contamination to aquifer material is typically represented as an equilibrium process characterized by the equilibrium distribution coefficient (K_d). In this approach, the sorbed- and dissolved-phase concentrations are assumed to be in equilibrium, and the sorbed-phase concentration divided by the dissolved-phase concentration is the K_d, which is specified in the numerical model.

Site- and contaminant-specific K_d values may be determined experimentally, and K_d values may be estimated from literature information.

Attachment 1 details the development of K_d values for total uranium, thorium, and radium for the Former Harshaw Chemical Company Site. Although this modeling study focuses on prediction of total uranium fate and transport, K_d values were also developed for thorium and radium for use in confirming that the proposed soil cleanup criteria for these two contaminants are also protective of groundwater (Section 6.3.5). Recommended K_d values for the Former Harshaw Chemical Company Site are as follows:

- Uranium: 1,000 milliliters per gram (mL/g)
- Thorium: 10,000 mL/g
- Radium: 1,000 mL/g

During active Harshaw Chemical Company operations, process acids were likely discharged to the environment along with total uranium, causing subsurface geochemical conditions to differ from those at present. The uranium K_d is very sensitive to low pH, and it is therefore likely that the K_d was much lower at the time of uranium release than it is today. Together with widespread contaminant release mechanisms (Section 3.8.1), this lower K_d in the past helps to explain the current extent of total uranium in groundwater (Section 3.8.2) under the very high present-day K_d value developed above.

3.9.3 Decay Rates

The primary uranium isotopes of interest at the Former Harshaw Chemical Company Site have slow decay rates. Uranium-238 (U-238), uranium-235 (U-235), and uranium-234 (U-234) have half-lives of 4.46E+9, 7.04E+8, and 2.45E+5 years, respectively (IEER 2011). These half-lives are much greater than the 1,000-year performance period for total uranium transport evaluation. Consequently, decay of uranium is neglected for this fate and transport analysis.

3.9.4 Dispersion

Dispersion is the spreading of contaminants in the subsurface resulting from a combination of mixing (due to local velocity variations) and diffusion. Dispersion is represented in numerical modeling via specification of the dispersivity parameter(s). For 3D flow and transport, these include the longitudinal dispersivity, transverse horizontal dispersivity, and transverse vertical dispersivity.

Site-specific dispersivity data are not available for the study area. Literature values are available, but dispersivity has frequently been shown to be scale-dependent (Schulze-Makuch 2005), meaning that the appropriate value is proportional to plume size. In an analysis of published longitudinal dispersivity data from 109 authors, an empirical power law was developed relating longitudinal dispersivity to the flow distance for various geologic media (Schulze-Makuch 2005). Using the power law scaling exponent and characteristic parameter developed therein for unconsolidated materials (0.81 and 0.085, respectively) and a flow distance of 300 ft (the rough size of the total uranium plume), a longitudinal dispersivity on the order of 10 ft may be estimated. Taking into account the stated uncertainty in estimates from the power law (Schulze-Makuch 2005), the site-specific longitudinal dispersivity may range up to an order of magnitude or more around this estimate of 10 ft. At Harshaw, where the groundwater flow system has a significant advective component, this uncertainty does not significantly affect transport predictions.

The transverse horizontal dispersivity is typically specified as an order of magnitude less than the longitudinal dispersivity. In turn, the transverse vertical dispersivity is typically specified as an order of magnitude less than the transverse horizontal dispersivity.

3.10 CONCEPTUAL MODEL SUMMARY

The key features governing groundwater flow and contaminant transport in the study area are summarized below. Flow is presented first, followed by contaminant transport. This conceptual model serves as the foundation from which to build the numerical groundwater flow and contaminant transport model.

3.10.1 Flow

Groundwater flow occurs primarily in the overburden and, to a lesser extent, in the underlying weathered bedrock. Soil texture varies significantly within each of the overburden units (Native Sediment, Old Fill, and New Fill). However, evaluation of available water level data from wells completed in these various units does not indicate significant vertical gradients across the different soil. Consequently, the overburden units are represented in the numerical groundwater flow model as a single layer (model layer 1). The weathered bedrock is represented as a second layer (layer 2). Flow in the weathered bedrock is believed to be controlled by flow in the overburden.

Groundwater flow is generally from the uplands on the west toward Cuyahoga River on the east and Big Creek on the south (Figure D-15). A potentiometric high occurs beneath and to the south of Building G-1, coincident with a bedrock high. Flow in the model area originates at the base of the western uplands from (1) throughflow in the adjacent unconsolidated zone and weathered bedrock and (2) surface water run-off from the upland slope during storm events. Flow also originates throughout the model area from infiltration of precipitation. Flow is unconfined within the model area.

The primary sinks in the model area are Cuyahoga River and Big Creek. An extraction well system also removes groundwater at an estimated rate below 5 gpm to limit infiltration of a nickel groundwater plume into and along the bedding of a sewer line running from Chemical Solvents, Inc. to a Harvard Avenue trunk line.

3.10.2 Transport

Total uranium contamination in soil and groundwater in the model area resulted from a wide variety of past activities at Harshaw Chemical, including:

- Releases to surface soil from air stacks, dusts, and spills around Building G-1;
- Releases to surface soil in MED material laydown yards;
- Releases to soil and groundwater via burial of contaminated soil and waste;
- Releases to soil and groundwater via use of contaminated soil and waste as fill; and
- Releases to soil and groundwater via leaky building drains (e.g., in Building G-1) and leaky sewer systems in general.

The current extent of total uranium in groundwater in the model area is presented in Figure D-20. Total uranium results exceeding the MCL of 30 µg/L are generally confined to the immediate vicinity of Building G-1, a primary source area. Impacts to wells north/northeast of Building G-1 are coincident with Building G-2 and the associated high-security storage yard (MED material laydown areas) to the north (between the building and railroad tracks). Analysis of aerial photos for the RI suggests the prior presence in these areas of significant quantities of MED materials, which were likely more highly contaminated than what is currently observed on-site. Although a gross removal of those materials was

conducted during historical site operations, soil and groundwater residuals help to explain the current contaminant distribution. The above-background results along the Cuyahoga River are consistent with the use of contaminated fill along the river bank.

The estimated site-specific K_d of 1,000 mL/g for total uranium corresponds to a contaminant transport retardation factor (Rf) of roughly 1E+4. The travel velocity of total uranium in the saturated zone would be reduced by this factor relative to the groundwater flow velocity. If this K_d had prevailed since the release of total uranium to the subsurface at Harshaw, insignificant lateral migration of total uranium would have occurred in the saturated zone since its release. However, at the time of total uranium release, the K_d was likely much lower due to discharge of process acids in the same areas. Together with the widespread contaminant releases listed above, this lower K_d in the past helps to explain the current extent of total uranium in groundwater (Figure D-20).

The uranium K_d lower limit of approximately 10 mL/g [indicated by the non-equilibrium 24-hour distribution ratio testing done in the RI (USACE 2009)] equates to an Rf of approximately 100. This Rf is sufficiently high that very little lateral saturated zone transport or vertical vadose zone leaching of uranium would have occurred from the time of release until the present. Thus, even at this lower uranium K_d limit established using laboratory data, uranium must have reached the groundwater by the type of mechanisms noted above. This reinforces the view that total uranium groundwater “plumes” are more likely a series of isolated occurrences of groundwater contamination associated with corresponding contaminant releases at or very near those locations.

Similarly, given the very high total uranium K_d of 1,000 mL/g, residual total uranium in the vadose zone will leach extremely slowly to the saturated zone.

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4. MODELING CODE SELECTION AND DESCRIPTION

Once the conceptual model has been formulated, it is translated into a numerical representation of the groundwater flow system. The first step is selection of a numerical modeling code that can meet the objectives of the project and is appropriate to the hydrogeologic and contaminant features represented in the conceptual model.

MODFLOW-SURFACT version 2.2 (HydroGeoLogic 1996) was selected as the numerical modeling code for this project. MODFLOW-SURFACT is a fully integrated groundwater flow and solute transport code developed by HydroGeoLogic, Inc. based on the USGS groundwater modeling code, MODFLOW (Harbaugh and McDonald 1996; McDonald and Harbaugh 1988). Like MODFLOW, MODFLOW-SURFACT is a 3D finite-difference groundwater flow modeling package that can be used to simulate steady and non-steady flow. Aquifer layers can be simulated as confined, unconfined, or a combination thereof. External flow stresses such as wells, areal recharge, and flow through river beds can be simulated. Aquifer properties, such as hydraulic conductivity (K), may differ spatially and be anisotropic (although the principal direction of flow and anisotropy should be aligned with the grid axes).

MODFLOW-SURFACT provides a number of enhancements relative to MODFLOW, including:

- The ability to simulate variably saturated flow with pseudo-soil water retention functions;
- The ability to readily accommodate conditions of desaturation/resaturation of aquifer systems;
- The fractured well package can overcome MODFLOW limitations when simulating pumping wells in areas of thin saturated thickness;
- The robust pre-conditioned conjugate gradient solver for solving the flow equation, combined with a Newton-Raphson linearization solver with backtracking scheme for step control, to improve the robustness of simulations for unconfined or unsaturated fluid flow cases;
- The ability to perform transient simulations efficiently using an adaptive time-stepping scheme;
- The state-of-the-art numerical schemes for solving the transport equation, including a total variation diminishing (TVD) flux-limiting scheme designed to provide accurate, physically correct, and strictly mass-conserved numerical solutions. Numerical dispersion as a result of grid discretization is virtually eliminated by this scheme;
- The ability to perform multi-component reactive transport simulations; and
- The adaptive implicit transport scheme is available to minimize temporal discretization errors.

The first two related enhancements are significant for this model because they permit efficient and more accurate simulation of the area of thin saturated thickness overlying the bedrock high at Building G-1. In addition, the integrated transport capability in MODFLOW-SURFACT is generally easier to use and more robust than contaminant transport options generally coupled with MODFLOW.

The flow model calibration was automatically calibrated using PEST software (Watermark Numerical Computing 2010). PEST is a non-linear parameter estimator with a range of powerful model calibration

options. Parameter adjustments are made within established ranges to simulate observed water levels and flows that match observed data within an acceptable range of error.

To assist in qualitative contaminant transport model calibration, the USGS computer program MODPATH was used. MODPATH is a groundwater particle-tracking package that computes 3D flow paths using output from steady-state or transient groundwater flow simulations by MODFLOW (Pollock 1994). MODPATH allows for the analysis of groundwater flow times and flow directions. For example, if contaminant release is known to have occurred at a given location 50 years ago, particle tracking simulations may be performed with groundwater particles starting at the source location and allowed to travel in the flow field for 50 years. The particle locations at 50 years (i.e., the present) may then be compared to the current extent of the known contamination. This can provide a helpful gauge to determine if the flow directions/patterns and velocities are appropriate. It is important to realize that particle tracking includes only the effects of advective flow, and neglects dispersion, sorption, and degradation. These factors must be kept in mind when comparing the particle tracking results to the observed contaminant distribution.

Contaminant leaching in the vadose zone was simulated using the Finite Element Heat and Mass Transfer Code (FEHM) v3.0 (Zyvoloski 2007). FEHM can be used to simulate 3D, time-dependent, multi-phase, multi-component, non-isothermal, reactive flow through porous and fractured media. It can accurately represent complex 3D geologic media and structures and their effects on subsurface flow and transport. FEHM has been used to simulate groundwater and contaminant flow and transport in deep and shallow, fractured and unfractured porous media throughout the United States Department of Energy (DOE) complex. Specific capabilities include:

- 3D simulation;
- Flow of gas, water, oil, and heat;
- Flow of air, water, and heat;
- Flow of carbon dioxide (CO_2), water, and heat;
- Simulation of gas hydrates;
- Multiple chemically reactive and sorbing tracers;
- Finite element/finite volume formulation;
- Coupled stress module;
- Saturated and unsaturated media;
- Preconditioned conjugate gradient solution of coupled linear equations;
- Fully-implicit, fully-coupled Newton-Raphson solution of nonlinear equations;
- Double porosity and double porosity/double permeability capabilities; and
- Complex geometries with unstructured grids.

For application to Harshaw, the capability for robust simulation of unsaturated zone flow and transport is key. Leaching simulations for the RI were previously conducted using the SESOIL model, a one-dimensional, vertical transport model for the unsaturated zone. The FEHM code is far more robust and sophisticated than the screening-level SESOIL code, and was therefore selected for FS vadose zone leaching simulations.

5. NUMERICAL GROUNDWATER FLOW MODEL

This section documents the construction, calibration, and uncertainties in the numerical groundwater flow model.

5.1 CONSTRUCTION

Construction of the numerical groundwater flow model involves translating the conceptual flow model into a numerical representation within the selected modeling code, MODFLOW-SURFACT.

5.1.1 Model Grid

The model area is first discretized by superimposing a 3D, block-centered grid over the system. The areal and vertical structure of this grid is described below.

5.1.1.1 Vertical Structure

Vertically, the model includes two layers to simulate flow and transport in the overburden (layer 1) and weathered bedrock (layer 2). The top of layer 1 is specified based on the topography and the top of layer 2 is specified based upon the top of the weathered bedrock (see Section 3.3.2). Layer 2 is uniformly specified as 5 ft thick throughout the model area.

5.1.1.2 Areal Structure

Areally, the block-centered, finite-difference grid superimposed over each layer in the model area is a grid of cells measuring 20 ft by 20 ft. The overall footprint and areal discretization of this grid are shown in Figure D-21. The lateral extent of the grid was established according to two considerations: (1) the grid must encompass the region of interest for simulating groundwater flow (and solute transport), and (2) the grid extent should correspond to appropriate natural hydrogeologic boundaries to the extent practical. As shown in Figure D-21, some portions of the grid are active and some are inactive (no-flow). This is done in order to best represent hydrologic boundaries discussed in the following section.

5.1.2 Boundary Conditions

Boundary conditions are conditions imposed upon a flow or transport model to simulate interaction between the area modeled and internal or external influences, such as rivers along the edge of the model domain or wells discharging from within the model domain. Four boundary condition types were specified in this model: no-flow, constant head, constant flux, and well boundaries.

In general, it is desirable that model boundaries correspond to natural hydrogeologic boundaries (e.g., rivers, lakes, bedrock valley walls). However, when natural hydrogeologic boundaries are far removed from the model area, it may be numerically impractical to make lateral model boundaries correspond with natural hydrogeologic boundaries. In such cases, the model boundary is an artificial hydrogeologic boundary, specified according to conditions observed at or beyond the boundary location.

5.1.2.1 No-flow Boundaries

No-flow boundaries were specified in two primary types of locations: at the bottom of the model and along portions of the lateral boundary of the model.

A no-flow boundary was specified at the model bottom, as the underlying competent shale is expected to have a hydraulic conductivity at least two orders of magnitude less than that of the weathered shale (layer 2; bottom layer of model).

Laterally, no-flow boundaries were established in layer 1 at perimeter locations corresponding to flow lines (i.e., perpendicular to potentiometric surface contours). Potentiometric surfaces were examined to establish the active extent of the model and the appropriate no-flow boundaries. No-flow boundaries were specified in layer 1 at the locations indicated in Figure D-21. The no-flow boundaries are located along the extreme northern and western portions of the model area.

No-flow boundaries were assigned around the entire perimeter of the weathered bedrock (layer 2), thereby allowing the overburden (layer 1) to control bedrock conditions.

5.1.2.2 Constant Head Boundaries

Constant head boundaries were used to represent the Cuyahoga River and Big Creek in layer 1 (Figure D-21). Although river boundaries could also be used to represent these surface water features, specification of river boundaries is more complex, requiring specification of the conductance of the river bed material, a parameter for which data are not available for the site. Because monitoring well data near the Cuyahoga River and Big Creek indicate good hydraulic communication between the water-bearing zone and the surface water, and these are additionally surface water bodies with significant flows, representation of the Cuyahoga River and Big Creek with constant head boundaries is reasonable.

For the purposes of long-term total uranium transport prediction, short-term (both precipitation event and seasonal) fluctuations in river stage are unimportant. From this standpoint, the use of constant head boundaries is also appropriate.

The river stage data discussed in Section 3.4.3 were used to specify head values for the constant head boundaries representing the Cuyahoga River and Big Creek. At the confluence of the Cuyahoga River and Big Creek, a constant head of 574.75 ft (175.18 m) was specified. About 1,800 ft (548.6 m) downstream on the Cuyahoga River at the Harvard-Denison Bridge, a constant head of 574.61 ft (175.14 m) was specified. Constant head values were interpolated in 0.05-ft (0.02-m) increments between these locations. Additionally, the gradient between these locations (8E-5 ft/ft) was used to extrapolate constant heads downstream of the Harvard-Denison Bridge; these values were also specified in 0.05-ft (0.02-m) increments.

Approximately 500 ft upstream on Big Creek, at the rail bridge south of IA05, a constant head of 575.51 ft was specified. Between this location and the confluence with the Cuyahoga River (stage of 574.75 ft, as described above), constant head values were smoothly interpolated. The gradient between these locations (0.0015 ft/ft) was used to extrapolate constant heads on Big Creek upstream of the rail bridge. These values were specified in 0.5-ft increments.

5.1.2.3 Constant Flux Boundaries

The western boundary of the model representing flow from the toe of the western upland was assigned a constant flux boundary in layer 1 (Figure D-21). While general head boundaries could have been used here, no information was available to quantify either the head term for the distant boundary represented by the general head, or the conductance term from the actual model perimeter to the distant boundary. A constant flux boundary was instead more appropriate and simpler for representing flow into the model area at the toe of the western uplands both from (1) throughflow in the adjacent unconsolidated zone and weathered bedrock and (2) surface water run-off from the upland slope during storm events.

The magnitude of the constant flux was established by temporarily specifying constant head boundaries along the western upland and calibrating the model with these boundaries. The constant head values were specified by extrapolating the potentiometric surface to the toe of the western uplands. Once the model was calibrated, the constant head boundaries were then converted to constant flux using the simulated flux values from the constant heads. These simulated flux values average about 16 ft^3/day (0.5 m^3/day) for the model cells along the western upland. The simulated head distribution and water balance is unchanged by this conversion. However, the advantage of this conversion is that if additional stresses are imposed upon the model area, such as increased pumping, then the nearby constant flux boundaries will supply the same amount of water, whereas constant head boundaries would represent a potentially infinite source of water. Although the calibrated model includes an active extraction system, the total pumping rate is low (2.5 gpm), and thus the constant fluxes developed as described above are not unduly influenced by this system.

Constant flux boundaries may be implemented via either well boundaries or recharge in MODFLOW-SURFACT (as in MODFLOW). In this case, the constant flux boundaries at the toe of the western uplands were implemented using well boundaries.

5.1.2.4 Well Boundaries

As described above, well boundaries were used to specify constant fluxes along the toe of the western uplands.

In addition, well boundaries were used to represent the extraction well system operated in the model area to limit infiltration of a nickel groundwater plume into and along the bedding of a sewer line running from Chemical Solvents, Inc. to a Harvard Avenue trunk line. As discussed in Section 3.7.4, personnel at Engelhard (the system operator) claim the system averages approximately 5 gpm while operating. Operation is not continuous, and for the purpose of model calibration, the central assumption was made that the system operates half the time. Under this assumption, the average extraction rate would be 2.5 gpm. No information is available on per-well extraction rates, and therefore this 2.5 gpm total was split equally among the eight wells in the system for simulation in the model (Figure D-21).

5.1.3 Hydraulic Parameters

Hydraulic parameters, including K and effective porosity (η_e), are assigned to model grid cells based on a combination of site-specific measurements, literature values, and model calibration. The following sections discuss assignment of these properties.

5.1.3.1 Hydraulic Conductivity

The hydraulic conductivity distributions specified in the model for the overburden (layer 1) and the weathered bedrock (layer 2) are presented in Figures D-22 and D-23, respectively. In the overburden, the sanitary sewer line bedding is expected to have a high horizontal hydraulic conductivity (Kh), representative of gravel. The Kh along the sanitary sewer line in the overburden layer was permitted to vary between 100 and 500 ft/day during PEST auto-calibration, with a uniform value maintained along the entire line. The PEST calibrated value was 100 ft/day.

The Kh of the remainder of the overburden was permitted to vary within specified limits during PEST auto-calibration. Consistent with the Kh range from slug test data (Section 3.6.1), overburden Kh values were generally permitted to vary between 0.1 and 100 ft/day. Exceptions to this were the extreme northern portion of the model (~750 ft interval) and the extreme western portion of the model (~500 ft

interval), where no water level target data are available. Due to the lack of target data in these areas, PEST calibration is insensitive to (and can therefore be hindered by excess) adjustment of conductivities in these areas. Consequently, the Kh in these areas was allowed to vary within a narrower range of 2 to 4 ft/day (consistent with the geometric mean of slug test data).

The final PEST-derived Kh distribution for the overburden (exclusive of the sanitary sewer line bedding) varies spatially between 0.1 and 50 ft/day (Figure D-22). Areas of higher Kh are evident along the IA-04 river bank, consistent with fill emplacement. Areas of lower Kh are evident in higher hydraulic gradient areas, such as between Building G-1 and IA-04.

The majority of the weathered bedrock was assigned a Kh of 1 ft/day, while the bedrock high area under and near building G-1 was assigned a lower Kh of 0.1 ft/day (Figure D-23). The bedrock high Kh (0.1 ft/day) is consistent with slug test results for weathered bedrock well RMW-38 (Section 3.6.1), which is located within this zone. The bedrock high was previously lowered (excavated) to develop the property, so the remaining exposed bedrock at this high should be less weathered and therefore have a lower conductivity than the weathered bedrock in the balance of the site. Thus, the balance of the site was assigned an order of magnitude higher Kh (1 ft/day). During model calibration, simulated water levels were relatively insensitive to these bedrock Kh values.

Kz was uniformly specified as one-tenth of the Kh during PEST auto-calibration.

5.1.3.2 Effective Porosity

Effective porosities of 0.18 and 0.08 were assigned to the overburden (layer 1) and the weathered bedrock (layer 2), respectively. Both are consistent with expected ranges based on site-specific information and literature (Section 3.6.2).

5.1.3.3 Specific Yield

The Sy is relevant only for transient flow simulations. Because only steady-state flow simulations were conducted, Sy values were not assigned for this model.

5.1.3.4 Specific Storage

As with Sy, Ss is relevant only for transient flow simulations. Because only steady-state flow simulations were conducted, Ss values were not assigned for this model.

5.1.4 Recharge

The recharge distribution specified in the model is presented in Figure D-24. Recharge was specified based on land-cover considerations combined with literature data for the region and site-specific HELP and SESOIL simulations (see Section 3.4.4).

Zone 1 represents areas with vegetated soil and was assigned a recharge rate of 6 in/yr, consistent with both regional info on recharge to groundwater for similar water table depth and site-specific HELP and SESOIL simulations conducted for the RI, as discussed in Section 3.4.4.

Zone 2 represents cracked pavement and gravel and was assigned a recharge rate of 12 in/yr. HELP simulations for cracked pavement suggest recharge ranging from approximately 10 to 17 in/yr, as discussed in Section 3.4.4. For gravel areas, infiltration would be higher than for cracked pavement, but

so too would be evapotranspiration. The limited gravel areas were therefore assumed to have the same recharge as the cracked pavement areas.

Zone 3 represents relatively impervious areas (intact pavement and buildings). A recharge rate of 1 in/yr was assigned in these areas.

Zone 4 represents an area of highly fragmented pavement present between Building G-1 and the Cuyahoga River. This area is thoroughly vegetated, and similar recharge is expected here as in unpaved, vegetated areas. Consequently, a recharge rate of 6 in/yr was assigned in this area.

Zone 5 represents an area of focused recharge coincident with the eastern portion of the Building G-1 footprint. During the RI, precipitation was observed to collect on the building floor in this area. Cracks present in the slab provide a preferential pathway for leakage into the subsurface here. In addition, leaky roof and floor drains promote focused recharge in this area. A recharge rate of 25 in/yr was assigned in this small area.

Zone 6 has a zero recharge rate and is assigned to model cells along the toe of the western uplands. As discussed in Section 5.1.2.3 and depicted in Figure D-21, these cells are assigned constant flux (well) boundary conditions to represent flow into the model area at the toe of the western uplands both from (1) throughflow in the adjacent unconsolidated zone and weathered bedrock and (2) surface water run-off from the upland slope during storm events.

5.2 CALIBRATION

Model calibration is an iterative process by which model input parameters (i.e., boundary conditions, hydraulic conductivity, stresses, etc.) are varied within plausible ranges until model predictions (e.g., simulated water levels) match observed conditions (e.g., target water levels). Calibration of the flow model was completed to ensure that the model can be reliably used for predictive assessment of groundwater flow (and ultimately contaminant transport, as discussed in Section 6). Components of flow model calibration include comparison of simulated water levels to target water levels, evaluation of the flow budget, and completion of a sensitivity analysis.

The model was calibrated using the automated calibration software PEST (Watermark Numerical Computing 2010). As described in Section 5.1.3.1, acceptable ranges were specified for the conductivity of various areas of model layer 1. Other model parameters, including boundary conditions and recharge, were fixed at values described in Sections 5.1.2 and 5.1.4, respectively. PEST then varied the conductivity distribution until the difference between observed and simulated heads (i.e., the head residuals) was reduced to a user-specified, acceptable level. During this auto-calibration, a regularization constraint was imposed in PEST. In simple terms, this constraint homogenizes or smoothes the calibrated conductivity field, avoiding extreme heterogeneity resulting from overfitting. This typically results in a slightly poorer match of the observed heads, with the benefit of a less extreme conductivity distribution.

Model calibration was performed for steady-state conditions using the May 2005 water level dataset as water level calibration targets. The calibration simulation includes operation of the groundwater extraction system at rates and locations described in Section 5.1.2.4.

5.2.1 Head Calibration

Evaluation of the steady-state head calibration is both qualitative and quantitative. For the former, the simulated steady-state potentiometric surface for the overburden (layer 1) is qualitatively compared to the May 2005 potentiometric surface (Section 3.4.2) to ensure that general flow directions and patterns are

matched. For the latter, simulated water levels are compared to May 2005 observed target water levels at well locations in the model domain. Residuals (observed minus simulated water levels) are calculated for each target location. A residual of 0 ft indicates that the observed and simulated water levels match; deviation from 0 (either positive or negative) indicates a decreasing match. Residual statistics are calculated and compared to accepted standards.

Simulated potentiometric surfaces for the overburden (layer 1) and the weathered bedrock (layer 2) are presented in Figures D-25 and D-26. These are very similar to one another, as the weathered bedrock is modeled as an extension of the overburden. Simulated flow patterns in the overburden (Figure D-25) are very similar to observed May 2005 flow patterns (Figure D-15). Flow is generally from the toe of the western uplands toward the Cuyahoga River and Big Creek. The potentiometric high coincident with the bedrock high in the Building G-1 area is also reproduced, as is the potentiometric low associated with operation of the groundwater extraction system.

Head residuals are posted on Figures D-25 and D-26, and also presented in Table D-3. Residuals are generally near zero, demonstrating that simulated water levels match well with the observed water levels. In addition, the residuals do not show significant spatial bias (i.e., positive and negative residuals are distributed more or less randomly). Summary statistics are provided in Table D-4. The residual mean is -0.1 ft, indicating that the model has an insignificant overall bias toward overpredicting heads. The residual standard deviation and the absolute residual mean are low, indicating that residuals are generally tightly clustered around the ideal value of 0 ft. The residual standard deviation divided by the overall range in target head values is a critical measure of model calibration. The range for a well-calibrated model is 10 to 15% (Environmental Simulations Inc. 2004). As shown in Table D-4, this parameter is 6.4%, well within acceptable limits.

Another useful visualization of model calibration is a plot of simulated versus observed water levels (Figure D-27). For an ideal calibration, all points lie on a 45-degree line (i.e., slope = 1) passing through the origin. As shown in Figure D-27, the simulated versus observed data are tightly clustered around the ideal 45-degree line. The correlation coefficient (R^2) of the observed versus measured water levels is 0.95 (Figure D-27), indicating a good fit of the simulated to the observed heads.

In summary, the quantitative and qualitative evaluations indicated that the model accurately reproduces water levels and flow patterns in the model area.

5.2.2 Flow Budget

Table D-5 presents the water balance results in the calibrated steady-state model. The total water balance error is 0.02%, two orders of magnitude below the typical maximum acceptable limit of 1%. Recharge is the primary source of inflow in the model, contributing approximately 4,800 ft^3/day, or about 66% of the inflow. The constant flux boundaries at the toe of the western uplands contribute approximately 2,500 ft^3/day, or approximately 34% of the inflow. For outflow, 73% is to the Cuyahoga River, 21% is to Big Creek, and 6% is to the groundwater extraction system.

5.2.3 Calibration Sensitivity Analysis

In a flow model sensitivity analysis, the sensitivity of the dependent variable (hydraulic head) to the independent variables is determined. An independent variable that significantly affects the calibrated model condition, when changed within the range of measured or observed values, is considered to be a sensitive parameter.

The parameters considered for this sensitivity analysis are hydraulic conductivity (Kh and Kz), recharge, and the nickel extraction system pumping rate. Only one parameter (e.g., Kh) was varied at a time to determine the sensitivity of the model to this parameter alone. The Kh distribution for the entire model was multiplied by 0.5, 0.75, 0.9, 1.0, 1.1, 1.25, and 1.5 to ascertain the effects on the model flow solution. For the Kz distribution, multipliers of 0.1, 0.3, 1.0, 3.0, and 10.0 were used. For recharge, parameters were varied on a zonal basis; multipliers of 0.5, 0.75, 0.9, 1.0, 1.1, 1.25, and 1.5 were applied to each recharge zone (zones 1 through 5) individually. For the extraction system rate, multipliers of 0.5, 2.0, and 4.0 were used.

The results of the sensitivity analysis for Kh, Kz, recharge, and extraction system pumping rate are presented in Figures D-28 through D-31. As shown on these figures, sensitivity results are evaluated in terms of the percent change in root mean square error (RMSE) of the residuals relative to the base case. The base case is the calibrated model described in the preceding sections (i.e., the base case uses the parameter values described in the preceding sections) and is the case with multipliers for all zones equal to 1.0. For the base case, the RMSE of the residuals is calculated by squaring all the residuals, summing the squares, dividing the sum by the number of residuals, and taking the square root of this quotient. The same operation is done for each sensitivity run. Finally, for each sensitivity run, the change in RMSE relative to the base case ($RMSE_{Run_i} – RMSE_{base}]/RMSE_{base}$) is calculated. For a given sensitivity run, a positive change in RMSE relative to the base case indicates poorer water level calibration relative to the base case, while a negative change indicates better calibration.

Because the RMSE involves squaring residuals, this measure of error is more sensitive to extreme residuals than other measures of error, such as the mean residual. This is desirable from the standpoint of identifying, based on this summary statistic alone, unacceptable localized impacts in the sensitivity analysis simulations.

Model calibration is very sensitive to changes in Kh, with the best results occurring for the base case (Figure D-28). Model calibration is insensitive to changes in Kz, with the RMSE varying by only a few percentage points from the base case (Figure D-29).

Model calibration is sensitive to the recharge values for zones 1 and 2, and insensitive to the recharge values for zones 3 through 5 (Figure D-30). Model calibration is not sensitive to a decrease in extraction system pumping rate, but is very sensitive to an increase in pumping rate (Figure D-31).

5.3 UNCERTAINTIES

Sources of uncertainty associated with the steady-state flow model developed in this section include:

- Hydraulic conductivity,
- Recharge,
- Extraction system rate,
- Boundary conditions, and
- Head calibration target dataset.

5.3.1 Hydraulic Conductivity

Hydraulic conductivity can vary over several orders of magnitude even in fairly homogeneous geologic materials. However, extensive site-specific slug test data provide realistic bounds on the K, and the flow model calibration and sensitivity analysis demonstrate that the K field developed for this model adequately reproduces observed water levels and flow patterns.

5.3.2 Recharge

Recharge may vary spatially over a wide range, depending primarily upon land cover. Recharge was specified based on land-cover considerations combined with literature data for the region and site-specific HELP and SESOIL simulations (see Section 3.4.4). A realistic, well-founded recharge distribution was established, and the model was able to be successfully calibrated by adjusting the K distribution within acceptable ranges.

5.3.3 Extraction System Rate

The extraction system rate was assumed to be a long-term average of 2.5 gpm based upon limited input from the system operator. While the model was calibrated with this rate, it is possible that the extraction rate may be significantly different from 2.5 gpm. To explore the effects of the uncertainty in extraction rate upon the model calibration, an alternate calibration was conducted in which the model was calibrated assuming an extraction rate of 5.0 gpm. The calibrated conductivity fields for 2.5 gpm and 5.0 gpm were very similar, with changes generally occurring very near the extraction wells. Differences would result in very little impact upon long-term fate and transport predictions.

5.3.4 Boundary Conditions

Little uncertainty is associated with the representation of Big Creek and the Cuyahoga River. Somewhat greater uncertainty is associated with the constant flux boundary conditions at the toe of the western uplands. These constant flux boundaries were established during calibration and depend somewhat upon the extraction system rate; thus, uncertainty in the extraction system rate leads to uncertainty in these constant flux boundary conditions.

5.3.5 Head Calibration Target Dataset

May 2005 water levels were used as the head calibration target dataset. Errors in water levels are limited to measurement and recording errors, which are slight in comparison to the observed head range over the model domain.

5.4 CONCLUSIONS

Section 5 documents the construction, calibration, and uncertainties of the numerical groundwater flow model for the model area. A two-layer numerical groundwater flow model, which simulates groundwater flow in the overburden (layer 1) and weathered bedrock (layer 2), was developed to support the evaluation of groundwater flow and contaminant transport in the model area. The flow model was developed by integrating all available field data, as discussed in the conceptual model presented in Section 3. The numerical flow model was calibrated under steady-state conditions. Sensitivity analyses were performed to aid in specification of parameter values and understanding of the flow system. Uncertainties were identified with respect to hydraulic parameters, boundary conditions, and model calibration data.

Major conclusions from the groundwater flow model development include:

- Vertical gradients are not evident across the overburden units, and these units can therefore be represented together as one model layer;

- The flow model was successfully calibrated and is suited for evaluation of future contaminant migration; and

- The uncertainties identified do not significantly impact the usefulness of the flow model.

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6. NUMERICAL CONTAMINANT TRANSPORT MODEL

This section documents the construction, calibration, future predictive simulations, and uncertainties in the numerical contaminant transport model.

6.1 CONSTRUCTION

Construction of the numerical contaminant transport model involves translating the conceptual transport model into a numerical representation within the selected modeling code, MODFLOW-SURFACT. The contaminant transport model uses the same 3D, finite-difference grid developed for the groundwater flow model. Appropriate solute transport-specific properties are specified for this 3D model grid as detailed in the following sections.

6.1.1 Grid Discretization and Solution Accuracy

In numerical modeling of contaminant transport, grid discretization typically impacts the accuracy and/or stability of the transport solution. Excessively large grid discretization can result in numerical dispersion in the transport solution (Holzbecher and Sorek 2005). For strongly advection-dominated problems (i.e., low dispersion relative to advection), fine grid discretization can be required to avoid numerical dispersion.

However, the adaptive implicit TVD transport scheme available in MODFLOW-SURFACT and used for this model virtually eliminates numerical dispersion as a result of grid discretization. Even for purely advective transport (i.e., no dispersion), virtually no numerical dispersion occurs (HydroGeoLogic 1996).

6.1.2 Temporal Discretization

Discretization of time is an important consideration in numerical contaminant transport modeling. As with spatial discretization, temporal discretization can impact the accuracy and/or stability of the transport solution. Excessively large temporal discretization can result in numerical dispersion in the transport solution (HydroGeoLogic 1996). The dimensionless Courant number ($Cou = v_x \cdot \Delta t / \Delta x$, where v_x is contaminant velocity in the x direction, Δt is the time-step size, and Δx is grid spacing in the x direction) is commonly used to guide temporal discretization for contaminant transport. For $Cou \leq 1$, numerical dispersion is acceptably minimal. Acceptably small *Cou* can always be achieved by specifying small time-step sizes; however, this may result in unacceptably long computation times. Thus, it is desirable to specify maximum time-step sizes such that $Cou \leq 1$ for all grid cells where contaminant transport is important. To do this, the following procedure was followed for each scenario:

- Contour the velocity field for the groundwater flow solution to visualize and determine the maximum seepage velocity in the area and layers where contaminant transport is important;
- From this maximum seepage velocity and the contaminant Rfs at the same location, determine the maximum v_x; and
- Rearrange the *Cou* expression and solve for Δt, assuming $Cou = 1$ (stability constraint) and using v_x as determined in the preceding bullet and a grid spacing of 20 ft (uniform throughout this model).

Using this procedure, maximum time-step sizes were approximately 5,000 days in areas where contaminant transport predictions were important. Maximum time-step sizes were conservatively set to 365 days in the actual transport simulations.

6.1.3 Initial Conditions

The initial conditions consist of the dissolved-phase contaminant concentrations specified at the start of a given simulation. For prediction of future transport of total uranium, the initial dissolved-phase concentrations were specified based upon the current total uranium plume presented in Section 3.8.2. This same initial plume was assigned conservatively to both the overburden (layer 1) and the weathered bedrock (layer 2).

6.1.4 Continuing Contaminant Source

For prediction of future transport of total uranium in the saturated zone, additional total uranium is added over the course of the simulation to represent leaching from the vadose zone. This contamination is added in the recharge entering the overburden (layer 1) in the model.

The concentration in recharge was estimated based upon site-specific sorption characteristics of total uranium (Section 3.9.2) and leaching simulations executed using the FEHM numerical modeling code. Given the very high site-specific total uranium K_d of 1,000 mL/g, residual total uranium in the vadose zone will leach extremely slowly to the saturated zone. To illustrate this, an FEHM leaching simulation was conducted using a unit constant source (concentration held constant at an arbitrary value of 1 concentration unit) in the pore water at an arbitrary location in the column. The predicted pore water concentration 2 ft below the source was monitored for 1,000 years, corresponding to the performance period for the FS alternatives. As shown in Figure D-32, at the end of the 1,000-year period, the predicted pore water concentration (0.01) is two orders of magnitude below the unit source concentration. Complete documentation of the FEHM leaching model is provided in Attachment 2.

Given this very slow leaching, leaching of uranium contamination to groundwater over the 1,000-year performance period depends on the current uranium concentration in the vadose zone immediately above the water table. By first mapping the total uranium concentration in soil just at/above the water table, and then dividing this two-dimensional (2D) soil concentration distribution by the total uranium K_d, a 2D map of the total uranium leachate concentration can be generated. This latter map can be used to directly specify spatially-varying total uranium concentration in recharge across the model domain.

Use of the total uranium K_d to convert from soil concentration to leachate concentration conservatively assumes that total uranium in soil and leachate are in equilibrium.

To map the total uranium concentration in soil just at/above the water table, it first must be recognized that the water table is variable over time. Consequently, to be conservative, a 3D model of total uranium data in soil (Figure D-33) was constructed from all available analytical data. This 3D model was then queried to extract the maximum concentration at every x,y location within 5 ft of the May 2005 water table, giving a 2D map that conservatively represents the total uranium concentration in soil at the water table (Figure D-34). This map was then divided by the total uranium Kd to give a 2D map that conservatively represents the total uranium concentration in leachate at the water table (Figure D-35). A factor of 0.681 picoCuries per microgram (pCi/μg) was also used to convert from the activity units (pCi) used in Figure D-34 to the mass units (μg) used in Figure D-35. This conversion factor reflects uranium in leachate or groundwater resulting from soil contaminated at a 1:0.046:1 isotopic ratio (U234:U235:U238). Finally, the spatially-varying leachate concentrations in Figure D-35 were then directly specified in recharge and held constant over the course of the 1,000-year saturated zone transport simulation.

Using this latter map (Figure D-35) to specify spatially-varying total uranium concentration in recharge across the model domain is conservative because (1) it is based upon the maximum total uranium concentration in soil within 5 ft of the water table, and (2) it assumes that this maximum soil concentration is constant over the entire 1,000-year simulation period (decreases would actually occur with leaching). One significant advantage of this simplified approach is that it permits a 2D leachate concentration map to be developed efficiently by hand calculation, rather than requiring hundreds to thousands of FEHM leaching simulations to develop the same kind of map.

Figure D-35 represents conservative leachate concentrations for current site conditions, assuming no excavation of impacted OU-1 soil exceeding cleanup criteria. In order to simulate the reduced leaching contribution for FS alternatives that include soil excavation, a modified leachate concentration map was prepared. The procedure detailed above was followed, except that the 3D model of total uranium data in soil was first modified to reflect clean backfill within the volume of the soil excavation defined for Alternatives 3, 4, and 5 in the FS. This modified 3D model was then queried to extract the maximum concentration at every x,y location within 5 ft of the May 2005 water table, giving a 2D map that conservatively represents the total uranium concentration in soil at the water table (Figure D-36), factoring in excavation with clean backfill. This map was then converted to the total uranium concentration in leachate at the water table (Figure D-37) using the same procedure described for the baseline (no excavation) case above.

The assumption of clean backfill used above represents a least conservative bounding case for backfill. This assumption was selected because the saturated flow and transport simulation that represents the effects under no excavation of impacted OU-1 soil represents a most conservative bounding case. Assuming both of these bookend bounding case scenarios satisfy the objective of no significant further degradation of groundwater (discussed in Section 1), then intermediate “grey” backfill cases are not necessary to simulate.

6.1.5 Solute Transport Parameters

Solute transport parameters are generally assigned to model grid cells based on a combination of site-specific measurements, values reported for the region in the literature, and model calibration. The following sections discuss assignment of these properties.

6.1.5.1 Effective Porosity

Effective porosities of 0.18 and 0.08 were assigned to the overburden (layer 1) and the weathered bedrock (layer 2), respectively. Both are consistent with expected ranges based on site-specific and literature information (Section 3.6.2).

6.1.5.2 Dry Bulk Density

ρ_b values of 1.6 and 2.4 g/cm^3 were specified for the overburden (layer 1) and weathered bedrock (layer 2), respectively. These values are consistent with data presented in Section 3.9.1. Assuming a soil grain density of 2.65 g/cm^3, the overburden dry bulk density corresponds to a total porosity of 0.4, a reasonable value for the mixed grain-size overburden at the site.

6.1.5.3 Sorption

Sorption of contaminant to the aquifer material was specified using a linear sorption isotherm. In this case, the sorbed- and dissolved-phased concentrations are assumed to be in equilibrium, and the sorbed-phase concentration divided by the dissolved-phase concentration is the K_d, which is specified in

the numerical model. K_ds may be specified via a combination of site-specific data, literature data, and contaminant transport model calibration.

The total uranium K_d specified in the model is 1,000 mL/g (Section 3.9.2). Development of this K_d is detailed in Attachment 1. For a K_d of 1,000 mL/g, the Rf ($Rf = 1 + K_d*\rho_b/\eta_e$, where ρ_b is dry bulk density and η_e is effective porosity) is approximately 9,000, using the dry bulk density and effective porosity values presented immediately above. The Rf is the factor by which contaminant movement is retarded (slowed) relative to groundwater flow due to sorption onto the matrix.

6.1.5.4 Decay Rates

As discussed in Section 3.9.3, decay of uranium isotopes is neglected for this fate and transport analysis.

6.1.5.5 Dispersivity

Dispersivity values of 10, 1, and 0.1 ft in the longitudinal, transverse horizontal, and transverse vertical directions, respectively, were used throughout the model domain, consistent with literature data and common modeling practice discussed in Section 3.9.4.

6.2 CALIBRATION AND PARTICLE TRACKING

Quantitative calibration of a contaminant transport model is generally desirable because this approach provides the greatest confidence that the selected values for the various transport parameters are representative of the modeled system and also provides additional confidence in the underlying groundwater flow model. In this approach, an initial contaminant source is typically specified in the model, and the evolution of the contaminant plume over time is simulated under the effects of advection, dispersion, sorption, and degradation. Simulated contaminant concentrations may then be compared to observed contaminant concentrations on a well-by-well basis to quantitatively assess contaminant transport model calibration (analogous to head comparisons for the flow model calibration). This process is resource-intensive, typically involving extensive refinement (both gross and fine-tuning) of model parameters to achieve an acceptable statistical match between the observed and simulated concentrations. In the case of this model, this approach is not beneficial because the times, strengths, and locations of past source releases in the model area are not well-known.

In fact, as discussed in Section 3.10.2, the high site-specific sorption characteristics of total uranium suggest that very little vertical leaching in the vadose zone or lateral transport in the saturated zone have occurred since total uranium was first released to the environment in the model area. The current distribution of total uranium is primarily accounted for by varied direct-release mechanisms to both soil and groundwater.

Given that total uranium data and release history do not support contaminant transport model calibration, it is worthwhile to explore whether the distribution of more mobile groundwater contaminants is consistent with the numerical flow model. In the model area, a lithium plume extends from source areas in and around Building G-1 downgradient (eastward) to the Cuyahoga River (Figure D-38). Although literature data indicate that lithium is not a conservative tracer, lithium sorption is relatively low with a K_d in the range of 1 to 10 mL/g (Sullivan, et al.; Reimus, et al. 2003), and lithium is generally much more mobile than uranium. The lithium plume has reached the river within a transport window of approximately 60 to 70 years (from 1940-1950 to the present). In fact, lithium concentrations are elevated and relatively uniform throughout the plume, indicating that lithium did not only recently reach the river. Thus, the actual transport time for lithium from Building G-1 to the river was likely considerably fewer than 60 to 70 years.

Particle tracking was performed using MODPATH to estimate advective travel times (i.e., neglecting dispersion, sorption, and decay) in the model from Building G-1 to the Cuyahoga River. As shown in Figure D-39, advective travel times are roughly 5 to 10 years. For a relatively mobile species such as lithium, contaminant transport times would not be drastically lengthened relative to this advective travel time. Therefore, the lithium transport time to the Cuyahoga River suggested by this MODPATH analysis is consistent with the timeline of the observed lithium plume. In turn, this increases confidence that flow model velocities are reasonable. On the other hand, if the MODPATH analysis had estimated an advective travel time of 50 to 100 years (for example) to the river, then this would indicate a problem with the flow velocities in the model, given that lithium is subject to some sorption (thereby increasing transport time) and appears to have reached the river in considerably fewer than 60 to 70 years. In such a case, further calibration of the flow model would have been required, likely increasing both conductivity, recharge, and boundary flux from the toe of the western uplands to together increase fluxes and flow velocities through the model.

6.3 SIMULATION OF FUTURE CONTAMINANT TRANSPORT

The purpose of developing the flow and transport model is to predict future transport of total uranium in groundwater at desired times. The transport simulations executed here are a function of the five FS soil alternatives for OU-1:

- Alternative 1 – No Action (OU-1);
- Alternative 2 – Limited Action and Land-Use Controls (OU-1);
- Alternative 3 – Consolidation and On-Site Disposal (OU-1);
- Alternative 4 – Complete Removal with Off-Site Disposal (OU-1); and
- Alternative 5 – Complete Removal with Ex-Situ Treatment and Off-Site Disposal (OU-1).

These alternatives are designed to directly address soil rather than groundwater contamination because groundwater remediation is not an objective of the FS. However, the FS objective to prevent significant further degradation of groundwater is interpreted to mean that the area exceeding the contaminant MCL should not be significantly increased by the continued leaching of vadose zone contamination. The above FS alternatives for OU-1 soil may impact future groundwater quality to varying degrees by affecting continued leaching of total uranium to the saturated zone (for example, by excavating such vadose zone contamination).

From the standpoint of impact upon groundwater, Alternatives 1 and 2 are equivalent, as neither involves active remediation of total uranium contamination in soil. Likewise, Alternatives 4 and 5 are equivalent in terms of the impact upon groundwater, as both include excavation of impacted OU-1 soil exceeding cleanup criteria; differences lie only in soil treatment/handling after removal. Finally, Alternative 3 is similar to Alternatives 4 and 5 in terms of soil excavation, but Alternative 3 also includes an on-site disposal cell in OU-1. The disposal cell will reduce recharge (and thereby reduce contaminant leaching from the vadose to the saturated zone within the cell footprint). Thus, three contaminant transport simulations are sufficient to evaluate the impacts on OU-1 groundwater from the five FS alternatives for OU-1 soil. In addition, a fourth contaminant transport simulation with no continuing source from contaminant leaching from the vadose zone was executed. This simulation provides a point of comparison for evaluating the other contaminant transport simulations against the objective of preventing significant further degradation of groundwater. Thus, the following four contaminant transport simulations were executed to evaluate the effects upon groundwater of the five FS alternatives for OU-1 soil:

- Transport Simulation A: represents future contaminant transport with no continuing leaching source;
- Transport Simulation B: represents future contaminant transport for Alternatives 1 and 2;
- Transport Simulation C: represents future contaminant transport for Alternative 3; and
- Transport Simulation D: represents future contaminant transport for Alternatives 4 and 5.

For each of these future transport simulations, the initial dissolved-phase concentrations were specified based upon the current total uranium plume as discussed in Section 6.1.3.

Continuing contaminant sources from vadose zone leaching were specified as discussed in Section 6.1.4. Leachate concentrations in Figure D-35 were used to specify sources for Transport Simulation B, while leachate concentrations in Figure D-37 were used to specify sources for Transport Simulations C and D. Sources were conservatively assumed to be constant throughout the simulation period. A simulation period of 1,000 years was used, consistent with the performance period of the FS alternatives.

Flow conditions used for the transport simulations were the same as in the steady-state calibrated flow model (Section 5.2), with the exception that recharge was reduced to 1 in/yr within the footprint of the disposal cell for Transport Simulation C. Continued operation of the nickel extraction system was included for all transport simulations.

6.3.1 Predictive Transport Results

Predicted total uranium groundwater plumes at 1,000 years into the future (calendar year 3011) for each of the transport simulations A, B, C, and D are presented in Figure D-40. Each panel on Figure D-40 includes the current total uranium plume for reference. As shown in Figure D-40, the predicted total uranium plumes at 1,000 years are nearly identical for the four transport simulations. In addition, the 1,000-year plumes differ little from the present-day total uranium plume. Transport Simulation A, with no continuing leaching source, shows very slight migration of the plume to the east toward the Cuyahoga River over the 1,000-year period. The same slight migration is evident in Transport Simulations B and D; the continuing leaching sources in these simulations are insufficient to alter the predicted plume relative to that in Transport Simulation A (no continuing leaching source). Although the Transport Simulation C predicted plume is very similar to the others, very slightly less migration toward the Cuyahoga River is predicted due to the recharge reduction associated with the disposal cell. Given the similarity of the predicted plumes for Transport Simulations B, C, and D (which represent the groundwater effects from the various FS soil alternatives) to that for Transport Simulation A (which represents predictions with no continuing leaching source), all of the FS alternatives for OU-1 soil meet the objective of preventing further degradation of groundwater via total uranium contamination. A variation on Transport Simulation C was also executed with reduced hydraulic conductivity in the excavation area to simulate engineered backfill. Predictions were insignificantly different than those for Transport Simulation C, which already dramatically reduces recharge in the excavation area and beyond to reflect installation of the on-site disposal cell.

The overall similarity of the 1,000-year transport predictions both (1) among the four simulations and (2) between the four simulations and the current plume is attributable to the strong affinity of total uranium to sorb to Harshaw soil. A total uranium K_d of 1,000 mL/g was developed using literature data together with site-specific soil sampling and groundwater quality data (Section 3.9.2 and Attachment 1). This K_d corresponds to an Rf of approximately 9,000 (Section 6.1.5.3). The Rf is the factor by which contaminant movement is retarded (slowed) relative to groundwater flow due to sorption onto the matrix. Thus, transport predictions are controlled by the high total uranium K_d, and the results in Figure D-40 are therefore not surprising.

Transport of total uranium in groundwater may have been much more pronounced in the years immediately after contaminant release due to the likely discharge of process acids at the time of uranium releases and the consequent temporary lowering of the total uranium K_d under low pH conditions (Section 3.9.2). These low pH and lowered K_d conditions would have been transient, and transport conditions at the present would be consistent with the total uranium K_d presented in Section 6.1.5.3.

A sensitivity simulation is described in Section 6.3.3 below to evaluate the impact of reduced sorption of total uranium on site soil. However, for Transport Simulations C and D (which represent the groundwater effects for FS alternatives involving soil excavation), it is very reasonable to expect no further groundwater degradation even under greatly reduced sorption/retardation conditions relative to the baseline condition (K_d = 1,000 mL/g) modeled above. Excavation of above-criteria soil will remove the most significant potential continuing leaching sources, which have been in place for up to 60 to 70 years. If they had provided a significant source of continuing contamination to groundwater in the past, that contribution would be tremendously diminished via excavation in FS Alternatives 3, 4, and 5.

6.3.2 Mass Balance

To solve the transport equation, the adaptive implicit TVD flux-limiting scheme was used in MODFLOW-SURFACT. This scheme is designed to provide accurate, physically correct, and strictly mass-conserved numerical solutions. Accordingly, the mass balance errors in the transport simulations are on the order of 1E-8 (unitless). Acceptable mass balance errors for solute transport simulations are on the order of 0.01 to 0.1 (i.e., 1% to 10%).

For Transport Simulations B, C, and D, the mass of total uranium introduced into the model over 1,000 years via recharge (representing vadose zone contaminant leaching) is roughly 0.2%, 0.06%, and 0.1%, respectively, of the initial mass in the saturated zone (aqueous and sorbed combined). Thus, proportionally little additional mass is predicted to be introduced into the saturated zone. From this standpoint, all of the FS alternatives for OU-1 soil meet the objective of preventing further significant degradation of groundwater via total uranium contamination.

6.3.3 Sensitivity Simulation

The predictions of future total uranium transport in groundwater presented in Section 6.3.1 are controlled by the strong affinity of total uranium to sorb to Harshaw soil (estimated site-specific K_d of 1,000 mL/g). To explore the impacts of uncertainty in this baseline K_d, a sensitivity simulation was executed with an order-of-magnitude reduction in K_d. Application of the reduced K_d (100 mL/g) in the saturated zone is straightforward, requiring only adjustment of this parameter in the saturated zone flow and transport model. However, application of the reduced K_d to vadose zone leaching, which provides continuing contaminant input to the saturated zone flow and transport model over time, is more complex.

As discussed in Section 6.1.4, given the very slow leaching implied by a baseline K_d of 1,000 mL/g, the total uranium concentration in leachate at the water table over the 1,000-year performance period is driven by the total uranium concentration in soil at and just above the water table. With a reduced K_d of 100 mL/g, leaching will be influenced by the total uranium concentration in a larger vertical interval above the water table. To quantify this, an FEHM leaching simulation similar to that described in Section 6.1.4 (unit source held constant for 1,000 years) was conducted with the K_d reduced from 1,000 to 100 mL/g. Again, the predicted concentration below the unit source was monitored for the 1,000-year simulation period. As shown in Figure D-41, at the end of the 1,000-year period, at 5 ft below the unit source, the predicted concentration is approximately 0.2, or 20% of the unit source concentration. Complete documentation of the FEHM leaching model is provided in Attachment 2.

Although this still indicates very limited leaching (as expected with a K_d of 100 mL/g), leaching is enhanced relative to the baseline K_d of 1,000 mL/g (Section 6.1.4). The predicted leaching in Figure D-41 suggests that a larger vertical interval of approximately 5 ft above the water table influences leaching over the 1,000-year performance period.

As in the baseline leaching case, it is desirable to be able to develop spatially-varying leachate input into the saturated zone flow model without executing thousands of FEHM simulations to do so. That was accomplished for the baseline case by recognizing that the total uranium concentration in soil at the water table drove the leaching predictions. A conservative estimate was made of the spatially-varying total uranium concentration in soil at the water table (using the maximum concentration within 5 ft of the May 2005 water table), and this was assumed to be constant over the course of 1,000 years for the purpose of specifying a leaching source. In this sensitivity simulation, because leaching to the water table within the 1,000-year timeframe is influenced by a much larger vertical interval above the water table, the average (rather than this maximum) total uranium concentration in soil within 5 ft of the May 2005 water table was used to develop a simplified basis for leaching to the saturated zone.

Using the same method as in the baseline leaching case, this 2D soil concentration distribution (Figure D-42) was divided by the total uranium K_d (100 mL/g, in this sensitivity case), yielding a 2D map of the total uranium leachate concentration (Figure D-43). This latter map was then used to directly specify spatially-varying total uranium concentration in recharge across the model domain. These concentrations were conservatively held constant throughout the 1,000-year transport simulation. A second transport simulation was executed without a continuing leaching source and also with a K_d of 100 mL/g. As with Transport Simulation A in Section 6.3.1, this second simulation provides a point of comparison for evaluating the sensitivity simulation against the objective of preventing significant further degradation of groundwater.

The predicted total uranium groundwater plumes at 1,000 years into the future for these two reduced K_d sensitivity simulations (with and without continuing leaching sources) are presented in Figure D-44. For comparison, the current total uranium plume is also displayed in Figure D-44. Using a K_d of 100 mL/g results in greater transport distances relative to those predicted for the baseline K_d of 1,000 mL/g (Figure D-40). However, the transport distance remains small (100 to 200 ft) over the 1,000-year period, as a K_d of 100 mL/g corresponds to a still high Rf of approximately 900.

Comparing the 1,000-year predictions with and without continuing leaching sources, the following observations can be made:

- The leading edge of the primary plume is identical in both cases;
- The footprint of the high concentration areas is largely identical (as contaminant leaching is still limited at a K_d of 100 mL/g); and
- Minor differences are present in the overall footprint of the plume above the total uranium MCL.

Thus, under this highly conservative sensitivity simulation, insignificant further degradation of groundwater is predicted relative to that predicted without a continuing leaching source. The small predicted impacts near the river under this conservative sensitivity simulation would not result in significant impacts to the river itself, due to the very low groundwater flux to the river compared to the river flow. Consistent with this, surface water and sediment sampling during the RI revealed no unacceptable total uranium impacts.

6.3.4 Thorium Transport

Along with total uranium, thorium is also a COC in groundwater in the model area. Transport of thorium in OU-1 can be evaluated qualitatively by comparison to the quantitative predictions for total uranium transport in OU-1. The extent of thorium contamination is much less than that of total uranium in the model area. Additionally, the site-specific K_d for thorium (10,000 mL/g) is an order of magnitude greater than that for total uranium (1,000 mL/g); therefore, thorium is significantly less mobile than total uranium in the model area. Finally, as described in the following section, the cleanup criterion for thorium in soil at Harshaw is protective of groundwater, so no further significant groundwater impacts are expected due to leaching of thorium from the vadose zone. Taking these considerations together with the preceding quantitative predictions for total uranium transport, thorium is not predicted to cause further degradation of groundwater either.

6.3.5 Soil Cleanup Criteria and Protectiveness of Groundwater

Although this modeling effort focuses upon predicting the transport of total uranium in OU-1 groundwater, a secondary objective is to evaluate whether the OU-1 and OU-2 proposed soil cleanup criteria for total uranium, thorium-230, thorium-232, and radium-226 are protective of groundwater. The predictive simulations for total uranium presented in Section 6.3.1 demonstrate that the proposed total uranium cleanup criterion for OU-1 soil is protective of groundwater. This section addresses the groundwater protectiveness of the remaining proposed soil cleanup criteria (i.e., thorium-230, thorium-232, and radium-226 in OU-1 and total uranium, thorium-230, thorium-232, and radium-226 in OU-2).

Consistent with Section 6.3.1, a proposed soil cleanup criterion is considered protective of groundwater if leaching from vadose zone contamination at or below that cleanup criterion will not result in an increase in the groundwater plume footprint exceeding a given contaminant MCL. As a worst-case scenario to bound the evaluation, the vadose zone soil concentration can be hypothetically assumed to be at the cleanup criterion. Then, the contaminant concentration in leachate can be calculated from the vadose zone soil concentration divided by the contaminant K_d (assumes equilibrium partitioning using a linear sorption isotherm). If this leachate concentration is lower than the contaminant MCL, then the soil cleanup criterion is protective of groundwater. If the leachate concentration exceeds the contaminant MCL, then the soil cleanup criterion may or may not be protective of groundwater, depending, for example, upon the degree to which the leachate concentration is attenuated in the saturated zone.

For each contaminant, Table D-6 presents the proposed soil cleanup criteria (both OU-1 and OU-2), the K_d, the corresponding bounding case leachate concentrations (again, both OU-1 and OU-2), and the MCL. As shown, bounding case leachate concentrations are lower than the corresponding MCL for thorium-230 and thorium-232 in both OU-1 and OU-2 and for radium-226 in OU-2. For these cases, the proposed soil cleanup criteria are protective of groundwater.

For radium-226 in OU-1, and total uranium in both OU-1 and OU-2, the bounding case leachate concentrations exceed the corresponding MCL, and further evaluation is therefore necessary to ascertain whether the corresponding proposed soil cleanup criteria are protective of groundwater. As demonstrated by the refined modeling analysis presented earlier in this section, the OU-1 proposed soil cleanup criteria for total uranium is protective of OU-1 groundwater.

The groundwater flow and contaminant transport model presented in this appendix can also be used to evaluate whether the OU-1 proposed soil cleanup criteria for radium-226 is protective of groundwater. The bounding case leachate concentration of 9.1 picoCuries per liter (pCi/L) can be specified in the saturated zone flow model as the site-wide concentration in recharge, thereby providing a highly conservative source term to groundwater. Attenuation of this leachate concentration can then be

predicted by the flow and transport model. For this simulation, an radium-226 K_d of 1,000 mL/g (developed as described in Section 3.9.2 and Attachment 1) was used. The predicted radium-226 groundwater distribution is presented in Figure D-45. Two small areas are predicted to exceed the radium-226 MCL (5 pCi/L) after 1,000 years. Saturated thickness is limited in these areas, resulting in little attenuation of the assumed leachate concentration of 9.1 pCi/L. Given the highly conservative assumed leachate concentration used in the simulation and the resulting very limited areas predicted to exceed the radium-226 MCL, the radium-226 proposed soil cleanup criterion is protective of groundwater.

Finally, further evaluation is necessary to ascertain whether the OU-2 proposed soil cleanup criteria for total uranium is protective of OU-2 groundwater. Although the OU-1 flow and transport model cannot be used to directly assess attenuation of total uranium leachate in OU-2, observations from the OU-1 modeling effort are relevant. In particular, due to the high total uranium K_d, FEHM simulations predict that leaching of uranium contamination to groundwater over the 1,000-year performance period depends on the current uranium concentration in the vadose zone immediately above the water table (Section 6.1.4). In OU-2, the total uranium contamination is surficial, with all results deeper than 2 ft below ground surface (BGS) near or below total uranium background. Groundwater is approximately 15 to 20 ft BGS in the OU-2 areas where above background total uranium is present. Thus, the total uranium contamination in OU-2 is not a threat to leach to groundwater and the OU-2 proposed soil cleanup criteria for total uranium is therefore protective of OU-2 groundwater. Consistent with this, available total uranium results in OU2 groundwater are all below the total uranium MCL.

In summary, all of the proposed soil cleanup criteria for OU-1 and OU-2 are protective of groundwater.

6.4 UNCERTAINTIES

This section discusses sources of uncertainty associated with the contaminant transport model and associated predictive transport simulations. The sources of uncertainty evaluated in this section include sorption, decay rates, dispersion, initial conditions, and continuing contaminant source.

6.4.1 Sorption

K_ds were developed using literature data together with site-specific soil sampling and groundwater quality data (Section 3.9.2 and Attachment 1). Although the literature and site-specific data are consistent with one another, at least moderate uncertainty is nonetheless present in the K_d values. Consequently, a sensitivity simulation was conducted with a large reduction in the total uranium K_d (order of magnitude reduction from 1,000 to 100 mL/g). Like the baseline transport simulation, this sensitivity analysis predicted insignificant further degradation of groundwater due to total uranium in OU-1 soil.

6.4.2 Decay Rates

Decay rates for uranium isotopes are well-established. However, due to the long decay half-lives relative to the 1,000-year performance period, decay of uranium isotopes was neglected for the predictive transport analysis.

6.4.3 Dispersion

The dispersivity values specified in the model are consistent with estimates from literature data and with common modeling practice.

6.4.4 Initial Conditions

The present-day total uranium groundwater plume is used to specify initial conditions for prediction of future transport. The monitoring well density is relatively large in the model area, and the uncertainty in this plume is therefore relatively small. As discussed in Section 3.10.2, this plume is conservatively contoured from the monitoring well data; given the strong sorption characteristics of total uranium in the model area, relatively less contaminated areas are likely to exist within the interpreted groundwater plume.

6.4.5 Continuing Contaminant Source

Continuing contaminant source to groundwater is provided by leaching of residual vadose zone contamination. Contamination in the vadose zone is relatively well characterized and therefore has relatively low uncertainty given the extensive soil sampling data (particularly in the areas most likely to be contaminated). The source term due to leaching from the vadose zone was conservatively specified in the total uranium transport simulations, further reducing the impacts of source uncertainty.

6.5 CONCLUSIONS

Section 6 documents (1) the construction, calibration, and uncertainties of the numerical transport model and (2) future contaminant transport predictions for the model area. The numerical transport model was constructed from the conceptual flow and transport model presented in Section 3. While total uranium data and release history do not support contaminant transport model calibration, consistency of the model with observed travel times and velocities was verified by comparing particle tracking predictions to known site history, timeframes, and groundwater quality data for lithium.

The numerical groundwater flow and transport model was then used to predict future transport of total uranium in the model area for three scenarios which together represent predicted future groundwater effects from the five FS alternatives for OU-1 soil. Transport predictions were controlled by the strong affinity of total uranium to sorb to site soil. All of the transport simulations resulted in very similar predictions, whether with continuing leaching source (three different simulations) or without. These simulations confirm that all of the FS alternatives for OU-1 soil meet the objective of preventing further degradation of groundwater via total uranium contamination.

For transport simulations representing the groundwater effects for FS alternatives involving soil excavation, it is very reasonable to expect no further groundwater degradation, regardless of the total uranium sorption conditions. Excavation of above-criteria soil will remove the most significant potential continuing leaching sources of total uranium, which have been in place for up to 60 to 70 years. If they had provided a significant source of continuing contamination to groundwater in the past, that contribution would be tremendously diminished via excavation.

A sensitivity simulation was executed with an order of magnitude reduction in K_d to explore the impacts of uncertainty in the baseline total uranium K_d. Under this highly conservative sensitivity simulation, insignificant further degradation of groundwater was predicted.

Future transport of thorium in OU-1 groundwater was qualitatively evaluated through comparison to model-predicted transport of total uranium in OU-1. As with total uranium, no further degradation of OU-1 groundwater is predicted to occur due to thorium.

Proposed soil cleanup criteria for total uranium, thorium-230, thorium-232, and radium-226 in OU-1 and OU-2 were evaluated and found to be protective of groundwater.

Finally, uncertainties were identified with respect to transport parameters, initial conditions, and continuing contaminant sources. The greatest uncertainty was in the K_d, which controls predictions of total uranium transport. As stated above, a sensitivity simulation demonstrated that a greatly reduced K_d still results in prediction of insignificant further degradation of groundwater.

7. SUMMARY AND CONCLUSIONS

7.1 SUMMARY

The purpose of this task is to update the existing RI groundwater flow and contaminant transport model for OU-1, as well as related models (including the geologic framework model and vadose zone leaching models), and to predict saturated zone transport of total uranium in OU-1 under the conditions of the various FS alternatives. To accomplish this task, SAIC evaluated and synthesized site-specific geologic, hydrogeologic, and geochemical (contaminant migration) characteristics in the study area, along with relevant literature data.

The conceptual flow and transport model developed in the RI was refined, including incorporating boring logs, groundwater quality data, and water level data collected subsequent to the original model development during the RI. The conceptual model describes the hydrogeochemistry of the study area, including the source and extent of total uranium contamination in groundwater. Information is integrated from soil and groundwater sampling events, monitoring well installation and sampling, river gauging, groundwater extraction rate data, aerial photography, site-specific tests, and literature studies. The conceptual model includes two layers, with layer 1 representing the combined overburden units and layer 2 representing an underlying 5-ft thick weathered bedrock zone. Vertical gradients are not evident across the overburden units, and these units can therefore be represented together as a single model layer.

Total uranium contamination in soil and groundwater in the model area resulted from a wide variety of past activities at Harshaw Chemical, including:

- Releases to surface soil from air stacks, dusts, and spills around Building G-1;
- Releases to surface soil in MED material laydown yards;
- Releases to soil and groundwater via burial of contaminated soil and waste;
- Releases to soil and groundwater via use of contaminated soil and waste as fill; and
- Releases to soil and groundwater via leaky building drains (e.g., in Building G-1) and leaky sewer systems in general.

Figure D-20 presents the current total uranium plume in groundwater at Harshaw resulting from these releases. Total uranium results exceeding the MCL of 30 µg/L are generally confined to the immediate vicinity of Building G-1, a primary source area. Above-background results are present along the Cuyahoga River, consistent with the use of contaminated fill along the river bank. Elevated results at DM-27R may also have originated from known past discharge of Engelhard treatment facility water (treated for lead; untreated for total uranium) to the storm sewer. Bank collapses at the Cuyahoga River in this area prompted replacement of well DM-27 with well DM-27R and may have promoted leaks in this sewer line that caused localized groundwater impacts.

The estimated site-specific K_d of 1,000 mL/g for total uranium corresponds to a contaminant transport Rf of roughly 1E+4. The travel velocity of total uranium in the saturated zone would be reduced by this factor relative to the groundwater flow velocity. If this K_d had prevailed since the release of total uranium to the subsurface at Harshaw, insignificant lateral migration of total uranium would have occurred in the saturated zone since its release. However, at the time of total uranium release, the K_d was likely much lower due to discharge of process acids in the same areas. Together with the widespread contaminant

release mechanisms listed above, this lower K_d in the past helps to explain the current extent of total uranium in groundwater (Figure D-20).

In the future, residual total uranium in the vadose zone will leach extremely slowly to the saturated zone, and transport within the saturated zone will be highly retarded, both due to the high total uranium K_d.

From this conceptual model, a two-layer numerical groundwater flow and transport model was developed to predict future total uranium migration in OU-1 groundwater. The numerical flow model was calibrated under steady-state conditions using PEST to systematically adjust the hydraulic conductivity field within realistic ranges. Sensitivity analyses were performed to aid in the specification of parameter values and understanding of the flow system. Uncertainties were identified with respect to hydraulic parameters, extraction rates, boundary conditions, and model calibration data. While total uranium data and release history do not support contaminant transport model calibration, consistency of the contaminant transport model with observed travel times and velocities was verified by comparing particle tracking predictions to known site history, timeframes, and groundwater quality data for lithium.

The numerical groundwater flow and transport model was then used to predict future transport of total uranium in the model area for three scenarios, which together represent predicted future groundwater effects from the five FS alternatives for OU-1 soil. Transport predictions were controlled by the strong affinity of total uranium to sorb to site soil. All of the transport simulations resulted in very similar predictions, whether with continuing leaching source (three different simulations) or without. These simulations confirm that all of the FS alternatives for OU-1 soil meet the objective of preventing further degradation of groundwater via total uranium contamination.

For transport simulations representing the groundwater effects for FS alternatives involving soil excavation, it is very reasonable to expect no further groundwater degradation, regardless of the total uranium sorption conditions. Excavation of above-criteria soil will remove the most significant potential continuing leaching sources of total uranium, which have been in place for up to 60 to 70 years. If they had provided a significant source of continuing contamination to groundwater in the past, that contribution would be tremendously diminished via excavation.

A sensitivity simulation was executed with an order of magnitude reduction in K_d to explore the impacts of uncertainty in the baseline total uranium K_d. Under this highly conservative sensitivity simulation, insignificant further degradation of groundwater was predicted.

Future transport of thorium in OU-1 groundwater was qualitatively evaluated through comparison to model-predicted transport of total uranium in OU-1. As with total uranium, no further degradation of OU-1 groundwater is predicted to occur due to thorium.

Proposed soil cleanup criteria for total uranium, thorium-230, thorium-232, and radium-226 in OU-1 and OU-2 were evaluated and found to be protective of groundwater.

Finally, uncertainties were identified with respect to transport parameters, initial conditions, and continuing contaminant sources. The greatest uncertainty was in the K_d, which controls predictions of total uranium transport. As stated above, a sensitivity simulation demonstrated that a greatly reduced K_d still results in prediction of insignificant further degradation of groundwater.

7.2 CONCLUSIONS

Major conclusions from the groundwater flow and contaminant transport model development and simulations include:

- Available site-specific and literature data present a consistent picture of a total uranium plume that is relatively immobile today.

- Total uranium transport in OU-1 groundwater was likely more significant at and near the time of contaminant release, due to a temporary lowering of the total uranium K_d caused by release of process acids to the environment.

- Model simulations predict very little transport of or change in this total uranium plume over the 1,000-year performance period of the FS alternatives. These simulations predict no further degradation of groundwater occurs for all FS alternatives.

- For transport simulations representing the groundwater effects for FS alternatives involving soil excavation, it is very reasonable to expect no further groundwater degradation, regardless of the total uranium sorption conditions. Excavation of above-criteria soil will greatly diminish any future leaching to groundwater.

- A sensitivity simulation with a greatly reduced total uranium K_d (100 mL/g versus the baseline value of 1,000 mL/g) also predicts insignificant further degradation of groundwater.

- The proposed soil cleanup criteria for total uranium, thorium-230, thorium-232, and radium-226 in OU-1 and OU-2 are protective of groundwater.

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8. REFERENCES

ASTM (American Society for Testing and Materials) 2004. *Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem*, ASTM D5447-04.

Argonne National Lab 2011. http://web.ead.anl.gov/resrad/datacoll/soildens.htm

Barber 1994. *Ground Water Pollution Potential of Cuyahoga County, Ohio*; Ground Water Pollution Potential Report No. 4, Ohio Department of Natural Resources, Division of Water, Ground Water Resources Section. April 1994.

Crowell 1979. *Groundwater Resources of Cuyahoga County Map*.

Environmental Simulations Inc. 2004. *Guide to Using Groundwater Vistas Version 4: Environmental Simulations Inc.*, 358 p.

Fetter, C. W., Jr. 1988. *Applied Hydrogeology*, Second Edition, Charles E. Merrill and Co., 592 p.

Harbaugh, A.W., and M.G. McDonald 1996. *User's documentation for MODFLOW-96, an update to the U.S. Geological Survey modular finite-difference ground-water flow model*. U.S. Geological Survey Open-File Report 96-485, 56 p.

Holzbecher and Sorek 2005. "Numerical Models of Groundwater Flow and Transport," in *Encyclopedia of Hydrological Sciences*, Edited by M.G. Anderson, John Wiley & Sons, Ltd.

HydroGeoLogic 1996. *MODFLOW-SURFACT Software (version 2.2) Documentation*. Herndon, Virginia.

IEER 2011. http://www.ieer.org/fctsheet/uranium.html. Accessed 7/21/2001.

McDonald, M.G., and A.W. Harbaugh 1988. *A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A1*, 586 p.

McWhorter and Sunada 1977. *Ground-water Hydrology and Hydraulics*. Water Resources Publications, Fort Collins, CO. ISBN 0918334187.

Morris, D.A. and A.I. Johnson 1967. *Summary of hydrologic and physical properties of rock and soil material as analyzed by the Hydrologic Laboratory of the U.S. Geological Survey 1948–60*. U.S. Geological Survey Water-Supply Paper 1839–D, 42 p.

Ohio Division of Geological Survey 2003. Bedrock-Topography Data for Ohio: Ohio Geological Survey BG-2, 1 CD-ROM, Shape and Geodatabase GIS file formats. (ftp://ftp.dot.state.oh.us/pub/Districts/D05/Other/GIS/BTcontours)

OGRIP (Ohio Geographically Referenced Information Program) 2006. LIDAR-derived Digital Elevation Models. (downloaded March 2010 from http://gis4.oit.ohio.gov/osiptiledownloads/default.aspx in ESRI GRID format).

Pollock, D.W., 1994, *User's Guide for MODPATH/MODPATH-PLOT, Version 3: A particle tracking post-processing package for MODFLOW, the U.S. Geological Survey finite-difference ground-water flow model*, U.S. Geological Survey Open-File Report 94-464, 234 p.

Porges and Hammer 2001. *The Compendium of Hydrogeology*, National Ground Water Association, Dublin, OH.

Reimus, et al. 2003. Paul W. Reimus, Marc J. Haga, Andrew I. Adams, Timothy J. Callahan, H.J. Turin, Dale A. Counce. "Testing and parameterizing a conceptual solute transport model in saturated fractured tuff using sorbing and nonsorbing tracers in cross-hole tracer tests". *Journal of Contaminant Hydrology* 62–63 (2003) p.613–636.

Schulze-Makuch 2005. "Longitudinal Dispersivity Data and Implications for Scaling Behavior," *Groundwater*, Volume 43, No. 3, May-June 2005 (pages 443-456).

Sullivan, et al. E. J. Sullivan, P.W. Reimus, M. Ding. *Effects of Mineralogy, Grain Size, and Solution Composition on Lithium Sorption to Saturated Alluvium South of Yucca Mountain, Nevada*. http://lib-www.lanl.gov/la-pubs/00818183.pdf. Accessed April 2011.

USACE 2009. *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1*. October.

Watermark Numerical Computing 2010. *PEST: Model-Independent Parameter Estimation. User Manual: 5th Edition*.

Zyvoloski, G. A. 2007. *FEHM: A control volume finite element code for simulating subsurface multi-phase multi-fluid heat and mass transfer*. LAUR-07-3359.

TABLES

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Table D-1. Lithologic Pick Data

Station	Easting (ft)	Northing (ft)	Ground Surface Elevation (ft)	Ground Surface Elevation Source	Depth BGS (ft)					Elevation (ft amsl)				
					Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth	Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth
AB1	2191855.51	650912.69	592.07	BackInt	0	2			20	592.07	590.07			572.07
AB2	2191886.15	650953.21	591.07	BackInt	0		5		16	591.07		586.07		575.07
AB3	2191930.02	650898.63	592.98	BackInt	0		4		16	592.98		588.98		576.98
AB4	2191999.3	650891.82	593.65	BackInt	0		6		24	593.65		587.65		569.65
AB5	2192043.81	650841.66	592.34	BackInt	0		3		16	592.34		589.34		576.34
AB6	2192143.18	650814.18	589.82	BackInt	0		2		16	589.82		587.82		573.82
AB7	2192290.56	650731.41	589.90	BackInt	0		3		24	589.90		586.90		565.90
AB8	2192434.89	650670.52	588.17	BackInt	0		11		16	588.17		577.17		572.17
B-18A	2191780	650531	594.22	BackInt	0	Unclear*	4	9.8	10	594.22		590.22	584.42	584.22
B-18B	2191945.35	650565.1	594.53	BackInt	0	Unclear*	4	12.5	13.5	594.53		590.53	582.03	581.03
BGD1	2192268.43	649872.1	588.66	BackInt	0	5	15		16	588.66	583.66	573.66		572.66
BGD11	2192373.96	650143.27	580.94	BackInt	0	12			12	580.94	568.94			568.94
BGD13	2192144.75	649929.73	583.51	BackInt	0	14	15		20	583.51	569.51	568.51		563.51
BGD14	2192314.57	649944.46	587.40	BackInt	0	6	15		16	587.40	581.40	572.40		571.40
BGD15	2192399.09	649987.61	586.63	BackInt	0	4	15		16	586.63	582.63	571.63		570.63
BGD16	2192519.13	650049.18	583.44	BackInt	0		12		20	583.44		571.44		563.44
BGD2	2192329.12	649866.19	591.56	BackInt	0	8	12		12	591.56	583.56	579.56		579.56
BGD4	2192481.54	649875.84	593.10	BackInt	0	10	12		12	593.10	583.10	581.10		581.10
BGD6	2192663.85	650132.49	582.33	BackInt	0		6		8	582.33		576.33		574.33
BGD8	2192728.71	650180.31	582.78	BackInt	0		8		8	582.78		574.78		574.78
BKA-51	2191592.312	649653.7465	593.18	Survey	0	3	23	34.75	35.5	593.18	590.18	570.18	558.43	557.68
BKA-52	2191758.053	649730.4758	593.40	Survey	0	4	19.5	39	39	593.40	589.40	573.90	554.40	554.40
BKA-53	2191937.296	649459.3179	591.16	Survey	0	8	20	35.5	35.5	591.16	583.16	571.16	555.66	555.66
BKG-MW0001	2191081.119	649708.8771	592.67	Survey	0	3	14.5		16	592.67	589.67	578.17		576.67
BKG-MW0002	2191322.012	649989.1733	594.39	Survey	0	2	18.3	20.48	21.5	594.39	592.39	576.09	573.91	572.89
BKG-MW0003	2191324.767	650473.3022	592.73	Survey	0	2	14	24.34	26	592.73	590.73	578.73	568.39	566.73
BKG-MW0004	2191331.183	650541.243	592.69	Survey	0	3	14	25.34	26	592.69	589.69	578.69	567.35	566.69
BKG-MW0005	2191218.208	651099.725	592.37	Survey	0	3	16	27.95	28	592.37	589.37	576.37	564.42	564.37
CB1	2192363.77	648327.8	594.72	BackInt	0	4	15		16	594.72	590.72	579.72		578.72
CB10	2192352.23	648425.98	592.90	BackInt	0	4	15		16	592.90	588.90	577.90		576.90
CB11	2192298.54	648509.31	591.08	BackInt	0	2	15		16	591.08	589.08	576.08		575.08
CB12	2192219.27	648552.07	591.47	BackInt	0	1	15		20	591.47	590.47	576.47		571.47
CB13	2192264.35	648657.2	589.69	BackInt	0	4	15		16	589.69	585.69	574.69		573.69
CB14	2192397.77	648565.95	591.05	BackInt	0	2	15		16	591.05	589.05	576.05		575.05
CB15	2192490.45	648510.32	591.67	BackInt	0	2	15		16	591.67	589.67	576.67		575.67
CB16	2192631.11	648415.41	591.28	BackInt	0	4	15		16	591.28	587.28	576.28		575.28
CB2	2192299.51	648371.94	593.88	BackInt	0	2	12		12	593.88	591.88	581.88		581.88
CB4	2192226.44	648336.23	595.95	BackInt	0	2	12		12	595.95	593.95	583.95		583.95
CB6	2192083.46	648483.33	591.24	BackInt	0	1	15		16	591.24	590.24	576.24		575.24
CB7	2192133.84	648518.9	592.48	BackInt	0	2	15		16	592.48	590.48	577.48		576.48
CB8	2192252.21	648417.77	593.56	BackInt	0	2	12		16	593.56	591.56	581.56		577.56
CB9	2192409.4	648458.14	592.02	BackInt	0	1	15		16	592.02	591.02	577.02		576.02
DM-1	2191465.837	650137.0198	593.71	Survey	0	1.5	11	19.8	19.5	593.71	592.21	582.71	573.91	574.21
DM-10	2191405.927	650534.869	594.38	BackInt	0	5	11	28	31	594.38	589.38	583.38	566.38	563.38
DM-11	2191520.52	650597.8245	593.88	Survey	0	2	6	24	25	593.88	591.88	587.88	569.88	568.88
DM-12	2191426.005	650643.803	593.93	Survey	0	2.5	14	25.5	27.5	593.93	591.43	579.93	568.43	566.43
DM-13	2191478	650694	593.11	BackInt	0	1.5	10.6	18.5	20	593.11	591.61	582.51	574.61	573.11
DM-14	2191443.511	650747.0274	594.19	Survey	0	1	6.5	18.5	19	594.19	593.19	587.69	575.69	575.19
DM-15	2191564.933	650795.4526	594.26	Survey	0	7	13	18.5	19	594.26	587.26	581.26	575.76	575.26
DM-16	2191498.52	650263.82	594.47	BackInt	0	2		4.64	7	594.47	592.47		589.83	587.47
DM-17	2191757.22	650824.52	592.55	BackInt	0	9	13	14.5	16	592.55	583.55	579.55	578.05	576.55
DM-19	2191615.6	650207.89	593.75	BackInt	0	5	13	22.77	22.5	593.75	588.75	580.75	570.98	571.25
DM-2	2191511.783	650188.4044	594.25	Survey	0	1.5	11	14.87	17	594.25	592.75	583.25	579.38	577.25
DM-20	2191605.2	650055.47	594.46	BackInt	0	3	15.5	25	25	594.46	591.46	578.96	569.46	569.46
DM-21	2191580.97	649715.56	593.90	BackInt	0		21	35.55	35	593.90		572.90	558.35	558.90
DM-22R	2191721.351	649560.4916	592.70	Survey	0	3	20	38.01	39.5	592.70	589.70	572.70	554.69	553.20
DM-23R	2191933.532	649357.3416	590.82	Survey	0	10	24	34.16	35	590.82	580.82	566.82	556.66	555.82
DM-24	2191946.31	649625.73	592.45	BackInt	0		Unclear*	36.54	37	592.45			555.91	555.45
DM-25R	2191937.078	650039.9422	593.37	Survey	0	2.5	15.5	35.01	35.5	593.37	590.87	577.87	558.36	557.87
DM-26	2191850.747	650200.8935	593.48	Survey	0	6	20	36.43	36	593.48	587.48	573.48	557.05	557.48
DM-27R	2192072.441	650184.8481	592.29	Survey	0	16.5	20.5	36.32	37	592.29	575.79	571.79	555.97	555.29
DM-28R	2192219.275	650346.0888	592.57	Survey	0			37	37	592.57			555.57	555.57
DM-29R	2192116.315	650463.8564	593.16	Survey	0	8	24	38.59	37	593.16	585.16	569.16	554.57	556.16
DM-3	2191431.176	650291.1612	594.48	Survey	0	3.25	12	12.49	13.1	594.48	591.23	582.48	581.99	581.38
DM-30R	2192328.275	650525.0468	593.02	Survey	0			35.5	35.5	593.02			557.52	557.52
DM-4	2191471.877	650294.5296	594.20	Survey	0	3	14	14.43	15	594.20	591.20	580.20	579.77	579.20
DM-5	2191432.21	650360.7256	594.13	Survey	0	4	16.5	18.26	19	594.13	590.13	577.63	575.87	575.13
DM-6	2191544.94	650367.44	594.52	BackInt	0	3		15.34	17.5	594.52	591.52		579.18	577.02
DM-7	2191408.85	650424.43	592.53	BackInt	0	3.33	12.25	27	27.5	592.53	589.20	580.28	565.53	565.03
DM-8	2191459	650488	594.78	BackInt	0	2.5	14	27	28	594.78	592.28	580.78	567.78	566.78
DM-9	2191527.007	650452.6445	594.83	Survey	0	1	15	18	19	594.83	593.83	579.83	576.83	575.83

Table D-1. Lithologic Pick Data (continued)

Station	Easting (ft)	Northing (ft)	Ground Surface Elevation (ft)	Ground Surface Elevation Source	Depth BGS (ft)					Elevation (ft amsl)				
					Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth	Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth
ENG1	2191601.35	650862.46	592.88	BackInt	0	4.5	13	16	17.5	592.88	588.38	579.88	576.88	575.38
ENG11	2191916.18	650753.62	593.74	BackInt	0	2.75	12	13.5	14	593.74	590.99	581.74	580.24	579.74
ENG12	2191573.55	650783.01	594.43	BackInt	0	1	14	18.5	18.5	594.43	593.43	580.43	575.93	575.93
ENG13	2191667.13	650753.08	594.95	BackInt	0	2	9	16	16.5	594.95	592.95	585.95	578.95	578.45
ENG14	2191762.3	650718.23	594.69	BackInt	0	Unclear*	1	10.5	11	594.69		593.69	584.19	583.69
ENG15	2191855.56	650688.72	594.90	BackInt	0	Unclear*	4	13.5	14	594.90		590.90	581.40	580.90
ENG16	2191882.92	650605.98	595.51	BackInt	0		4		12	595.51		591.51		583.51
ENG17	2191818.72	650577.66	595.56	BackInt	0	Unclear*	4	8.5	9	595.56		591.56	587.06	586.56
ENG2	2191633.04	650851.48	593.26	BackInt	0	2.5	15	16	17.5	593.26	590.76	578.26	577.26	575.76
ENG20	2191649.25	650494.64	594.22	BackInt	0	Unclear*	2	6.5	7	594.22		592.22	587.72	587.22
ENG21	2191586.49	650516.45	594.04	BackInt	0	2.5	Unclear*	16.5	17	594.04	591.54		577.54	577.04
ENG22	2191555.25	650635.29	594.04	BackInt	0	Unclear*	Unclear*		16	594.04				578.04
ENG23	2191538.32	650711.98	594.11	BackInt	0	Unclear*	10		16	594.11		584.11		578.11
ENG3	2191663.25	650841.43	593.18	BackInt	0	2.5	12	17.5	17.5	593.18	590.68	581.18	575.68	575.68
ENG4	2191694.95	650829.67	593.02	BackInt	0	5.75	12	17	18	593.02	587.27	581.02	576.02	575.02
ENG5	2191727.03	650818.55	592.74	BackInt	0	4	14.5	15.5	16	592.74	588.74	578.24	577.24	576.74
ENG6	2191757.72	650807.96	593.15	BackInt	0	4	12	15.5	16	593.15	589.15	581.15	577.65	577.15
ENG7	2191788.94	650800.17	593.33	BackInt	0	6	Unclear*	14	14.5	593.33	587.33		579.33	578.83
ERM-45	2191840.27	649934.39	594.48	BackInt	0	3.5	20.5	37.35	42.5	594.48	590.98	573.98	557.13	551.98
ERM-46	2191691.35	650011.18	593.74	BackInt	0	8	18.6	34.02	34	593.74	585.74	575.14	559.72	559.74
ERM-47	2191934.553	650347.5881	593.56	Survey	0	5.5	16	32.05	32.5	593.56	588.06	577.56	561.51	561.06
IA03-SB0001	2191602.83	650627.68	594.69	BackInt	0	3.5	12	18.2	19.3	594.69	591.19	582.69	576.49	575.39
IA03-SB0002	2191713.91	650583.44	595.04	BackInt	0	1.5		4.5	5.8	595.04	593.54		590.54	589.24
IA03-SB0005	2191621.48	650708.21	594.97	BackInt	0	1	12	16.7	18.7	594.97	593.97	582.97	578.27	576.27
IA03-SB0006	2191847.249	650923.336	591.89	BackInt	0	4			10	591.89	587.89			581.89
IA03-SB0007	2191794.91	650919.99	590.42	BackInt	0	1			10	590.42	589.42			580.42
IA03-SB0008	2191917.46	650974.55	591.30	BackInt	0	1.8	4.7		12	591.30	589.50	586.60		579.30
IA03-SB0009	2191720.72	650989.67	589.83	BackInt	0	2			12	589.83	587.83			577.83
IA03-SB0010	2191667.202	650976.695	589.84	BackInt	0	2.5	2.5		10	589.84	587.34	587.34		579.84
IA03-SB0011	2191557.04	650841.84	593.59	BackInt	0	8			12	593.59	585.59			581.59
IA03-SB0012	2191725	650827.55	592.53	BackInt	0	2	4		12	592.53	590.53	588.53		580.53
IA03-SB0013	2191852.04	650478.81	594.28	BackInt	0	2	Unclear*	8.5	9	594.28	592.28		585.78	585.28
IA03-SB0014	2191881.49	650647.58	595.16	BackInt	0	4	5.2	13	13.3	595.16	591.16	589.96	582.16	581.86
IA03-SB0015	2191850.2	650696.6	594.81	BackInt	0	1.5	4		12	594.81	593.31	590.81		582.81
IA03-SB0016	2191698.39	650518.82	594.16	BackInt	0	2	4	4.8	6.3	594.16	592.16	590.16	589.36	587.86
IA03-SB0017	2191611.34	650518.82	594.22	BackInt	0	4			12	594.22	590.22			582.22
IA03-SB0018	2191523.09	650568.96	594.20	BackInt	0				12	594.20				582.20
IA03-SB0019	2191531.85	650665.45	594.04	BackInt	0	5.25			12	594.04	588.79			582.04
IA03-SB0020	2191409.6	650664.87	592.61	BackInt	0	4.2			12	592.61	588.41			580.61
IA03-SB0021	2191591.38	650442.4	594.82	BackInt	0	Unclear*	Unclear*		7	594.82				587.82
IA03-SB0022	2191538.24	650519.25	593.97	BackInt	0	4.5			12	593.97	589.47			581.97
IA03-SB0023	2191485.11	650561.17	595.03	BackInt	0	1.9	12	20.8	24	595.03	593.13	583.03	574.23	571.03
IA03-SB0024	2191796.92	650510.87	594.58	BackInt	0	2	4	9.1	9.7	594.58	592.58	590.58	585.48	584.88
IA03-SB0025	2191856.81	650559.26	595.35	BackInt	0	0.2	8.4	10.9	11.3	595.35	595.15	586.95	584.45	584.05
IA03-SB0026	2191485.11	650608.68	595.30	BackInt	0	8			12	595.30	587.30			583.30
IA03-SB0027	2191504.15	650649.71	593.76	BackInt	0	4	8		12	593.76	589.76	585.76		581.76
IA03-SB0028	2191521.3	650723.27	593.89	BackInt	0	2			12	593.89	591.89			581.89
IA03-SB0029	2191470.56	650743.27	593.98	BackInt	0	Unclear*			12	593.98				581.98
IA03-SB0030	2191882.79	650725.58	595.15	BackInt	0	0.5	4		12	595.15	594.65	591.15		583.15
IA03-SB0031	2191774.67	650817.53	592.69	BackInt	0	3			12	592.69	589.69			580.69
IA03-SB0032	2191692.723	650873.179	591.12	BackInt	0	3			12	591.12	588.12			579.12
IA03-SB0033	2191660.83	650749.83	595.02	BackInt	0	1.2			12	595.02	593.82			583.02
IA03-SB0034	2191835.79	650799.7	592.76	BackInt	0	1	9	10.6	12	592.76	591.76	583.76	582.16	580.76
IA03-SB0035	2191970.62	650763.99	592.49	BackInt	0	2	10		12	592.49	590.49	582.49		580.49
IA03-SB0036	2191595.626	650903.145	591.93	BackInt	0	0.5	4		12	591.93	591.43	587.93		579.93
IA03-SB0037	2191640.821	650878.88	592.33	BackInt	0	Unclear*	4.3		12	592.33		588.03		580.33
IA03-SB0038	2191514.85	651113.56	591.20	BackInt	0	4			10	591.20	587.20			581.20
IA03-SB0039	2191651.18	651101.29	591.50	BackInt	0	4.3			10	591.50	587.20			581.50
IA03-SB0040	2191484.777	651156.4852	591.16	BackInt	0	4.2			6	591.16	586.96			585.16
IA03-SB0041	2191566.295	651142.4673	591.56	BackInt	0	4.1			6	591.56	587.46			585.56
IA03-SB0042	2191546.135	651075.0046	590.78	BackInt	0	Unclear*			6	590.78				584.78
IA03-SB0043	2191664.468	651034.7023	590.07	BackInt	0	2.25			10	590.07	587.82			580.07
IA03-SB0044	2191757.382	651040.8352	590.59	BackInt	0	1.3			10	590.59	589.29			580.59
IA03-SB0045	2191789.814	650979.5057	590.62	BackInt	0	2.1			10	590.62	588.52			580.62
IA03-SB0046	2191850.296	650961.1068	591.02	BackInt	0	1.6			6	591.02	589.42			585.02
IA03-SB0048	2191526.799	651206.4198	591.41	BackInt	0				4	591.41				587.41
IA03-SB0049	2191619.871	651223.6472	591.26	BackInt	0				4	591.26				587.26
IA03-SB0050	2191773.611	651112.7024	591.09	BackInt	0		1.75		4	591.09		589.34		587.09
IA03-SB0051	2191824.628	651076.8693	590.90	BackInt	0	2			4	590.90	588.90			586.90

Table D-1. Lithologic Pick Data (continued)

Station	Easting (ft)	Northing (ft)	Ground Surface Elevation (ft)	Ground Surface Elevation Source	Depth BGS (ft)					Elevation (ft amsl)				
					Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth	Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth
IA03-SB0052	2191865.994	651049.3053	590.79	BackInt	0	1.75			4	590.79	589.04			586.79
IA03-SB0053	2191817.734	651026.5649	591.08	BackInt	0	4.5			8	591.08	586.58			583.08
IA03-SB0054	2191637.119	650900.132	591.84	BackInt	0	1.9	3.7		12	591.84	589.94	588.14		579.84
IA03-SB0055	2191735.694	650857.973	591.15	BackInt	0	4.9			8	591.15	586.25			583.15
IA03-SB0056	2191534.383	650798.4732	593.77	BackInt	0	1	4		8	593.77	592.77	589.77		585.77
IA03-SB0057	2191504.048	650864.6267	592.21	BackInt	0	1.7			12	592.21	590.51			580.21
IA03-SB0058	2191486.813	650677.881	593.32	BackInt	0	1.33	5		12	593.32	591.99	588.32		581.32
IA03-SB0059	2191411.61	650712.45	593.44	BackInt	0	4			8	593.44	589.44			585.44
IA03-SB0060	2191412.77	650631.14	594.02	BackInt	0		4.5		8	594.02		589.52		586.02
IA03-SB0061	2191418.561	650552.4652	594.95	BackInt	0	0.4			12	594.95	594.55			582.95
IA03-SB0062	2191610.219	650549.7085	595.68	BackInt	0	2	3.66		6	595.68	593.68	592.02		589.68
IA03-SB0063	2191531.625	650453.924	594.44	BackInt	0	1.8	5		8	594.44	592.64	589.44		586.44
IA03-SB0064	2191588.158	650413.267	594.65	BackInt	0	2	4.5	6	7.2	594.65	592.65	590.15	588.65	587.45
IA03-SB0065	2191492.553	651137.162	591.45	BackInt	0	2.25			6	591.45	589.20			585.45
IA03-SB0066	2191512.714	651106.672	591.08	BackInt	0	4			6	591.08	587.08			585.08
IA03-SB0067	2191564.9	651039.86	589.96	BackInt	0	4			6	589.96	585.96			583.96
IA03-SB0068	2191518.138	651115.956	591.26	BackInt	0	4			7.5	591.26	587.26			583.76
IA03-SB0069	2191583.481	651072.747	592.43	BackInt	0	3			3	592.43	589.43			589.43
IA03-SB0070	2191535.623	651074.91	590.92	BackInt	0	4			6	590.92	586.92			584.92
IA03-SB0071	2191515.268	651146.675	591.45	BackInt	0	5			7.5	591.45	586.45			583.95
IA03-SB0072	2191644.6	650976.88	589.68	BackInt	0	1.25			10	589.68	588.43			579.68
IA03-SB0073	2191669.09	650963.42	589.71	BackInt	0	2			10	589.71	587.71			579.71
IA03-SB0074	2191716.938	650941.211	590.29	BackInt	0	1.75			10	590.29	588.54			580.29
IA03-SB0075	2191755.314	650925.395	589.96	BackInt	0	2			10	589.96	587.96			579.96
IA03-SB0076	2191789.272	650911.33	590.10	BackInt	0	1			10	590.10	589.10			580.10
IA03-SB0077	2191832.444	650895.705	589.98	BackInt	0	1.75			10	589.98	588.23			579.98
IA03-SB0078	2191873.298	650879.728	591.37	BackInt	0	1.5			14	591.37	589.87			577.37
IA03-SB0079	2191615.551	650927.143	590.48	BackInt	0				10	590.48				580.48
IA03-SB0080	2191644.898	650912.22	590.74	BackInt	0	4			10	590.74	586.74			580.74
IA03-SB0081	2191678.331	650898.881	590.59	BackInt	0	3			10	590.59	587.59			580.59
IA03-SB0082	2191707.126	650883.152	590.55	BackInt	0	2			10	590.55	588.55			580.55
IA03-SB0083	2191735.838	650871.347	590.95	BackInt	0	2			10	590.95	588.95			580.95
IA03-SB0084	2191766.859	650859.321	591.08	BackInt	0	4			10	591.08	587.08			581.08
IA03-SB0085	2191637.119	650900.132	591.84	BackInt	0	4			8	591.84	587.84			583.84
IA03-SB0086	2191692.723	650873.179	591.12	BackInt	0	4			8	591.12	587.12			583.12
IA03-SB0087	2191735.694	650857.973	591.15	BackInt	0				4	591.15				587.15
IA03-SB0088	2191724.453	650989.458	589.87	BackInt	0	4	14		15	589.87	585.87	575.87		574.87
IA03-SB0089	2191796.361	650923.21	590.58	BackInt	0	1.7			5	590.58	588.88			585.58
IA03-SB0090	2191864.416	650906.339	592.32	BackInt	0	4	10.5		15	592.32	588.32	581.82		577.32
IA03-SB0091	2191733.544	650946.918	590.46	BackInt	0	4			10	590.46	586.46			580.46
IA03-SB0092	2191823.517	650955.843	590.91	BackInt	0	4			10	590.91	586.91			580.91
IA03-SB0093	2191865.035	650945.536	591.36	BackInt	0	4.4			10	591.36	586.96			581.36
IA03-SB0094	2191474.307	650873.134	590.55	BackInt	0	2			8	590.55	588.55			582.55
IA03-SB0095	2191500.32	650867.121	592.10	BackInt	0				4.7	592.10				587.40
IA03-SB0096	2191556.663	650845.043	593.52	BackInt	0	1			4.6	593.52	592.52			588.92
IA03-SB0097	2191520.635	650833.036	592.64	BackInt	0				4	592.64				588.64
IA03-SB0098	2191547.814	650883.96	592.14	BackInt	0	4			4	592.14	588.14			588.14
IA03-SB0099	2191707.678	650818.192	592.84	BackInt	0	4			8	592.84	588.84			584.84
IA03-SB0100	2191495.382	650692.041	593.56	BackInt	0	4			8	593.56	589.56			585.56
IA03-SB0101	2191469.332	650674.271	593.35	BackInt	0	6			8	593.35	587.35			585.35
IA03-SB0102	2191390.642	650671.048	591.66	BackInt	0				6	591.66				585.66
IA03-SB0103	2191418.738	650660.399	593.13	BackInt	0	4			8	593.13	589.13			585.13
IA03-SB0104	2191466.5	650603.825	595.13	BackInt	0	4.25			8	595.13	590.88			587.13
IA03-SB0105	2191459.124	650534.802	595.00	BackInt	0	5			8	595.00	590.00			587.00
IA03-SB0106	2191554.252	650448.429	594.39	BackInt	0	2	4		8	594.39	592.39	590.39		586.39
IA03-SB0107	2191789.852	650535.921	594.47	BackInt	0	0.75			8	594.47	593.72			586.47
IA03-SB0108	2191872.47	650612.313	595.55	BackInt	0	4			12	595.55	591.55			583.55
IA03-SB0109	2191897.347	650647.27	595.08	BackInt	0	4			12	595.08	591.08			583.08
IA03-SB0110	2191974.583	650606.05	594.40	BackInt	0	4.25			12	594.40	590.15			582.40
IA03-SB0111	2191936.671	650661.966	594.82	BackInt	0	4			12	594.82	590.82			582.82
IA03-SB0112	2191901.034	650695.569	594.81	BackInt	0	4			8	594.81	590.81			586.81
IA03-SB0113	2191849.077	650697.115	594.81	BackInt	0	4.5			6.5	594.81	590.31			588.31
IA03-SB0114	2191883.858	650758.845	593.74	BackInt	0	Unclear*	4.5		7	593.74		589.24		586.74
IA03-SB0115	2191842.323	650730.61	594.80	BackInt	0	1.75	5		8	594.80	593.05	589.80		586.80
IA03-SB0116	2191579.714	650740.0579	595.13	BackInt	0	1		14	14	595.13	594.13		581.13	581.13
IA03-SB0117	2191789.6	650679.7717	594.50	BackInt	0	2.8	Unclear*	11.5	12	594.50	591.70		583.00	582.50
IA03-SB0118	2191729.872	650629.5332	594.80	BackInt	0	Unclear*	5	7	7.75	594.80		589.80	587.80	587.05
IA03-SB0119	2191650.607	650650.745	594.90	BackInt	0	1	Unclear*	10	10	594.90	593.90		584.90	584.90
IA03-SB0120	2191589.204	650590.4588	594.67	BackInt	0	Unclear*	5	18.5	19	594.67		589.67	576.17	575.67
IA03-SB0121	2191660.096	650569.8053	595.49	BackInt	0	0.5	1	2.5	5	595.49	594.99	594.49	592.99	590.49

Table D-1. Lithologic Pick Data (continued)

Station	Easting (ft)	Northing (ft)	Ground Surface Elevation (ft)	Ground Surface Elevation Source	Depth BGS (ft)					Elevation (ft amsl)				
					Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth	Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth
IA03-SB0123	2191615.061	650896.507	592.08	BackInt	0	2.6			6	592.08	589.48			586.08
IA03-SB0124	2191682.094	650846.023	592.71	BackInt	0	4			6	592.71	588.71			586.71
IA03-SB0125	2191420.449	650685.082	593.05	BackInt	0	4			6	593.05	589.05			587.05
IA03-SB0126	2191443.275	650662.799	593.10	BackInt	0	4			6	593.10	589.10			587.10
IA03-SB0127	2191452.703	650692.859	593.24	BackInt	0	4			6	593.24	589.24			587.24
IA03-SB0128	2191476.051	650703.666	593.51	BackInt	0	1			6	593.51	592.51			587.51
IA03-SB0129	2191473.629	650637.787	593.59	BackInt	0	4			6	593.59	589.59			587.59
IA03-SB0130	2191501.91	650543.435	594.89	BackInt	0	2.5			6	594.89	592.39			588.89
IA03-SB0131	2191930.771	650680.606	594.74	BackInt	0	2	4	13	13.2	594.74	592.74	590.74	581.74	581.54
IA03-SB0132	2191974.236	650656.562	594.55	BackInt	0	2			6.5	594.55	592.55			588.05
IA03-SB0133	2191948.58	650631.014	594.90	BackInt	0	4			6	594.90	590.90			588.90
IA03-SB0134	2191918.854	650709.728	594.70	BackInt	0	2			6	594.70	592.70			588.70
IA03-SB0135	2191869.256	650737.205	594.55	BackInt	0	Unclear*			6.5	594.55				588.05
IA03-SB0136	2191647.696	650767.677	594.97	BackInt	0	1.5	14.5	19.5	20.5	594.97	593.47	580.47	575.47	574.47
IA03-SB0137	2191672.752	650767.241	594.82	BackInt	0	2	13.75	17.6	18	594.82	592.82	581.07	577.22	576.82
IA03-SB0144	2191864.937	650819.784	591.83	BackInt	0				0.5	591.83				591.33
IA03-SB0145	2191497.18	650872.98	591.98	BackInt	0				1	591.98				590.98
IA03-SB0146	2191492.503	650881.244	591.24	BackInt	0				1	591.24				590.24
IA03-SB0147	2191479.618	651168.016	591.61	BackInt	0	2.9			7	591.61	588.71			584.61
IA03-SB0148	2191922.124	650901.253	593.25	BackInt	0	5.5			10	593.25	587.75			583.25
IA03-SB0149	2191896.01	650862.972	591.97	BackInt	0	1.5	13.4		18	591.97	590.47	578.57		573.97
IA03-SB0150	2191917.467	650853.795	590.66	BackInt	0				2	590.66				588.66
IA03-SB0151	2191960.557	650836.261	590.81	BackInt	0				1	590.81				589.81
IA03-TW0001	2191929.067	650543.648	593.90	Survey	0			12.4	12.7	593.90			581.50	581.20
IA03-TW0002	2191860.418	650782.562	593.17	Survey	0			10.5	16.8	593.17			582.67	576.37
IA03-TW0003	2191537.923	650917.841	590.49	Survey	0			19.2	20.8	590.49			571.29	569.69
IA03-TW0004	2191684.589	650974.55	589.80	Survey	0	Unclear*	Unclear*	28.5	29	589.80			561.30	560.80
IA03-TW0005	2191745.413	650655.763	594.56	Survey	0	Unclear*	Unclear*	8.75	9	594.56			585.81	585.56
IA03-TW0006	2191802.078	650651.718	594.51	Survey	0	2	4	11.25	11.9	594.51	592.51	590.51	583.26	582.61
IA04-SB0001	2191578.92	649966.3	592.52	BackInt	0	0.6	3.5		12	592.52	591.92	589.02		580.52
IA04-SB0002	2191707.78	650021.26	593.65	BackInt	0		4.5		12	593.65		589.15		581.65
IA04-SB0003	2191787.97	650114.37	593.25	BackInt	0		5		12	593.25		588.25		581.25
IA04-SB0004	2191859.42	650171.76	593.17	BackInt	0		8.3		12	593.17		584.87		581.17
IA04-SB0005	2191991.96	650245.28	592.84	BackInt	0		9.3		12	592.84		583.54		580.84
IA04-SB0007	2191964.15	650343.48	592.94	BackInt	0	1.5	6.1		12	592.94	591.44	586.84		580.94
IA04-SB0008	2191793.68	650324.96	593.49	BackInt	0				12	593.49				581.49
IA04-SB0009	2191664.72	650356.09	594.25	BackInt	0		1.5	8	10.5	594.25		592.75	586.25	583.75
IA04-SB0010	2191441.07	650279.62	594.34	BackInt	0		4		12	594.34		590.34		582.34
IA04-SB0011	2192422.88	650460.36	591.07	BackInt	0				26	591.07				565.07
IA04-SB0012	2192321.01	650452.44	593.40	BackInt	0	8.5			9.9	593.40	584.90			583.50
IA04-SB0013	2192449.75	650565.2	590.49	BackInt	0	5.2			12	590.49	585.29			578.49
IA04-SB0014	2192686.29	650560.66	586.96	BackInt	0	2			12	586.96	584.96			574.96
IA04-SB0019	2192456.125	650462.09	581.41	BackInt	0				5	581.41				576.41
IA04-SB0020	2192458.057	650591.516	594.27	BackInt	0	3.5			5	594.27	590.77			589.27
IA04-SB0021	2192441.934	650571.073	590.31	BackInt	0				4	590.31				586.31
IA04-SB0022	2192468.128	650540.405	590.89	BackInt	0	3.5	5.75	35	35.5	590.89	587.39	585.14	555.89	555.39
IA04-SB0023	2192391.141	650493.851	592.91	BackInt	0	14	22	37.9	39.5	592.91	578.91	570.91	555.01	553.41
IA04-SB0024	2192302.19	650410.293	593.06	BackInt	0		26.5	39	39.3	593.06		566.56	554.06	553.76
IA04-SB0025	2192206.544	650340.404	592.63	BackInt	0	8.5	25	37.8	39.5	592.63	584.13	567.63	554.83	553.13
IA04-SB0026	2192018.707	650127.939	592.38	BackInt	0	18.5	20	38	39	592.38	573.88	572.38	554.38	553.38
IA04-SB0027	2192123.701	650254.693	592.96	BackInt	0		22	39	40	592.96		570.96	553.96	552.96
IA04-SB0028	2191934.894	650021.007	593.30	BackInt	0	8	20	39.7	40	593.30	585.30	573.30	553.60	553.30
IA04-SB0029	2191879.37	650208.714	593.49	BackInt	0				4.8	593.49				588.69
IA04-SB0030	2191837.348	650170.725	593.21	BackInt	0				4.75	593.21				588.46
IA04-SB0031	2191840.127	650217.682	593.50	BackInt	0				4.4	593.50				589.10
IA04-SB0032	2192397.827	650443.9996	591.04	BackInt	0				19	591.04				572.04
IA04-SB0033	2192445.38	650479.9541	588.39	BackInt	0	16.25	17.5		24	588.39	572.14	570.89		564.39
IA04-SB0035	2192400.147	650517.6483	592.42	BackInt	0		8		10	592.42		584.42		582.42
IA04-SB0036	2192360.713	650492.1322	593.05	BackInt	0				6	593.05				587.05
IA04-SB0038	2191867.209	650234.6518	593.52	BackInt	0	Unclear*	Unclear*		4.2	593.52				589.32
IA04-SB0039	2191904.903	650230.0125	593.41	BackInt	0	Unclear*	Unclear*		4	593.41				589.41
IA04-SB0044	2192451.668	650502.982	591.99	BackInt	0	1.5	13		13	591.99	590.49	578.99		578.99
IA04-SB0048	2192361.363	650446.062	593.14	BackInt	0	5.5			13	593.14	587.64			580.14
IA04-SB0049	2192377.184	650423.767	592.12	BackInt	0		18		24	592.12		574.12		568.12
IA04-SB0051	2192348.384	650554.506	593.03	BackInt	0	4			10	593.03	589.03			583.03
IA04-SB0053	2192316.047	650468.966	593.28	BackInt	0				13	593.28				580.28
IA04-SB0054	2192288.212	650455.623	593.49	BackInt	0				13	593.49				580.49
IA04-TW0001	2191867.547	649878.02	592.71	Survey	0			38	38.4	592.71			554.71	554.31
IA04-TW0002	2191510.294	649967.139	591.86	Survey	0				23.5	591.86				568.36
IA04-TW0003	2192075.239	650700.562	592.94	Survey	0			14.2	15.3	592.94			578.74	577.64

Table D-1. Lithologic Pick Data (continued)

Station	Easting (ft)	Northing (ft)	Ground Surface Elevation (ft)	Ground Surface Elevation Source	Depth BGS (ft)					Elevation (ft amsl)				
					Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth	Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth
IA04-TW0004	2192426.352	650466.22	591.22	Survey	0			35	35.3	591.22			556.22	555.92
IA04-TW0005	2192127.987	650840.906	590.24	Survey	0			24.5	25	590.24			565.74	565.24
IA04-TW0006	2192521.622	650652.209	586.35	Survey	0			32.6	32.9	586.35			553.75	553.45
IA05-SB0003	2191959.78	649356.9	591.34	BackInt	0	12	16		20	591.34	579.34	575.34		571.34
IA05-SB0005	2191996.37	649422.89	590.23	BackInt	0		12.5		16	590.23		577.73		574.23
IA05-SB0007	2191885.26	649406.07	590.67	BackInt	0		12		24	590.67		578.67		566.67
IA05-SB0009	2191939.09	649393.76	591.12	BackInt	0		20	33.8	34	591.12		571.12	557.32	557.12
IA05-SB0010	2191859.31	649436.18	591.30	BackInt	0		13		16	591.30		578.30		575.30
IA05-SB0014	2191618.02	649614.26	592.62	BackInt	0	1	12	37.2	37.8	592.62	591.62	580.62	555.42	554.82
IA05-SB0015	2191776.78	649597.3	593.01	BackInt	0	1	10		14	593.01	592.01	583.01		579.01
IA05-SB0016	2191626.71	649574.02	591.68	BackInt	0	3			12	591.68	588.68			579.68
IA05-SB0019	2191780.505	649650.4348	593.02	BackInt	0	1.3			8	593.02	591.72			585.02
IA05-SB0020	2191729.489	649572.5666	592.73	BackInt	0	1.2			8	592.73	591.53			584.73
IA05-SB0021	2191824.628	649569.8103	592.85	BackInt	0	1			8	592.85	591.85			584.85
IA05-SB0022	2191956.997	649627.0054	591.07	BackInt	0	4	8		16	591.07	587.07	583.07		575.07
IA05-SB0023	2191941.274	649658.727	591.58	BackInt	0	2	4		12	591.58	589.58	587.58		579.58
IA05-SB0025	2191956.378	649642.101	587.90	BackInt	0	17	22.5	35.2	37	587.90	570.90	565.40	552.70	550.90
IA05-SB0026	2191946.656	649660.082	589.78	BackInt	0	10.6			20	589.78	579.18			569.78
IA05-SB0027	2191939.288	649686.155	588.75	BackInt	0	12	18		14	588.75	576.75	570.75		574.75
IA05-SB0028	2191934.181	649697.584	589.98	BackInt	0	12	17		20	589.98	577.98	572.98		569.98
IA05-SB0029	2191978.46	649527.643	590.86	BackInt	0	12			12	590.86	578.86			578.86
IA05-SB0030	2191991.125	649453.54	591.10	BackInt	0				20	591.10				571.10
IA05-SB0031	2191950.502	649434.387	591.35	BackInt	0				10.5	591.35				580.85
IA05-SB0032	2191944.484	649389.05	591.18	BackInt	0	10.5	15	33.9	36	591.18	580.68	576.18	557.28	555.18
IA05-SB0033	2191955.697	649401.498	591.56	BackInt	0	9.5			16.5	591.56	582.06			575.06
IA05-SB0034	2191952.459	649347.21	591.40	BackInt	0				14	591.40				577.40
IA05-SB0035	2191884.366	649440.708	591.86	BackInt	0	8			10	591.86	583.86			581.86
IA05-SB0036	2191866.134	649455.67	591.64	BackInt	0				10.65	591.64				580.99
IA05-SB0037	2191771.04	649571.859	593.26	BackInt	0				4	593.26				589.26
IA05-SB0038	2191754.186	649621.252	592.95	BackInt	0	0.9			6	592.95	592.05			586.95
IA05-SB0039	2191800.756	649608.384	593.07	BackInt	0	1			4	593.07	592.07			589.07
IA05-SB0044	2191902.405	649424.455	591.72	BackInt	0				7.5	591.72				584.22
IA05-SB0045	2191975.107	649383.893	591.15	BackInt	0	6	16		25	591.15	585.15	575.15		566.15
IA05-SB0046	2191954.648	649412.711	591.73	BackInt	0	5	16		23	591.73	586.73	575.73		568.73
IA05-SB0047	2191894.97	649401.813	590.53	BackInt	0	13			23.5	590.53	577.53			567.03
IA05-SB0048	2191964.377	649452.52	591.38	BackInt	0	13			20	591.38	578.38			571.38
IA05-SB0049	2191981.242	649475.063	591.05	BackInt	0	18			20	591.05	573.05			571.05
IA05-SB0050	2191921.268	649447.736	591.24	BackInt	0				7.5	591.24				583.74
IA05-SB0051	2191929.377	649473.129	591.23	BackInt	0				10	591.23				581.23
IA05-SB0052	2191957.146	649504.955	591.55	BackInt	0				6	591.55				585.55
IA05-SB0053	2191843.005	649476.506	591.91	BackInt	0				10	591.91				581.91
IA05-SB0054	2191937.074	649642.622	593.03	BackInt	0	4	13		15	593.03	589.03	580.03		578.03
IA05-SB0055	2191920.617	649687.503	592.37	BackInt	0	2	8		15	592.37	590.37	584.37		577.37
IA05-SB0056	2191924.061	649667.727	593.16	BackInt	0	2	13		15	593.16	591.16	580.16		578.16
IA05-TW0001	2191929.224	649644.711	593.16	BackInt	0			37.4	37.8	593.16			555.76	555.36
IA06-SB0001	2192323.02	649891.17	589.84	BackInt	0		4		10	589.84		585.84		579.84
IA06-SB0003	2192311.22	649977.57	585.08	BackInt	0				5.5	585.08				579.58
IA06-SB0004	2192398.6	650056.11	579.56	BackInt	0	Absent	6.5		10	579.56		573.06		569.56
IA06-SB0005	2192713.49	650138.7	583.73	BackInt	0		4		10	583.73		579.73		573.73
IA06-SB0006	2192523.97	650159.35	582.29	BackInt	0	Absent	2		10	582.29		580.29		572.29
IA06-SB0007	2192657.03	650269.55	580.46	BackInt	0	Absent	4		10	580.46		576.46		570.46
IA06-SB0008	2192397.536	649879.2155	592.02	BackInt	0				2.5	592.02				589.52
IA07-SB0001	2192364.182	648329.274	594.62	BackInt	0				10	594.62				584.62
IA07-SB0002	2192470.981	648440.853	591.30	BackInt	0	8			10	591.30	583.30			581.30
IA07-SB0003	2192177.917	648508.57	591.60	BackInt	0	2			10	591.60	589.60			581.60
IA07-SB0004	2192107.153	648603.495	596.73	BackInt	0	6			12	596.73	590.73			584.73
IA07-SB0005	2192050.955	648508.17	596.92	BackInt	0	6			10	596.92	590.92			586.92
IA07-SB0006	2192167.545	648688.414	595.23	BackInt	0	8			10	595.23	587.23			585.23
IA07-SB0010	2192385.65	648552.46	590.76	BackInt	0		7		10	590.76		583.76		580.76
IA07-SB0011	2191724.5	649051.9	593.06	BackInt	0	Unclear*	11	38	38	593.06		582.06	555.06	555.06
IA07-SB0012	2191520.753	649250.42	592.29	BackInt	0		28		28	592.29		564.29		564.29
IA07-SB0013	2191665.847	649306.445	584.65	BackInt	0	4			10	584.65	580.65			574.65
IA07-SB0014	2191331.512	649353.998	593.45	BackInt	0			27.5	28	593.45			565.95	565.45
IA07-SB0015	2191384.854	649510.127	587.90	BackInt	Absent	0	5		12		587.90	582.90		575.90
IA07-SB0016	2191517.942	649532.643	587.38	BackInt	0		11		12	587.38		576.38		575.38
IA07-SB0017	2192058.655	648524.141	597.75	BackInt	0				2	597.75				595.75
IA07-SB0018	2192036.971	648515.726	596.80	BackInt	0				2	596.80				594.80
IA07-SB0025	2191431.952	649496.861	587.24	BackInt	Absent	0	1.5		12		587.24	585.74		575.24
IA07-SB0026	2192076.416	648494.858	591.62	BackInt	0				2	591.62				589.62
IA07-SB0027	2192056.075	648485.628	595.15	BackInt	0				1.4	595.15				593.75

Table D-1. Lithologic Pick Data (continued)

Station	Easting (ft)	Northing (ft)	Ground Surface Elevation (ft)	Ground Surface Elevation Source	Depth BGS (ft)					Elevation (ft amsl)				
					Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth	Top New Fill	Top Old Fill	Top Native Sediment	Top Weathered Bedrock	Total Depth
IA07-SB0033	2192167.291	648637.812	596.20	BackInt	0	8.75			16	596.20	587.45			580.20
IA07-SB0034	2192089.549	648562.608	596.40	BackInt	0	8			12	596.40	588.40			584.40
IA07-SB0035	2192020.56	648556.271	597.35	BackInt	0	10			14	597.35	587.35			583.35
IA07-SB0036	2192037.065	648523.534	597.03	BackInt	0				2	597.03				595.03
IA07-SB0039	2192102.337	648576.024	596.51	BackInt	0	Unclear*	9		13	596.51		587.51		583.51
IA09-SB0002	2191767.483	650438.02	594.44	BackInt	0	5	Unclear*	6.5	8	594.44	589.44		587.94	586.44
IA09-SB0003	2191534.279	650722.066	594.05	BackInt	0			18.3	18.7	594.05			575.75	575.35
IA09-SB0005	2191662.7	650333.22	593.99	BackInt	0		5		8	593.99		588.99		585.99
IA10-MW0001	2191641.115	651100.676	591.61	Survey	0		3.01	29.51	30.5	591.61		588.60	562.10	561.11
IA10-MW0002	2191965.682	650913.4609	593.69	Survey	0		6.5	32.5	33.5	593.69		587.19	561.19	560.19
IA10-MW0003	2191901.556	650614.3214	595.55	Survey	0	1.5		13	14.5	595.55	594.05		582.55	581.05
IA10-MW0004	2192091.075	650693.7418	593.54	Survey	0	5	19	19.52	22	593.54	588.54	574.54	574.02	571.54
IA10-MW0005	2191901.5	650672.6	594.89	BackInt	0	2	6.25	13.7	14	594.89	592.89	588.64	581.19	580.89
IA10-MW0007	2191831.1	650386.5	593.64	BackInt	0	6.4	16.5	22.6	25	593.64	587.24	577.14	571.04	568.64
IA10-MW0008	2192040.3	650208.7	592.85	BackInt	0	17	22	37	38.5	592.85	575.85	570.85	555.85	554.35
IA10-MW0009	2191743.5	649359.7	584.61	Survey	0	3.4	6.6		25	584.61	581.21	578.01		559.61
IA10-MW0010	2191831.9	649212.7	584.15	Survey	0	4	14		26	584.15	580.15	570.15		558.15
IA10-MW0011	2191925.6	649071.5	589.33	Survey	0	Unclear*	12.6	33.35	34	589.33		576.73	555.98	555.33
IA10-MW0012	2192019.8	648987	581.50	Survey	0	Absent	13.2	25.3	26	581.50		568.30	556.20	555.50
IA10-MW0013	2192125.2	648872.3	583.64	Survey	0	6	13.3		27	583.64	577.64	570.34		556.64
IA10-MW0014	2192165.7	648680.2	594.91	Survey	0	6	26	37	39	594.91	588.91	568.91	557.91	555.91
IA10-MW0015	2192086.7	648575.5	596.26	Survey	0	Unclear*	14.8	36	37.5	596.26		581.46	560.26	558.76
IA10-MW0016	2192480	648351.3	592.03	Survey	0	4.5	16	23.5	23.5	592.03	587.53	576.03	568.53	568.53
IA10-MW0017	2192578.9	648410.5	590.77	Survey	0	1.3	22	27.5	29	590.77	589.47	568.77	563.27	561.77
IA10-MW0018	2192698.4	648342.3	590.05	Survey	0	4.5	12.8	17.2	19	590.05	585.55	577.25	572.85	571.05
IA10-MW0019	2192813	648285.2	594.79	Survey	0	5	12	19.7	21	594.79	589.79	582.79	575.09	573.79
RMW-31	2191546.7	650364.95	594.48	BackInt	0		3	8.59	21	594.48		591.48	585.89	573.48
RMW-35	2191566.085	650682.821	594.65	Survey	0	0.5	13	18	18	594.65	594.15	581.65	576.65	576.65
RMW-38	2191739.009	650453.1165	594.55	Survey	0	4	6		22	594.55	590.55	588.55		572.55
RMW-39	2191523.348	650696.531	593.78	Survey	0	7.88	16.88	18.88	19	593.78	585.90	576.90	574.90	574.78
RMW-41	2191568.71	650805.2	594.21	BackInt	0	2	6.5	18.64	19	594.21	592.21	587.71	575.57	575.21
RMW-42	2191562.55	650809.76	594.09	BackInt	0	Unclear*	Unclear*	18.66	19	594.09			575.43	575.09
RMW-43	2191544.22	650468.22	594.18	BackInt	0	6.7	Unclear*	18.37	19	594.18	587.48		575.81	575.18
RMW-44	2191532.49	650459.37	594.35	BackInt	0	2.5	14.5	17.9	19	594.35	591.85	579.85	576.45	575.35
RPZ32	2191544.01	650462.24	593.94	BackInt	0	7	Unclear*	17	20.5	593.94	586.94		576.94	573.44
RPZ33	2191588	650390	594.67	BackInt	0	2	5	5.04	23	594.67	592.67	589.67	589.63	571.67
RPZ34	2191737	650405	594.27	BackInt	0	2	3	8	22	594.27	592.27	591.27	586.27	572.27
RPZ36	2191540.64	650590.44	594.05	BackInt	0	5	16		23	594.05	589.05	578.05		571.05
RPZ37	2191530	650126	593.60	BackInt	0		5	21.48	23	593.60		588.60	572.12	570.60

Notes:
BackInt = Ground surface elevation back-interpolated from topographic elevation at station x,y location.
Unclear* = Pick not able to be made from log. Unit may or may not be present.
Absent = Unit absent

Table D-2. Water Level Data Collected from June 2003 through July 2010

Well ID	Easting (ft)	Northing (ft)	TOC Elevation (ft)	Ground Elevation (ft)	Water Level Measurement													Statistics			Difference from Well Mean (ft)												
					6/3/2003	7/3/2003	12/3/2003	5/23/2004	8/24/2004	8/27/2004	10/21/2004	12/14/2004	5/3/2005	11/16/2006	8/18/2008	8/17/2009	6/7/2010	Count	Mean (ft)	Range (ft)	6/3/2003	7/3/2003	12/3/2003	5/23/2004	8/24/2004	8/27/2004	10/21/2004	12/14/2004	5/3/2005	11/16/2006	8/18/2008	8/17/2009	6/7/2010
BKA-48	2191690.02	650842.78	594.87	592.70	581.67	583.21	584.76	586.65	581.97	581.88	581.63	584.15	586.15	584.65	582.22	583.54	585.15	13	583.7	5.0	-2.0	-0.5	1.1	3.0	-1.7	-1.8	-2.0	0.5	2.5	1.0	-1.4	-0.1	1.5
BKA-51	2191592.31	649653.75	595.76	593.18	568.68	582.40	576.89	585.04	575.12	NM	574.83	576.19	577.90	579.30	575.05	575.78	578.11	12	577.1	16.4	-8.4	5.3	-0.2	7.9	-2.0		-2.3	-0.9	0.8	2.2	-2.1	-1.3	1.0
BKA-52	2191758.05	649730.48	593.13	593.40	573.90	578.82	575.71	585.46	574.15	NM	573.87	575.03	576.33	NM	NM	NM	NM	8	576.7	11.6	-2.8	2.2	-0.9	8.8	-2.5		-2.8	-1.6	-0.3				
BKA-53	2191937.30	649459.32	593.40	591.16	571.36	580.10	575.42	585.92	573.80	NM	573.66	574.88	575.59	580.05	573.41	573.39	575.32	12	576.1	14.6	-4.7	4.0	-0.7	9.8	-2.3		-2.4	-1.2	-0.5	4.0	-2.7	-2.7	-0.8
BKG-MW0001	2191081.12	649708.88	592.10	592.67	NM	NM	581.31	584.02	580.59	NM	580.40	592.10	582.36	581.99	580.58	581.15	581.72	10	582.6	11.7			-1.3	1.4	-2.0		-2.2	9.5	-0.3	-0.6	-2.0	-1.5	-0.9
BKG-MW0002	2191322.01	649989.17	593.42	594.39	NM	NM	581.87	580.03	580.01	NM	578.33	577.90	581.01	580.41	NM	NM	NM	7	579.9	4.0			1.9	0.1	0.1		-1.6	-2.0	1.1	0.5			
BKG-MW0003	2191324.77	650473.30	591.98	592.73	NM	NM	584.77	587.25	582.28	NM	581.73	583.97	586.76	NM	582.04	583.36	NM	8	584.0	5.5			0.8	3.2	-1.7		-2.3	0.0	2.7		-2.0	-0.7	
BKG-MW0004	2191331.18	650541.24	592.30	592.69	NM	NM	584.80	587.16	582.28	NM	581.69	583.96	586.74	584.32	NM	NM	NM	7	584.4	5.5			0.4	2.7	-2.1		-2.7	-0.5	2.3	-0.1			
BKG-MW0005	2191218.21	651099.72	592.20	592.37	NM	NM	584.60	586.48	582.13	NM	581.77	583.92	586.00	583.81	582.11	583.09	584.39	10	583.8	4.7			0.8	2.6	-1.7		-2.1	0.1	2.2	0.0	-1.7	-0.7	0.6
CDT-MW0001	2191310.37	649612.52	588.09	588.42	NM	NM	578.79	583.41	577.30	NM	577.04	578.10	580.57	NM	NM	578.20	NM	7	579.1	6.4			-0.3	4.4	-1.8		-2.0	-1.0	1.5			-0.9	
CDT-MW0002	2191471.66	649538.84	587.21	587.43	NM	NM	577.70	581.05	575.81	NM	575.25	576.10	577.96	NM	NM	575.61	NM	7	577.1	5.8			0.6	4.0	-1.3		-1.8	-1.0	0.9			-1.5	
DM-1	2191465.84	650137.02	596.13	593.71	580.67	584.94	582.75	582.32	581.62	578.09	578.44	580.80	586.06	585.24	580.39	591.34*	586.15	12	582.3	8.1	-1.6	2.6	0.5	0.0	-0.7	-4.2	-3.8	-1.5	3.8	3.0	-1.9		3.9
DM-10	2191405.93	650534.87	592.71	593.21	582.70	583.38	583.14	585.61	580.58	580.47	579.99	582.37	585.27	NM	580.43	581.72	583.24	12	582.4	5.6	0.3	1.0	0.7	3.2	-1.8	-1.9	-2.4	0.0	2.9		-2.0	-0.7	0.8
DM-11	2191520.52	650597.82	595.89	593.88	582.17	584.41	585.29	587.84	582.35	582.22	581.67	584.60	587.33	584.49	582.11	583.57	585.41	13	584.1	6.2	-1.9	0.3	1.2	3.7	-1.8	-1.9	-2.4	0.5	3.2	0.4	-2.0	-0.5	1.3
DM-12	2191426.01	650643.80	596.13	593.93	581.79	583.71	584.93	587.32	582.16	582.06	581.62	584.16	587.02	584.28	581.63	583.34	584.98	13	583.8	5.7	-2.0	-0.1	1.2	3.6	-1.6	-1.7	-2.1	0.4	3.3	0.5	-2.1	-0.4	1.2
DM-14	2191443.51	650747.03	596.33	594.19	581.42	581.92	584.73	587.10	582.05	581.90	581.51	584.06	586.92	584.41	582.38	583.65	585.56	13	583.7	5.7	-2.2	-1.7	1.1	3.4	-1.6	-1.8	-2.2	0.4	3.3	0.7	-1.3	0.0	1.9
DM-15	2191564.93	650795.45	596.46	594.26	581.27	581.80	584.72	587.11	582.06	581.89	581.28	584.25	586.75	584.03	579.98	583.14	583.80	13	583.2	7.1	-2.0	-1.4	1.5	3.9	-1.2	-1.3	-2.0	1.0	3.5	0.8	-3.3	-0.1	0.6
DM-2	2191511.78	650188.40	594.02	594.25	586.38	586.82	586.85	589.16	584.74	584.51	582.87	586.22	586.09	587.03	NM	NM	NM	10	586.1	6.3	0.3	0.8	0.8	3.1	-1.3	-1.6	-3.2	0.2	0.0	1.0			
DM-22R	2191721.35	649560.49	594.81	592.70	571.71	579.06	575.84	585.96	574.08	NM	573.88	575.20	576.12	579.90	573.60	573.75	575.79	12	576.2	14.3	-4.5	2.8	-0.4	9.7	-2.2		-2.4	-1.0	-0.1	3.7	-2.6	-2.5	-0.5
DM-23R	2191933.53	649357.34	593.06	590.82	571.35	583.66	575.60	586.18	573.84	NM	573.70	575.02	575.73	580.26	573.46	573.39	575.63	12	576.5	14.8	-5.1	7.2	-0.9	9.7	-2.6		-2.8	-1.5	-0.8	3.8	-3.0	-3.1	-0.9
DM-25R	2191937.08	650039.94	592.84	593.37	573.62	575.88	575.36	582.43	573.95	NM	573.54	574.53	575.60	578.13	573.57	573.76	575.45	12	575.5	8.9	-1.9	0.4	-0.1	6.9	-1.5		-1.9	-1.0	0.1	2.6	-1.9	-1.7	0.0
DM-26	2191850.75	650200.89	592.99	593.48	574.06	575.79	575.54	582.37	574.41	NM	573.97	574.62	576.32	580.30	573.80	574.28	575.79	12	575.9	8.6	-1.9	-0.1	-0.4	6.4	-1.5		-2.0	-1.3	0.4	4.4	-2.1	-1.7	-0.1
DM-27R	2192072.44	650184.85	594.78	592.29	570.71	572.53	575.20	582.24	573.85	NM	573.39	574.36	575.26	577.99	NM	NM	NM	9	575.1	11.5	-4.3	-2.5	0.1	7.2	-1.2		-1.7	-0.7	0.2	2.9			
DM-28R	2192219.27	650346.09	595.09	592.57	570.30	577.52	574.51	583.64	573.39	NM	572.93	573.95	574.74	579.03	572.94	573.17	574.56	12	575.1	13.3	-4.8	2.5	-0.5	8.6	-1.7		-2.1	-1.1	-0.3	4.0	-2.1	-1.9	-0.5
DM-29R	2192116.32	650463.86	595.49	593.16	570.81	579.66	574.63	582.93	573.53	NM	572.96	574.02	575.00	578.17	572.98	573.41	574.79	12	575.2	12.1	-4.4	4.4	-0.6	7.7	-1.7		-2.3	-1.2	-0.2	2.9	-2.3	-1.8	-0.5
DM-3	2191431.18	650291.16	594.14	594.48	592.11	590.96	592.51	592.76	591.66	591.49	591.61	592.63	592.47	592.81	590.02	591.90	592.57	13	592.0	2.8	0.2	-1.0	0.5	0.8	-0.3	-0.5	-0.4	0.7	0.5	0.8	-1.9	-0.1	0.6
DM-30R	2192328.28	650525.05	594.91	593.02	570.80	576.40	574.36	582.94	573.30	NM	572.71	573.80	574.69	578.23	572.71	573.03	574.35	12	574.8	12.1	-4.0	1.6	-0.4	8.2	-1.5		-2.1	-1.0	-0.1	3.5	-2.1	-1.7	-0.4
DM-4	2191471.88	650294.53	593.84	594.20	589.83	589.14	590.14	590.90	589.10	588.92	588.65	589.97	590.42	589.74	587.06	588.64	589.86	13	589.4	3.8	0.4	-0.3	0.7	1.5	-0.3	-0.5	-0.8	0.6	1.0	0.3	-2.4	-0.8	0.4
DM-5	2191432.21	650360.73	596.36	594.13	581.99	582.61	584.99	587.20	582.67	582.56	582.09	584.25	587.08	584.95	582.45	583.67	585.11	13	584.0	5.2	-2.0	-1.4	1.0	3.2	-1.3	-1.4	-1.9	0.3	3.1	1.0	-1.5	-0.3	1.1
DM-9	2191527.01	650452.64	598.01	594.83	583.93	582.73	584.19	586.34	581.77	581.52	581.07	583.62	585.97	584.10	581.27	583.51	586.04	13	583.5	5.3	0.4	-0.8	0.6	2.8	-1.8	-2.0	-2.5	0.1	2.4	0.6	-2.3	0.0	2.5
ERM-47	2191934.55	650347.59	593.06	593.56	573.56	577.43	NM	583.43	574.08	NM	573.44	574.46	575.89	579.18	573.50	579.38	590.32*	10	576.4	10.0	-2.9	1.0		7.0	-2.4		-3.0	-2.0	-0.5	2.7	-2.9	2.9	
IA03-TP0001	2191574.09	650912.44	594.16	591.50	NM	NM	NM	NM	NM	NM	580.70	582.84	582.84	582.67	580.89	NM	582.95	6	582.2	2.2							-1.4	0.7	0.7	0.5	-1.3		0.8
IA03-TW0001	2191929.07	650543.65	596.50	593.90	NM	589.28	NM	589.95	588.79	NM	591.30	591.97	586.87	592.80	590.11	NM	591.69	9	590.3	5.9		-1.0		-0.4	-1.5		1.0	1.7	-3.4	2.5	-0.2		1.4
IA03-TW0002	2191860.42	650782.56	595.39	592	NM	581.57	585.98	586.77	585.22	NM	584.71	585.08	586.61	586.35	585.29	NM	586.43	10	585.4	5.2		-3.8	0.6	1.4	-0.2		-0.7	-0.3	1.2	0.9	-0.1		1.0
IA03-TW0003	2191537.92	650917.84	593.39	590.49	NM	580.60	582.14	584.46	579.43	579.37	579.31	581.41	583.06	NM	579.39	580.97	581.48	11	581.1	5.1		-0.5	1.1	3.4	-1.6	-1.7	-1.7	0.4	2.0		-1.7	-0.1	0.4
IA03-TW0004	2191684.59	650974.55	592.92	589.80	NM	582.10	583.45	584.97	580.67	NM	580.34	582.89	584.54	583.28	580.77	NM	583.71	10	582.7	4.6		-0.6	0.8	2.3	-2.0		-2.3	0.2	1.9	0.6	-1.9		1.0
IA03-TW0005	2191745.41	650655.76	NA	596	NM	NM	NM	591.40	594.60	NM	NM	587.64	591.35	NM	NM	NM	NM	4	591.2	7.0				0.2	3.4			-3.6	0.1				
IA03-TW0006	2191802.08	650651.72	NA	596	NM	NM	NM	NM	595.00	NM	NM	587.60	591.33	NM	NM	NM	NM	3	591.3	7.4					3.7			-3.7	0.0				
IA04-TP0001	2191673.13	650365.68	596.32	594.34	NM	NM	NM	595*	585.51	NM	584.08	584.75	585.40	584.07	585.01	586.86	588.32	8	585.5	4.2					0.0		-1.4	-0.7	-0.1	-1.4	-0.5	1.4	2.8

Table D-2. Water Level Data Collected from June 2003 through July 2010 (continued)

Well ID	Easting (ft)	Northing (ft)	TOC Elevation (ft)	Ground Elevation (ft)	Water Level Measurement													Statistics			Difference from Well Mean (ft)												
					6/3/2003	7/3/2003	12/3/2003	5/23/2004	8/24/2004	8/27/2004	10/21/2004	12/14/2004	5/3/2005	11/16/2006	8/18/2008	8/17/2009	6/7/2010	Count	Mean (ft)	Range (ft)	6/3/2003	7/3/2003	12/3/2003	5/23/2004	8/24/2004	8/27/2004	10/21/2004	12/14/2004	5/3/2005	11/16/2006	8/18/2008	8/17/2009	6/7/2010
IA04-TP0002	2191830.51	650320.91	595.74	593.33	NM	NM	NM	582.12	574.58	NM	573.90	574.67	576.39	577.55	573.98	574.59	575.95	9	576.0	8.2				6.2	-1.4		-2.1	-1.3	0.4	1.6	-2.0	-1.4	0.0
IA04-TP0003	2192021.81	650334.47	595.39	592.77	NM	NM	NM	NM	573.80	NM	573.27	574.18	574.18	578.19	576.57	576.35	577.84	8	575.6	4.9					-1.7		-2.3	-1.4	-1.4	2.6	1.0	0.8	2.3
IA04-TP0004	2192055.73	650551.55	595.20	593.30	NM	NM	NM	582.39	578.29	NM	578.65	580.39	581.95	580.85	577.68	580.41	581.41	9	580.2	4.7				2.2	-1.9		-1.6	0.2	1.7	0.6	-2.5	0.2	1.2
IA04-TP0005	2192185.97	650635.66	594.47	591.92	NM	NM	NM	576.11	573.39	NM	572.82	573.62	574.83	578.01	572.83	NM	574.48	8	574.5	5.2				1.6	-1.1		-1.7	-0.9	0.3	3.5	-1.7		0.0
IA04-TW0001	2191867.55	649878.02	595.16	592.71	NM	576.58	575.06	582.34	573.60	NM	573.19	574.45	575.37	NM	573.19	NM	574.35	9	575.3	9.1		1.2	-0.3	7.0	-1.7		-2.2	-0.9	0.0		-2.2		-1.0
IA04-TW0002	2191510.29	649967.14	593.59	591.86	NM	579.32	577.79	NM	576.28	NM	575.67	576.91	579.16	NM	575.95	NM	578.83	8	577.5	3.6		1.8	0.3		-1.2		-1.8	-0.6	1.7		-1.5		1.3
IA04-TW0003	2192075.24	650700.56	596.03	592.94	NM	579.46	585.87	585.42	583.52	NM	583.39	585.71	586.53	586.30	583.57	NM	587.29	10	584.7	7.8		-5.2	1.2	0.7	-1.2		-1.3	1.0	1.8	1.6	-1.1		2.6
IA04-TW0004	2192426.35	650466.22	594.44	591.22	NM	577.69	575.86	584.89	574.74	NM	574.13	575.28	576.12	NM	577.01	NM	578.62	9	577.2	10.8		0.5	-1.3	7.7	-2.4		-3.0	-1.9	-1.0		-0.1		1.5
IA04-TW0005	2192127.99	650840.91	593.23	590.24	NM	583.07	583.03	584.82	581.18	NM	580.59	582.22	584.16	582.75	NM	571.97*	NM	8	582.7	4.2		0.3	0.3	2.1	-1.5		-2.1	-0.5	1.4	0.0			
IA04-TW0006	2192521.62	650652.21	589.71	586.35	NM	574.00	572.67	576.90	571.69	NM	571.21	571.98	573.06	574.83	571.30	NM	572.37	10	573.0	5.7		1.0	-0.3	3.9	-1.3		-1.8	-1.0	0.1	1.8	-1.7		-0.6
IA05-TW0001	2191929.22	649644.71	598.64	596.27	NM	580.16	578.44	578.83	577.03	NM	576.81	577.93	578.66	NM	NM	NM	577.51	8	578.2	3.4		2.0	0.3	0.7	-1.1		-1.4	-0.2	0.5				-0.7
IA10-MW0001	2191641.11	651100.68	593.86	591.61	NM	NM	584.93	586.36	581.94	NM	581.68	585.36	585.83	584.66	582.05	583.55	583.90	10	584.0	4.7			0.9	2.3	-2.1		-2.3	1.3	1.8	0.6	-2.0	-0.5	-0.1
IA10-MW0002	2191965.68	650913.46	595.72	593.69	NM	NM	584.87	586.39	582.15	NM	581.77	584.12	585.99	584.67	NM	583.50	585.40	9	584.3	4.6			0.6	2.1	-2.2		-2.5	-0.2	1.7	0.4		-0.8	1.1
IA10-MW0003	2191901.56	650614.32	597.98	595.55	NM	NM	585.15	585.66	583.38	NM	582.85	584.18	586.47	584.78	583.22	584.05	585.13	10	584.5	3.6			0.7	1.2	-1.1		-1.6	-0.3	2.0	0.3	-1.3	-0.4	0.6
IA10-MW0004	2192091.07	650693.74	595.88	593.54	NM	NM	585.88	587.51	582.67	NM	581.80	584.52	586.76	585.55	581.96	583.06	586.56	10	584.6	5.7			1.3	2.9	-2.0		-2.8	-0.1	2.1	0.9	-2.7	-1.6	1.9
RMW-35	2191566.09	650682.82	596.44	594.65	582.55	583.87	585.44	587.93	582.64	NM	581.84	584.78	587.24	NM	582.29	584.04	NM	10	584.3	6.1	-1.7	-0.4	1.2	3.7	-1.6		-2.4	0.5	3.0		-2.0	-0.2	
RMW-38	2191739.01	650453.12	596.76	594.55	583.34	586.01	NM	587.76	584.71	NM	583.86	585.35	587.53	586.26	584.43	585.83	587.25	11	585.7	4.4	-2.3	0.3		2.1	-1.0		-1.8	-0.3	1.9	0.6	-1.2	0.2	1.6
RMW-39	2191523.35	650696.53	595.93	593.78	581.84	584.12	585.38	587.49	582.43	582.21	581.43	585.15	587.21	584.87	582.06	583.60	586.57	13	584.2	6.1	-2.3	-0.1	1.2	3.3	-1.8	-2.0	-2.8	1.0	3.0	0.7	-2.1	-0.6	2.4
IA10-MW0005	2191901.5	650672.6	594.83	NA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	589.07	594.83	2	592.0	5.8												-2.9	2.9
IA10-MW0007	2191831.1	650386.5	592.95	NA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	575.45	576.06	2	575.8	0.6												-0.3	0.3
IA10-MW0008	2192040.3	650208.7	592.57	NA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	573.96	575.32	2	574.6	1.4												-0.7	0.7
count																					**27**	**38**	**46**	**52**	**56**	**14**	**55**	**57**	**57**	**44**	**45**	**40**	**47**
Mean of differences (ft)																					**-2.5**	**0.6**	**0.4**	**3.9**	**-1.4**	**-1.7**	**-2.0**	**-0.3**	**1.1**	**1.5**	**-1.8**	**-0.8**	**0.8**

Notes:
NA = Not Available
NM = Not Measured
Measurement with asterisk (e.g., 590.32*) indicates anomolous measurement not used in developing water level map.

Table D-3. May 2005 Water Level Calibration Targets, Simulated Heads, and Residuals

Well ID	Easting (ft)	Northing (ft)	Layer	Observed Head (ft)	Simulated Head (ft)	Residual (ft)
BKA-48	2191690.02	650842.78	1	586.15	585.68	0.47
BKA-51	2191592.31	649653.75	1	577.9	578.07	-0.17
BKA-52	2191758.05	649730.48	1	576.33	577.57	-1.24
BKA-53	2191937.3	649459.32	1	575.59	576.08	-0.49
BKG-MW0001	2191081.12	649708.88	1	582.36	581.52	0.84
BKG-MW0002	2191322.01	649989.17	1	581.01	583.53	-2.52
BKG-MW0003	2191324.77	650473.3	1	586.76	587.55	-0.79
BKG-MW0004	2191331.18	650541.24	1	586.74	587.25	-0.51
BKG-MW0005	2191218.21	651099.72	1	586	585.81	0.19
CDT-MW0001	2191310.37	649612.52	1	580.57	580.46	0.11
CDT-MW0002	2191471.66	649538.84	1	577.96	577.66	0.30
DM-1	2191465.84	650137.02	1	586.06	583.11	2.95
DM-10	2191405.93	650534.87	1	585.27	587.11	-1.84
DM-11	2191520.52	650597.82	1	587.33	586.69	0.64
DM-12	2191426	650643.8	1	587.02	586.84	0.18
DM-14	2191443.51	650747.03	1	586.92	586.48	0.44
DM-15	2191564.93	650795.45	1	586.75	585.37	1.38
DM-2	2191511.78	650188.4	1	586.09	583.45	2.64
DM-22R	2191721.35	649560.49	1	576.12	576.40	-0.28
DM-23R	2191933.53	649357.34	1	575.73	575.29	0.44
DM-25R	2191937.08	650039.94	1	575.6	575.22	0.38
DM-26	2191850.75	650200.89	1	576.32	575.61	0.71
DM-27R	2192072.44	650184.85	1	575.26	574.94	0.32
DM-28R	2192219.27	650346.09	1	574.74	574.89	-0.15
DM-29R	2192116.31	650463.86	1	575	575.75	-0.75
DM-3	2191431.18	650291.16	1	592.47	590.40	2.07
DM-30R	2192328.27	650525.05	1	574.69	575.11	-0.42
DM-4	2191471.88	650294.53	1	590.42	590.82	-0.40
DM-5	2191432.21	650360.73	1	587.08	588.70	-1.62
DM-9	2191527.01	650452.64	1	585.97	586.85	-0.88
ERM-47	2191934.55	650347.59	1	575.89	576.49	-0.60
IA03-TP0001	2191574.09	650912.44	1	582.84	584.94	-2.10
IA03-TW0001	2191929.07	650543.65	1	586.87	586.29	0.58
IA03-TW0002	2191860.42	650782.56	1	586.61	587.50	-0.89
IA03-TW0003	2191537.92	650917.84	1	583.06	584.99	-1.93
IA03-TW0004	2191684.59	650974.55	1	584.54	584.57	-0.03

Table D-3. May 2005 Water Level Calibration Targets, Simulated Heads, and Residuals (continued)

Well ID	Easting (ft)	Northing (ft)	Layer	Observed Head (ft)	Simulated Head (ft)	Residual (ft)
IA03-TW0005	2191745.41	650655.76	1	591.35	591.09	0.26
IA03-TW0006	2191802.08	650651.72	1	591.33	590.77	0.56
IA04-TP0001	2191673.13	650365.68	1	585.4	586.72	-1.32
IA04-TP0002	2191830.51	650320.91	1	576.39	576.66	-0.27
IA04-TP0003	2192021.81	650334.47	1	574.18	575.60	-1.42
IA04-TP0004	2192055.73	650551.55	1	581.95	581.67	0.28
IA04-TP0005	2192185.97	650635.66	1	574.83	577.13	-2.30
IA04-TW0001	2191867.55	649878.02	1	575.37	575.98	-0.61
IA04-TW0002	2191510.29	649967.14	1	579.16	581.95	-2.79
IA04-TW0003	2192075.24	650700.56	1	586.53	585.51	1.02
IA04-TW0004	2192426.35	650466.22	1	576.12	574.79	1.33
IA04-TW0005	2192127.99	650840.91	1	584.16	584.04	0.12
IA04-TW0006	2192521.62	650652.21	1	573.06	574.94	-1.88
IA05-TW0001	2191929.22	649644.71	1	578.66	576.86	1.80
IA10-MW0001	2191641.12	651100.68	1	585.83	584.24	1.59
IA10-MW0002	2191965.68	650913.46	1	585.99	585.38	0.61
IA10-MW0003	2191901.56	650614.32	1	586.47	588.12	-1.65
IA10-MW0004	2192091.08	650693.74	1	586.76	584.85	1.91
RMW-35	2191566.08	650682.82	1	587.24	586.58	0.66
RMW-38	2191739.01	650453.12	2	587.53	588.88	-1.35
RMW-39	2191523.35	650696.53	1	587.21	586.51	0.70

Table D-4. Water Level Calibration Summary Statistics

Statistic	Value
Residual Mean (ft)	-0.1
Residual Standard Deviation (ft)	1.3
Absolute Residual Mean (ft)	1.0
Number of Residuals	57
Minimum Residual (ft)	-2.8
Maximum Residual (ft)	3.0
Range in Observed Heads (ft)	19.4
Residual Standard Deviation / Range in Observed Heads	6.5%

Table D-5. Water Balance for Calibrated Flow Model

Description	Flux (ft^3/day)		
	Inflow	Outflow	Net
Recharge	4813	0	4813
Cuyahoga River (constant heads)	0	5318	-5318
Big Creek (constant heads)	0	1530	-1530
Nickel Extraction System	0	480	-480
Constant Flux Boundaries at Western Upland Toe	2517	0	2517
Total	7330	7329	1
% Error	0.02%		

Table D-6. OU-1 and OU-2 Proposed Soil Cleanup Criteria and Bounding Case Leachate Concentrations

Contaminant	Kd (ml/g)	Approved Soil Cleanup Criteria (pCi/g)		Equilibium Leachate Concentration (pCi/L)		MCL (pCi/L)
		OU1 (Worker)	OU2 (Resident)	OU1 (Worker)	OU2 (Resident)	
Total Uranium	1,000	400	300	400	300	27.0*
Ra-226	1,000	9.1	3.6	9.1	3.6	5
Th-230	10,000	35	16	3.5	1.6	15
Th-232	10,000	6	3.6	0.6	0.36	15

*Total uranium MCL of 30 µg/L is converted here to units of pCi/L using a factor of 0.9 pCi/µg for total uranium, which assumes naturally-occurring proportions of uranium isotopes (USEPA 2000). National Primary Drinking Water Regulations; Final Rule. 40 CFR Parts 9, 141, and 142.
Federal Register: December 7, 2000 (Volume 65, Number 236, Pages 76707-76753),
http://frwebgate4.access.gpo.gov/cgi-bin/waisgate.cgi?WAISdocID=26809021260+1+0+0&WAISaction=retrieve.

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FIGURES

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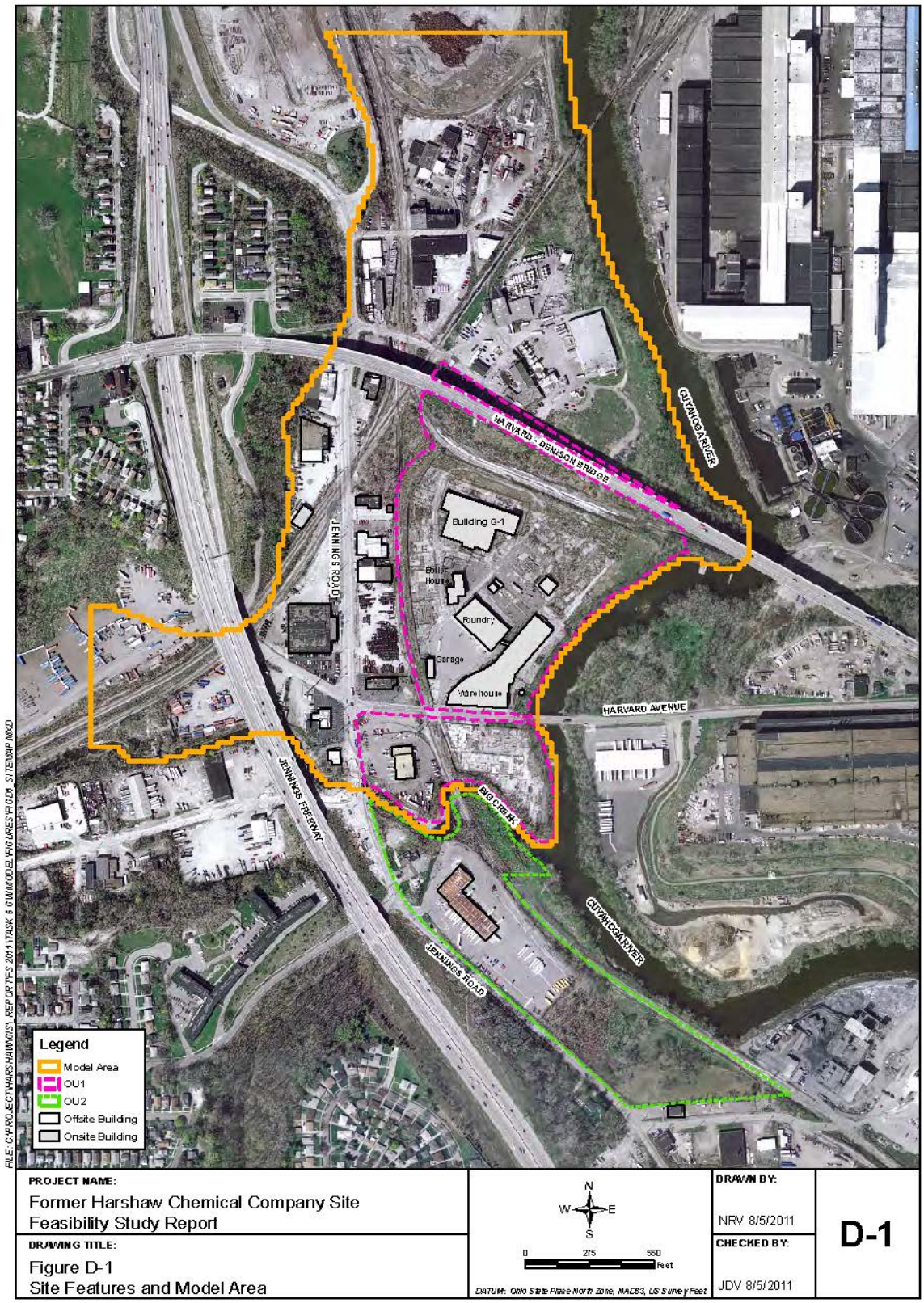

Figure D-1. Site Features and Model Area

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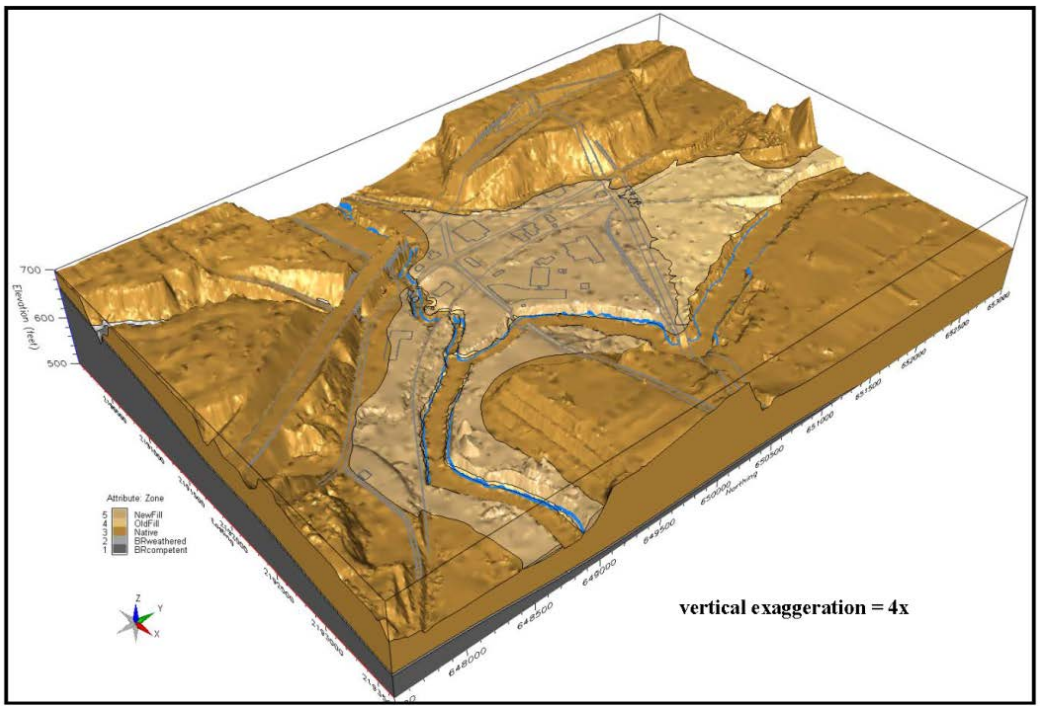

Figure D-2. Perspective View of 3D Geologic Model

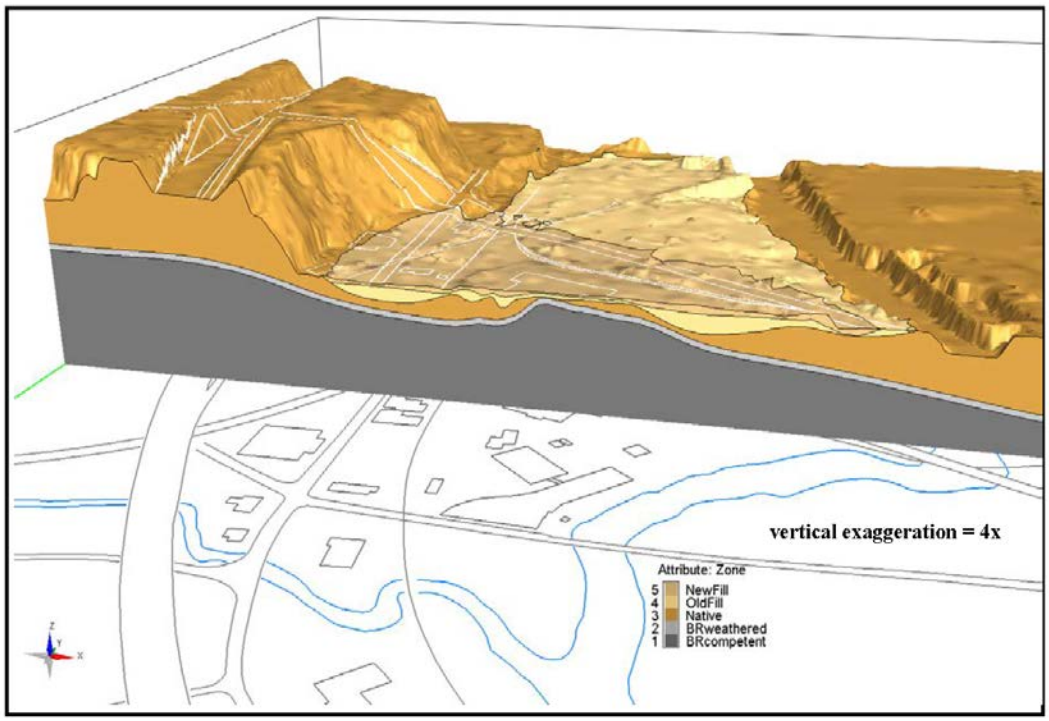

Figure D-3. Section through 3D Geologic Model at Building G-1

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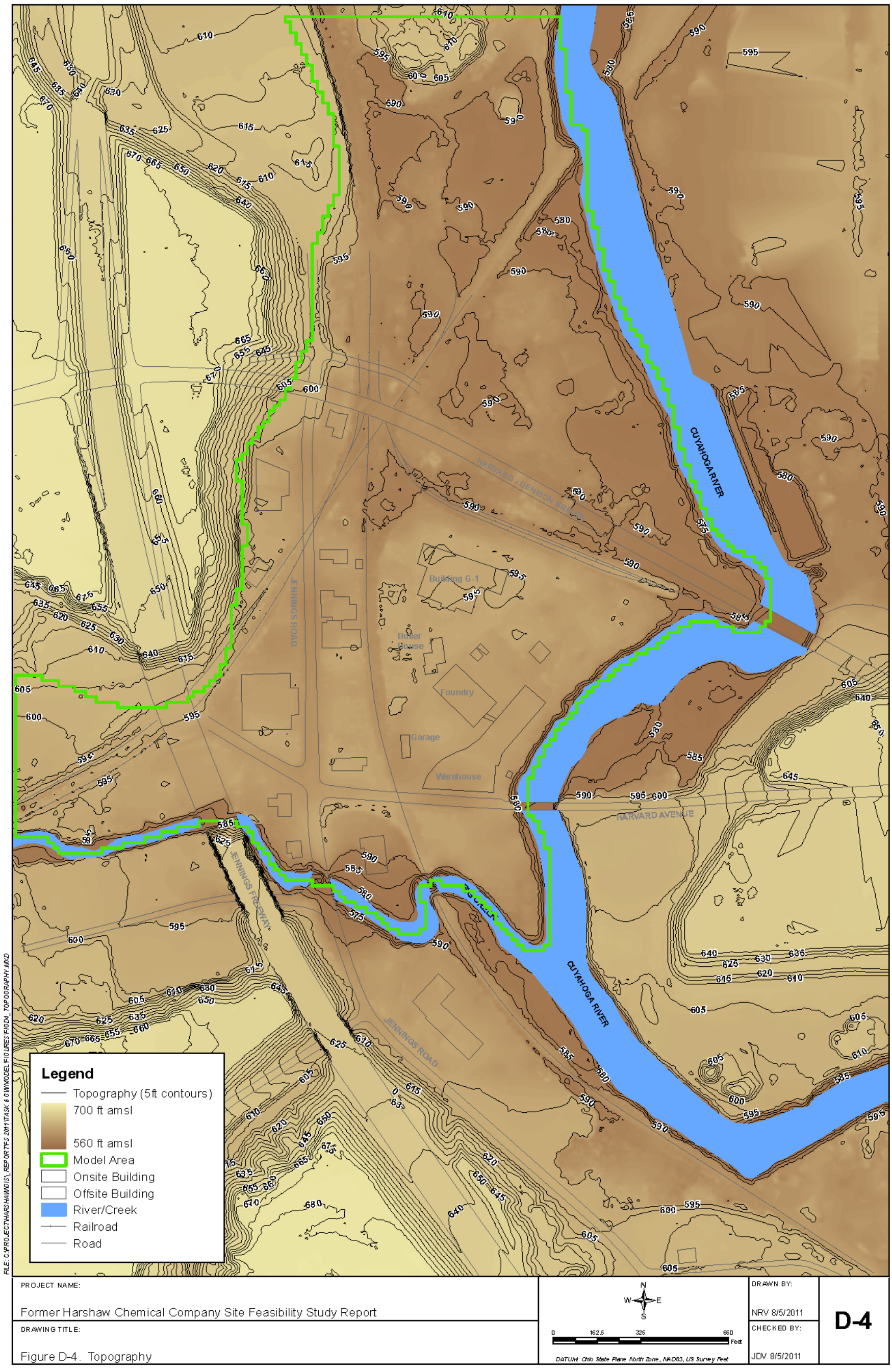

Figure D-4. Topography

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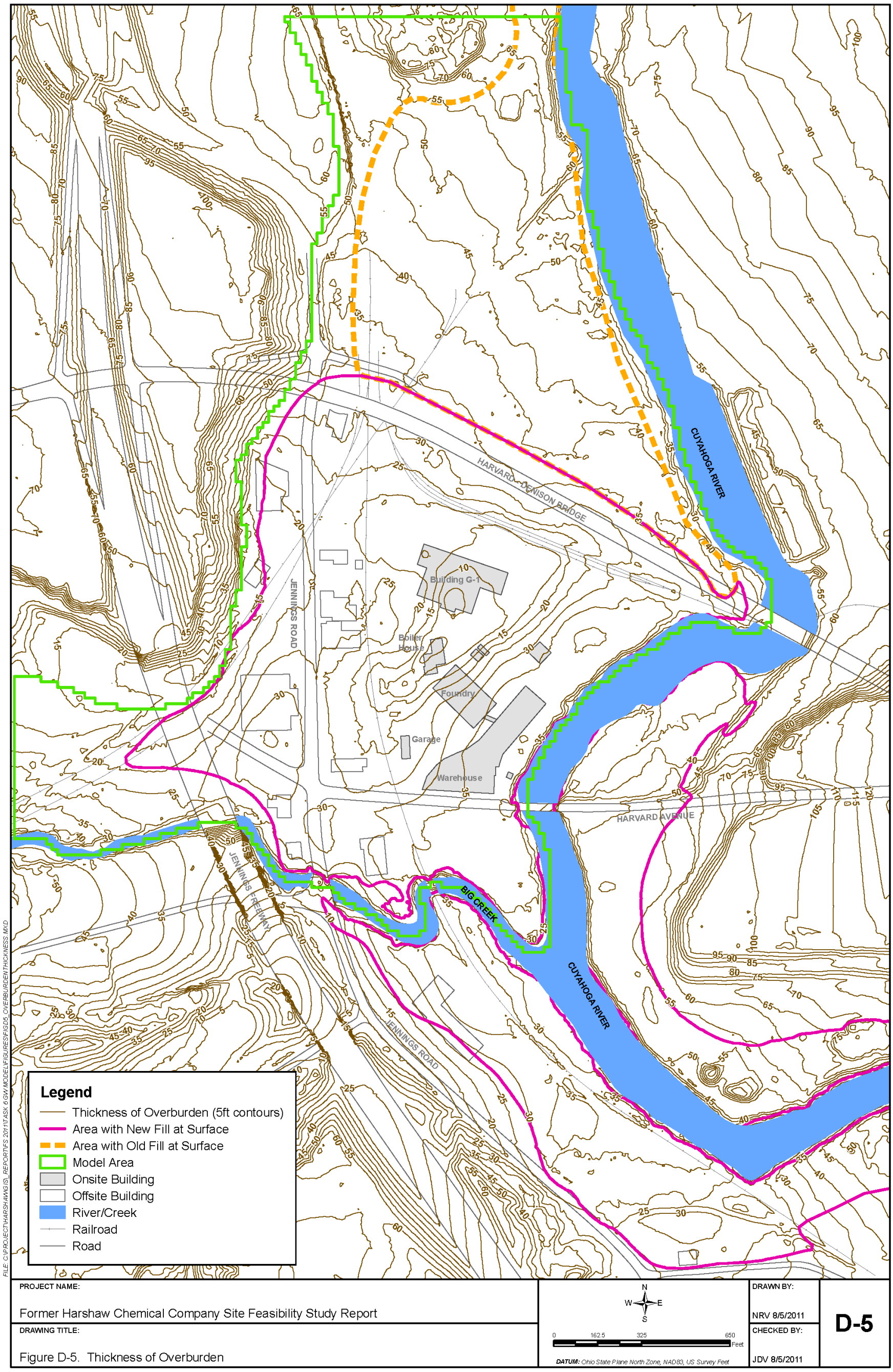

Figure D-5. Thickness of Overburden

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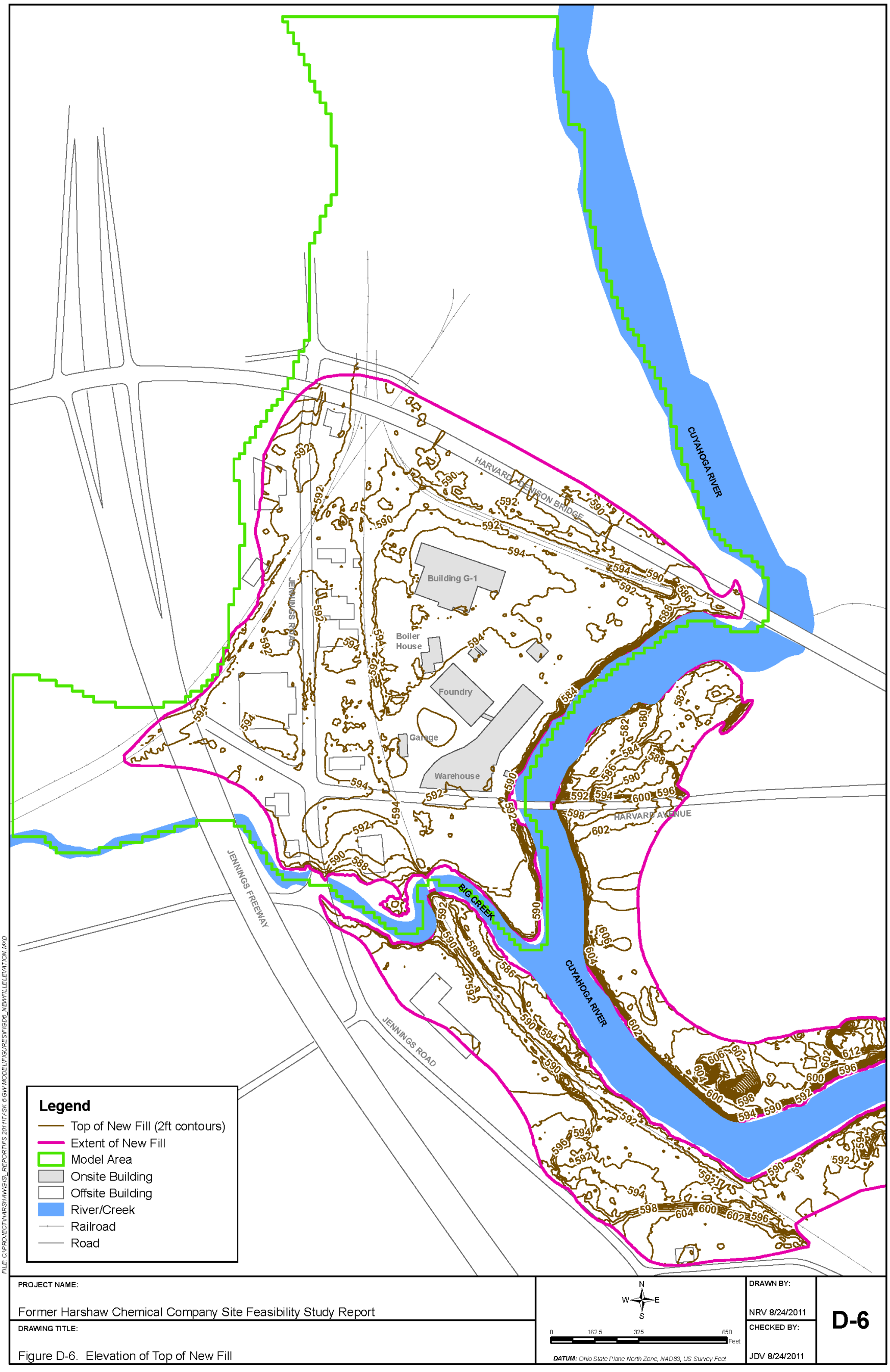

Figure D-6. Elevation of Top of New Fill

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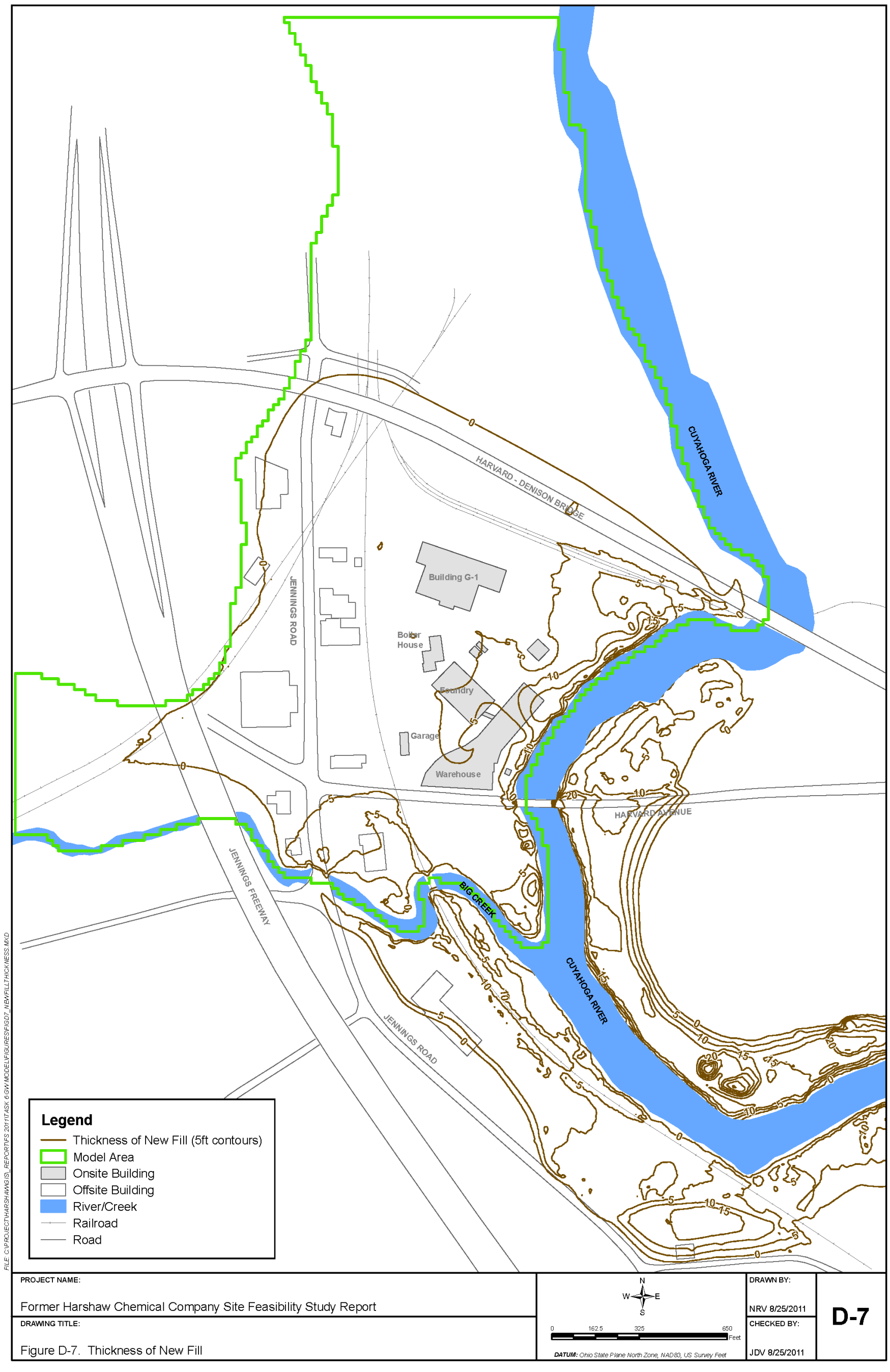

Figure D-7. Thickness of New Fill

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#	Station	Elev (ft)	#	Station	Elev (ft)
1	AB1	590.1	85	IA03-SB0019	588.8
2	BGD1	583.7	86	IA03-SB0020	588.4
3	BGD11	568.9	87	IA03-SB0022	589.5
4	BGD13	569.5	88	IA03-SB0023	593.1
5	BGD14	581.4	89	IA03-SB0024	592.6
6	BGD15	582.6	90	IA03-SB0025	595.2
7	BGD2	583.6	91	IA03-SB0026	587.3
8	BGD4	583.1	92	IA03-SB0027	589.8
9	BKA-51	590.2	93	IA03-SB0028	591.9
10	BKA-52	589.4	94	IA03-SB0030	594.7
11	BKA-53	583.2	95	IA03-SB0031	589.7
12	BKG-MW0001	589.7	96	IA03-SB0032	588.1
13	BKG-MW0002	592.4	97	IA03-SB0033	593.8
14	BKG-MW0003	590.7	98	IA03-SB0034	591.8
15	BKG-MW0004	589.7	99	IA03-SB0035	590.5
16	BKG-MW0005	589.4	100	IA03-SB0036	591.4
17	CB1	590.7	101	IA03-SB0038	587.2
18	CB10	588.9	102	IA03-SB0039	587.2
19	CB11	589.1	103	IA03-SB0040	587.0
20	CB12	590.5	104	IA03-SB0041	587.5
21	CB13	585.7	105	IA03-SB0043	587.8
22	CB14	589.1	106	IA03-SB0044	589.3
23	CB15	589.7	107	IA03-SB0045	588.5
24	CB16	587.3	108	IA03-SB0046	589.4
25	CB2	591.9	109	IA03-SB0051	588.9
26	CB4	594.0	110	IA03-SB0052	589.0
27	CB6	590.2	111	IA03-SB0053	586.6
28	CB7	590.5	112	IA03-SB0054	589.9
29	CB8	591.6	113	IA03-SB0055	586.2
30	CB9	591.0	114	IA03-SB0056	592.8
31	DM-1	592.2	115	IA03-SB0057	590.5
32	DM-10	589.4	116	IA03-SB0058	592.0
33	DM-11	591.9	117	IA03-SB0059	589.4
34	DM-12	591.4	118	IA03-SB0061	594.6
35	DM-13	591.6	119	IA03-SB0062	593.7
36	DM-14	593.2	120	IA03-SB0063	592.6
37	DM-15	587.3	121	IA03-SB0064	592.7
38	DM-16	592.5	122	IA03-SB0065	589.2
39	DM-17	583.5	123	IA03-SB0066	587.1
40	DM-19	588.7	124	IA03-SB0067	586.0
41	DM-2	592.8	125	IA03-SB0068	587.3
42	DM-20	591.5	126	IA03-SB0069	589.4
43	DM-22R	589.7	127	IA03-SB0070	586.9
44	DM-23R	580.8	128	IA03-SB0071	586.5
45	DM-25R	590.9	129	IA03-SB0072	588.4
46	DM-26	587.5	130	IA03-SB0073	587.7
47	DM-27R	575.8	131	IA03-SB0074	588.5
48	DM-29R	585.2	132	IA03-SB0075	588.0
49	DM-3	591.2	133	IA03-SB0076	589.1
50	DM-4	591.2	134	IA03-SB0077	588.2
51	DM-5	590.1	135	IA03-SB0078	589.9
52	DM-6	591.5	136	IA03-SB0080	586.7
53	DM-7	589.2	137	IA03-SB0081	587.6
54	DM-8	592.3	138	IA03-SB0082	588.5
55	DM-9	593.8	139	IA03-SB0083	588.9
56	ENG1	588.4	140	IA03-SB0084	587.1
57	ENG11	591.0	141	IA03-SB0085	587.8
58	ENG12	593.4	142	IA03-SB0086	587.1
59	ENG13	593.0	143	IA03-SB0088	585.9
60	ENG2	590.8	144	IA03-SB0089	588.9
61	ENG21	591.5	145	IA03-SB0090	588.3
62	ENG3	590.7	146	IA03-SB0091	586.5
63	ENG4	587.3	147	IA03-SB0092	586.9
64	ENG5	588.7	148	IA03-SB0093	587.0
65	ENG6	589.1	149	IA03-SB0094	588.5
66	ENG7	587.3	150	IA03-SB0096	592.5
67	ERM-45	591.0	151	IA03-SB0098	588.1
68	ERM-46	585.7	152	IA03-SB0099	588.8
69	ERM-47	588.1	153	IA03-SB0100	589.6
70	IA03-SB0001	591.2	154	IA03-SB0101	587.3
71	IA03-SB0002	593.5	155	IA03-SB0103	589.1
72	IA03-SB0005	594.0	156	IA03-SB0104	590.9
73	IA03-SB0006	587.9	157	IA03-SB0105	590.0
74	IA03-SB0007	589.4	158	IA03-SB0106	592.4
75	IA03-SB0008	589.5	159	IA03-SB0107	593.7
76	IA03-SB0009	587.8	160	IA03-SB0108	591.6
77	IA03-SB0010	587.3	161	IA03-SB0109	591.1
78	IA03-SB0011	585.6	162	IA03-SB0110	590.2
79	IA03-SB0012	590.5	163	IA03-SB0111	590.8
80	IA03-SB0013	592.3	164	IA03-SB0112	590.8
81	IA03-SB0014	591.2	165	IA03-SB0113	590.3
82	IA03-SB0015	593.3	166	IA03-SB0115	593.0
83	IA03-SB0016	592.2	167	IA03-SB0116	594.1
84	IA03-SB0017	590.2	168	IA03-SB0117	591.7

#	Station	Elev (ft)	#	Station	Elev (ft)
169	IA03-SB0119	593.9	217	IA05-SB0029	578.9
170	IA03-SB0121	595.0	218	IA05-SB0032	580.7
171	IA03-SB0123	589.5	219	IA05-SB0033	582.1
172	IA03-SB0124	588.7	220	IA05-SB0035	583.9
173	IA03-SB0125	589.0	221	IA05-SB0038	592.1
174	IA03-SB0126	589.1	222	IA05-SB0039	592.1
175	IA03-SB0127	589.2	223	IA05-SB0045	585.1
176	IA03-SB0128	592.5	224	IA05-SB0046	586.7
177	IA03-SB0129	589.6	225	IA05-SB0047	577.5
178	IA03-SB0130	592.4	226	IA05-SB0048	578.4
179	IA03-SB0131	592.7	227	IA05-SB0049	573.1
180	IA03-SB0132	592.5	228	IA05-SB0054	589.0
181	IA03-SB0133	590.9	229	IA05-SB0055	590.4
182	IA03-SB0134	592.7	230	IA05-SB0056	591.2
183	IA03-SB0136	593.5	231	IA07-SB0002	583.3
184	IA03-SB0137	592.8	232	IA07-SB0003	589.6
185	IA03-SB0147	588.7	233	IA07-SB0004	590.7
186	IA03-SB0148	587.8	234	IA07-SB0005	590.9
187	IA03-SB0149	590.5	235	IA07-SB0006	587.2
188	IA03-TW0006	592.5	236	IA07-SB0013	580.6
189	IA04-SB0001	591.9	237	IA07-SB0025	587.2
190	IA04-SB0007	591.4	238	IA07-SB0033	587.5
191	IA04-SB0012	584.9	239	IA07-SB0034	588.4
192	IA04-SB0013	585.3	240	IA07-SB0035	587.3
193	IA04-SB0014	585.0	241	IA09-SB0002	589.4
194	IA04-SB0020	590.8	242	IA10-MW0003	594.1
195	IA04-SB0022	587.4	243	IA10-MW0004	588.5
196	IA04-SB0023	578.9	244	IA10-MW0005	592.9
197	IA04-SB0025	584.1	245	IA10-MW0007	587.2
198	IA04-SB0026	573.9	246	IA10-MW0008	575.9
199	IA04-SB0028	585.3	247	IA10-MW0009	581.2
200	IA04-SB0033	572.1	248	IA10-MW0010	580.2
201	IA04-SB0044	590.5	249	IA10-MW0013	577.6
202	IA04-SB0048	587.6	250	IA10-MW0014	588.9
203	IA04-SB0051	589.0	251	IA10-MW0016	587.5
204	IA05-SB0003	579.3	252	IA10-MW0017	589.5
205	IA05-SB0014	591.6	253	IA10-MW0018	585.6
206	IA05-SB0015	592.0	254	IA10-MW0019	589.8
207	IA05-SB0016	588.7	255	RMW-35	594.2
208	IA05-SB0019	591.7	256	RMW-38	590.6
209	IA05-SB0020	591.5	257	RMW-39	585.9
210	IA05-SB0021	591.8	258	RMW-41	592.2
211	IA05-SB0022	587.1	259	RMW-43	587.5
212	IA05-SB0023	589.6	260	RMW-44	591.8
213	IA05-SB0025	570.9	261	RPZ32	586.9
214	IA05-SB0026	579.2	262	RPZ33	592.7
215	IA05-SB0027	576.8	263	RPZ34	592.3
216	IA05-SB0028	578.0	264	RPZ36	589.1

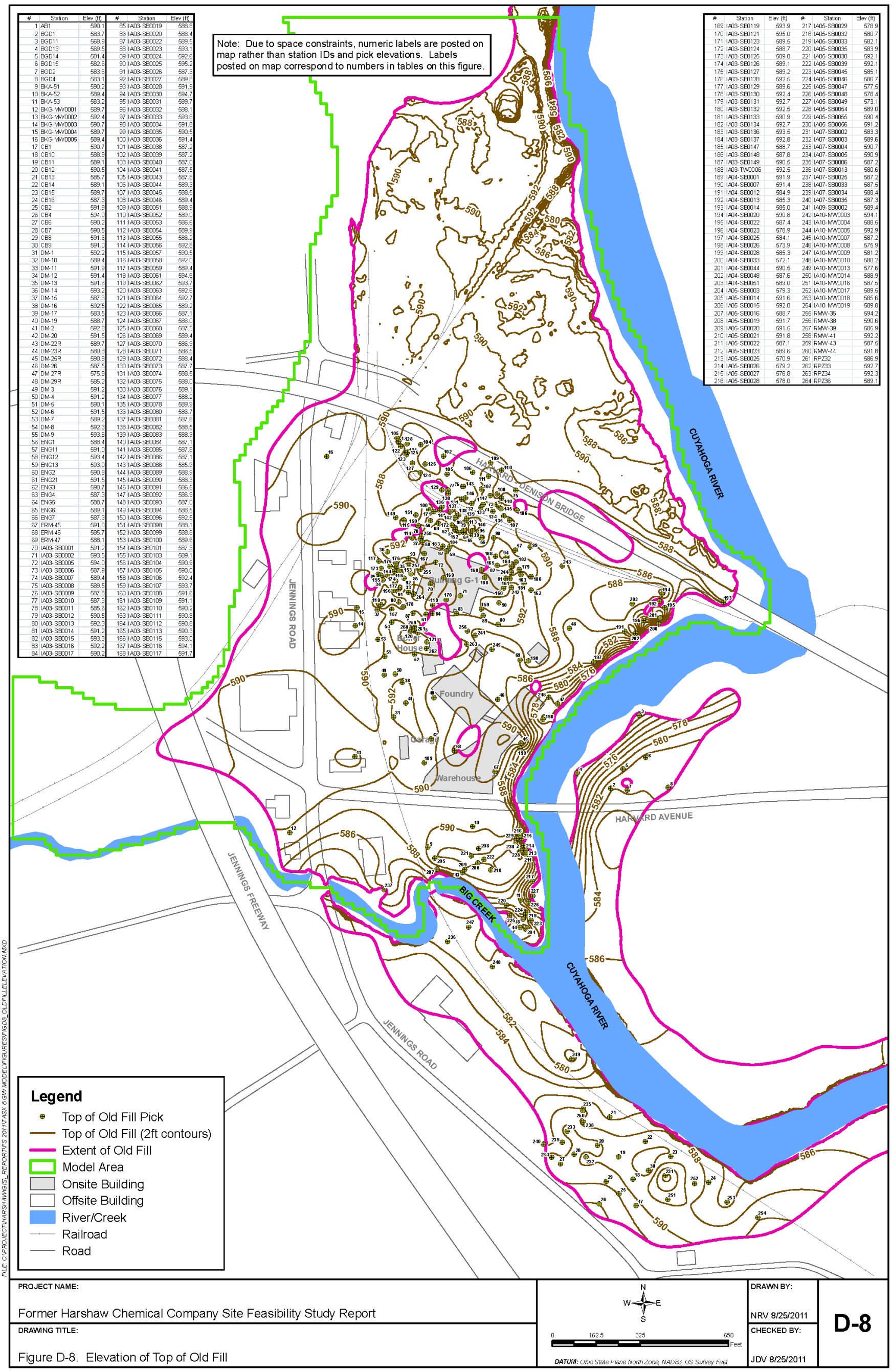

Figure D-8. Elevation of Top of Old Fill

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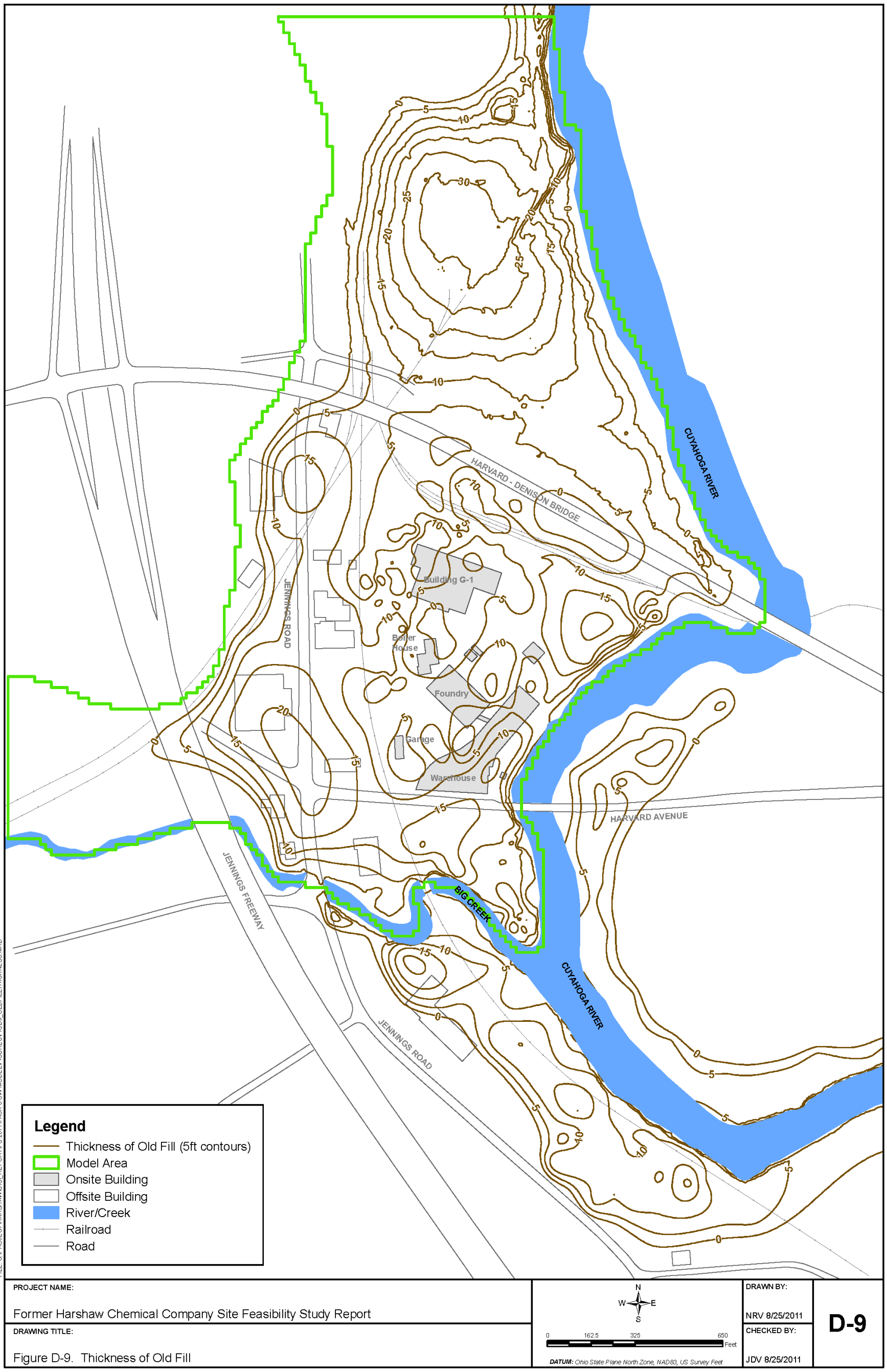

Figure D-9. Thickness of Old Fill

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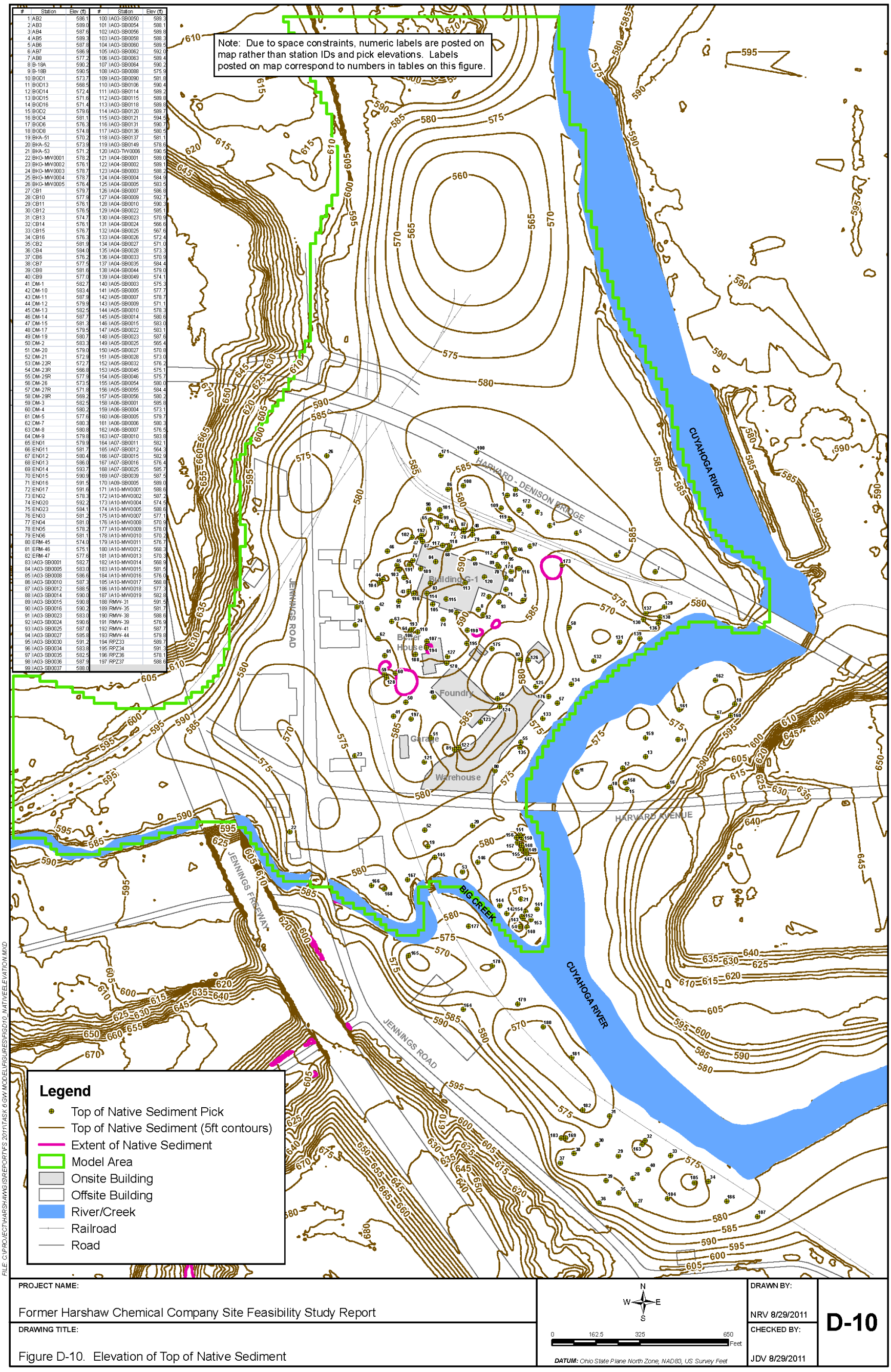

#	Station	Elev (ft)	#	Station	Elev (ft)
1	AB2	586.1	100	IA03-SB0050	589.3
2	AB3	589.0	101	IA03-SB0054	588.1
3	AB4	587.6	102	IA03-SB0056	589.8
4	AB5	589.3	103	IA03-SB0058	588.3
5	AB6	587.8	104	IA03-SB0060	589.5
6	AB7	586.9	105	IA03-SB0062	592.0
7	AB8	577.2	106	IA03-SB0063	589.4
8	B-18A	590.2	107	IA03-SB0064	590.2
9	B-18B	590.5	108	IA03-SB0088	575.9
10	BGD1	573.7	109	IA03-SB0090	581.8
11	BGD13	568.5	110	IA03-SB0106	590.4
12	BGD14	572.4	111	IA03-SB0114	589.2
13	BGD15	571.6	112	IA03-SB0115	589.8
14	BGD16	571.4	113	IA03-SB0118	589.6
15	BGD2	579.6	114	IA03-SB0120	589.7
16	BGD4	581.1	115	IA03-SB0121	594.5
17	BGD6	576.3	116	IA03-SB0131	590.7
18	BGD8	574.8	117	IA03-SB0136	580.5
19	BKA-51	570.2	118	IA03-SB0137	581.1
20	BKA-52	573.9	119	IA03-SB0149	578.6
21	BKA-53	571.2	120	IA03-TW0006	590.5
22	BKG-MW0001	578.2	121	IA04-SB0001	589.0
23	BKG-MW0002	576.1	122	IA04-SB0002	589.1
24	BKG-MW0003	578.7	123	IA04-SB0003	588.2
25	BKG-MW0004	578.7	124	IA04-SB0004	584.9
26	BKG-MW0005	576.4	125	IA04-SB0005	583.5
27	CB1	579.7	126	IA04-SB0007	586.6
28	CB10	577.9	127	IA04-SB0009	592.7
29	CB11	576.1	128	IA04-SB0010	590.3
30	CB12	576.5	129	IA04-SB0022	585.1
31	CB13	574.7	130	IA04-SB0023	570.9
32	CB14	576.1	131	IA04-SB0024	566.6
33	CB15	576.7	132	IA04-SB0025	567.6
34	CB16	576.3	133	IA04-SB0026	572.4
35	CB2	581.9	134	IA04-SB0027	571.0
36	CB4	584.0	135	IA04-SB0028	573.3
37	CB6	576.2	136	IA04-SB0033	570.9
38	CB7	577.5	137	IA04-SB0035	584.4
39	CB8	581.6	138	IA04-SB0044	579.0
40	CB9	577.0	139	IA04-SB0049	574.1
41	DM-1	582.7	140	IA05-SB0003	575.3
42	DM-10	583.4	141	IA05-SB0005	577.7
43	DM-11	587.9	142	IA05-SB0007	578.7
44	DM-12	579.9	143	IA05-SB0009	571.1
45	DM-13	582.5	144	IA05-SB0010	578.3
46	DM-14	587.7	145	IA05-SB0014	580.6
47	DM-15	581.3	146	IA05-SB0015	583.0
48	DM-17	579.5	147	IA05-SB0022	583.1
49	DM-19	580.7	148	IA05-SB0023	587.6
50	DM-2	583.3	149	IA05-SB0025	565.4
51	DM-20	579.0	150	IA05-SB0027	570.8
52	DM-21	572.9	151	IA05-SB0028	573.0
53	DM-22R	572.7	152	IA05-SB0032	576.2
54	DM-23R	566.8	153	IA05-SB0045	575.1
55	DM-25R	577.9	154	IA05-SB0046	575.7
56	DM-26	573.5	155	IA05-SB0054	580.0
57	DM-27R	571.8	156	IA05-SB0055	584.4
58	DM-29R	569.2	157	IA05-SB0056	580.2
59	DM-3	582.5	158	IA06-SB0001	585.8
60	DM-4	580.2	159	IA06-SB0004	573.1
61	DM-5	577.6	160	IA06-SB0005	579.7
62	DM-7	580.3	161	IA06-SB0006	580.3
63	DM-8	580.8	162	IA06-SB0007	576.5
64	DM-9	579.8	163	IA07-SB0010	583.8
65	EN31	579.9	164	IA07-SB0011	582.1
66	EN311	581.7	165	IA07-SB0012	564.3
67	EN312	580.4	166	IA07-SB0015	582.9
68	EN313	586.0	167	IA07-SB0016	576.4
69	EN314	593.7	168	IA07-SB0025	585.7
70	EN315	590.9	169	IA07-SB0039	587.5
71	EN316	591.5	170	IA09-SB0005	589.0
72	EN317	591.6	171	IA10-MW0001	588.6
73	EN32	578.3	172	IA10-MW0002	587.2
74	EN320	592.2	173	IA10-MW0004	574.5
75	EN323	584.1	174	IA10-MW0005	588.6
76	EN33	581.2	175	IA10-MW0007	577.1
77	EN34	581.0	176	IA10-MW0008	570.9
78	EN35	578.2	177	IA10-MW0009	578.0
79	EN36	581.1	178	IA10-MW0010	570.2
80	ERM-45	574.0	179	IA10-MW0011	576.7
81	ERM-46	575.1	180	IA10-MW0012	568.3
82	ERM-47	577.6	181	IA10-MW0013	570.3
83	IA03-SB0001	582.7	182	IA10-MW0014	568.9
84	IA03-SB0005	583.0	183	IA10-MW0015	581.5
85	IA03-SB0008	586.6	184	IA10-MW0016	576.0
86	IA03-SB0010	587.3	185	IA10-MW0017	568.8
87	IA03-SB0012	588.5	186	IA10-MW0018	577.3
88	IA03-SB0014	590.0	187	IA10-MW0019	582.8
89	IA03-SB0015	590.8	188	RMW- 31	591.5
90	IA03-SB0016	590.2	189	RMW- 35	581.7
91	IA03-SB0023	583.0	190	RMW- 38	588.6
92	IA03-SB0024	590.6	191	RMW- 39	576.9
93	IA03-SB0025	587.0	192	RMW- 41	587.7
94	IA03-SB0027	585.8	193	RMW- 44	579.8
95	IA03-SB0030	591.2	194	RPZ33	589.7
96	IA03-SB0034	583.8	195	RPZ34	591.3
97	IA03-SB0035	582.5	196	RPZ36	578.1
98	IA03-SB0036	587.9	197	RPZ37	588.6
99	IA03-SB0037	588.0			

Figure D-10. Elevation of Top of Native Sediment

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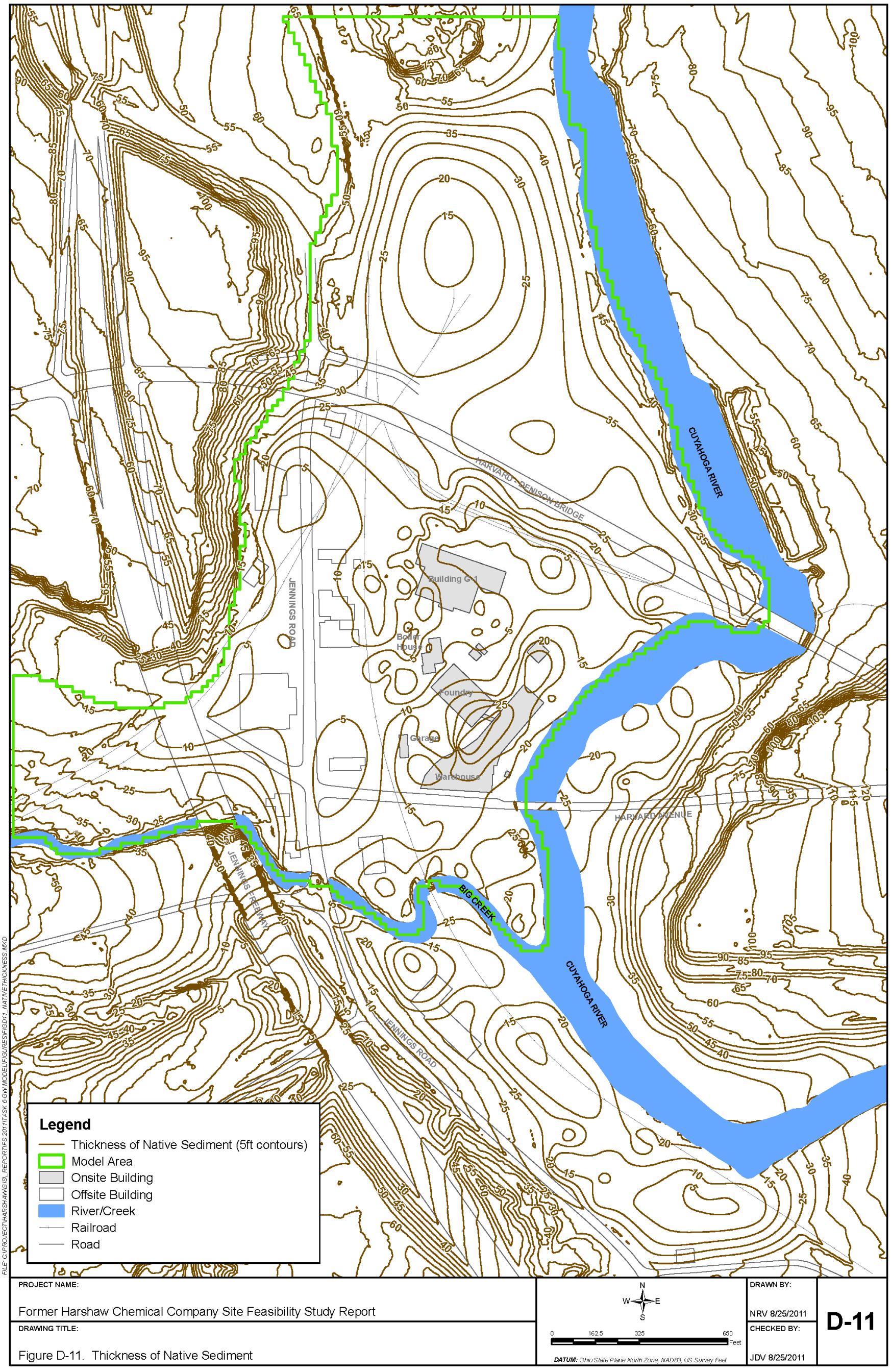

Figure D-11. Thickness of Native Sediment

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#	Station	Elev (ft)	#	Station	Elev (ft)
1	B-18A	584.4	66	IA03-SB0034	582.2
2	B-18B	582.0	67	IA03-SB0064	588.7
3	BKA-51	558.4	68	IA03-SB0116	581.1
4	BKA-52	554.4	69	IA03-SB0117	583.0
5	BKA-53	555.7	70	IA03-SB0118	587.8
6	BKG-MW0002	573.9	71	IA03-SB0119	584.9
7	BKG-MW0003	568.4	72	IA03-SB0120	576.2
8	BKG-MW0004	567.4	73	IA03-SB0121	593.0
9	BKG-MW0005	564.4	74	IA03-SB0131	581.7
10	DM-1	573.9	75	IA03-SB0136	575.5
11	DM-10	566.4	76	IA03-SB0137	577.2
12	DM-11	569.9	77	IA03-TW0001	581.5
13	DM-12	568.4	78	IA03-TW0002	582.7
14	DM-13	574.6	79	IA03-TW0003	571.3
15	DM-14	575.7	80	IA03-TW0004	561.3
16	DM-15	575.8	81	IA03-TW0005	585.8
17	DM-16	589.8	82	IA03-TW0006	583.3
18	DM-17	578.0	83	IA04-SB0009	586.2
19	DM-19	571.0	84	IA04-SB0022	555.9
20	DM-2	579.4	85	IA04-SB0023	555.0
21	DM-20	569.5	86	IA04-SB0024	554.1
22	DM-21	558.3	87	IA04-SB0025	554.8
23	DM-22R	554.7	88	IA04-SB0026	554.4
24	DM-23R	556.7	89	IA04-SB0027	554.0
25	DM-24	555.9	90	IA04-SB0028	553.6
26	DM-25R	558.4	91	IA04-TW0001	554.7
27	DM-26	557.1	92	IA04-TW0003	578.7
28	DM-27R	556.0	93	IA04-TW0004	556.2
29	DM-28R	555.6	94	IA04-TW0005	565.7
30	DM-29R	554.6	95	IA04-TW0006	553.8
31	DM-3	582.0	96	IA05-SB0009	557.3
32	DM-30R	557.5	97	IA05-SB0014	555.4
33	DM-4	579.8	98	IA05-SB0025	552.7
34	DM-5	575.9	99	IA05-SB0032	557.3
35	DM-6	579.2	100	IA05-TW0001	555.8
36	DM-7	565.5	101	IA07-SB0011	555.1
37	DM-8	567.8	102	IA07-SB0014	566.0
38	DM-9	576.8	103	IA09-SB0002	587.9
39	ENG1	576.9	104	IA09-SB0003	575.8
40	ENG11	580.2	105	IA10-MW0001	562.1
41	ENG12	575.9	106	IA10-MW0002	561.2
42	ENG13	579.0	107	IA10-MW0003	582.6
43	ENG14	584.2	108	IA10-MW0004	574.0
44	ENG15	581.4	109	IA10-MW0005	581.2
45	ENG17	587.1	110	IA10-MW0007	571.0
46	ENG2	577.3	111	IA10-MW0008	555.9
47	ENG20	587.7	112	IA10-MW0011	556.0
48	ENG21	577.5	113	IA10-MW0012	556.2
49	ENG3	575.7	114	IA10-MW0014	557.9
50	ENG4	576.0	115	IA10-MW0015	560.3
51	ENG5	577.2	116	IA10-MW0016	568.5
52	ENG6	577.6	117	IA10-MW0017	563.3
53	ENG7	579.3	118	IA10-MW0018	572.9
54	ERM-45	557.1	119	IA10-MW0019	575.1
55	ERM-46	559.7	120	RMW-31	585.9
56	ERM-47	561.5	121	RMW-35	576.7
57	IA03-SB0001	576.5	122	RMW-39	574.9
58	IA03-SB0002	590.5	123	RMW-41	575.6
59	IA03-SB0005	578.3	124	RMW-42	575.4
60	IA03-SB0013	585.8	125	RMW-43	575.8
61	IA03-SB0014	582.2	126	RMW-44	576.4
62	IA03-SB0016	589.4	127	RPZ32	576.9
63	IA03-SB0023	574.2	128	RPZ33	589.6
64	IA03-SB0024	585.5	129	RPZ34	586.3
65	IA03-SB0025	584.5	130	RPZ37	572.1

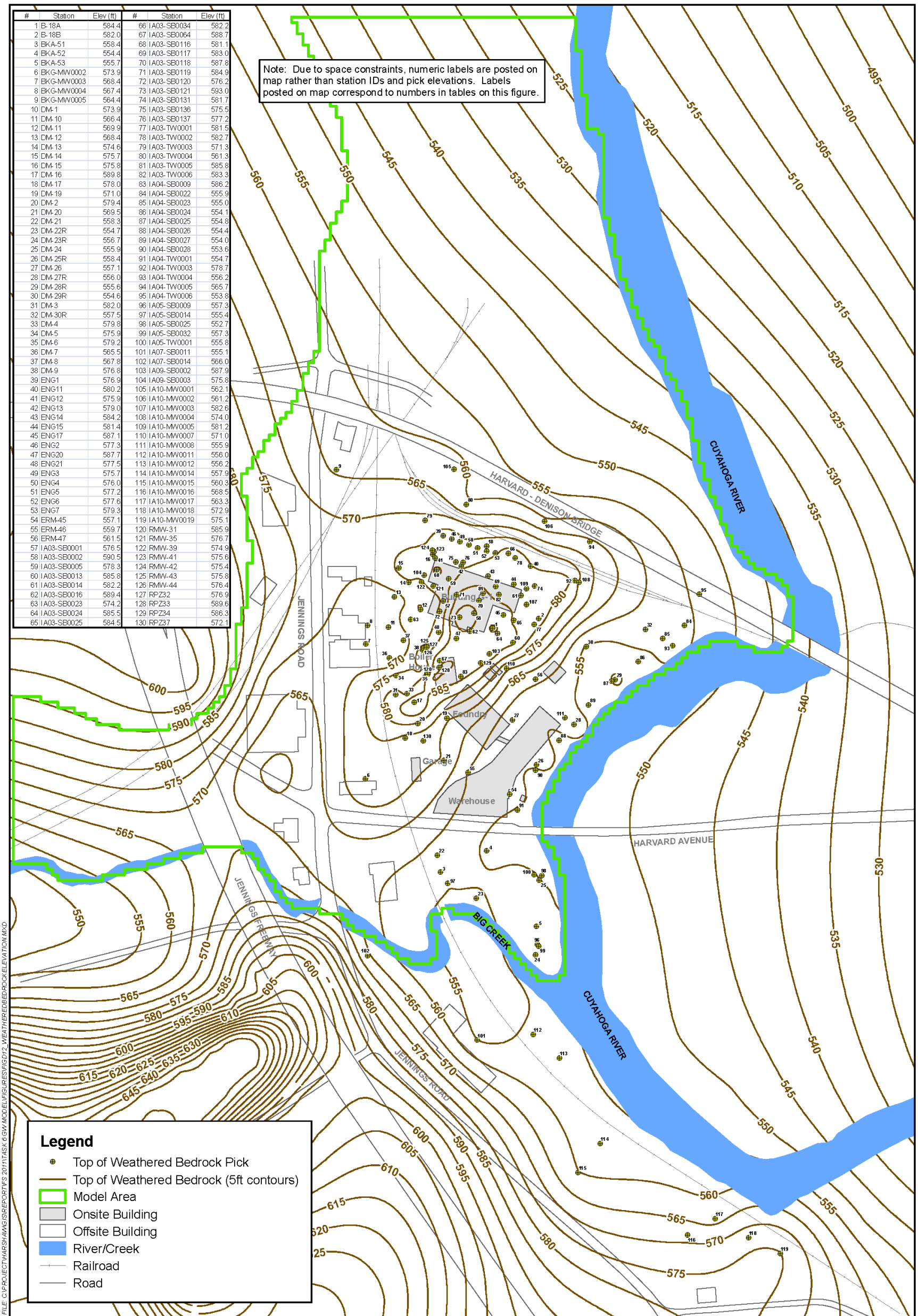

Figure D-12. Elevation of Top of Weathered Bedrock

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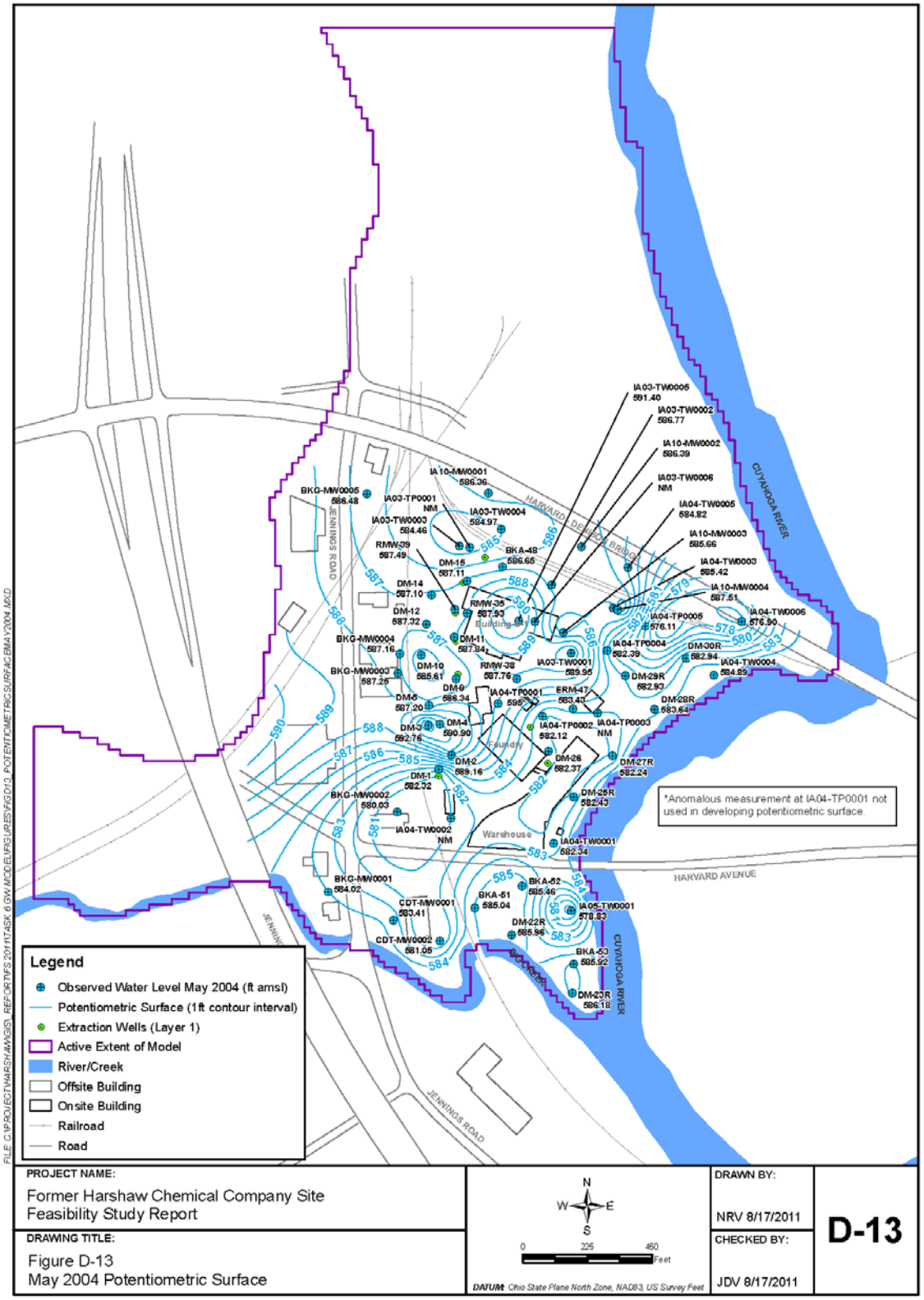

Figure D-13. May 2004 Potentiometric Surface

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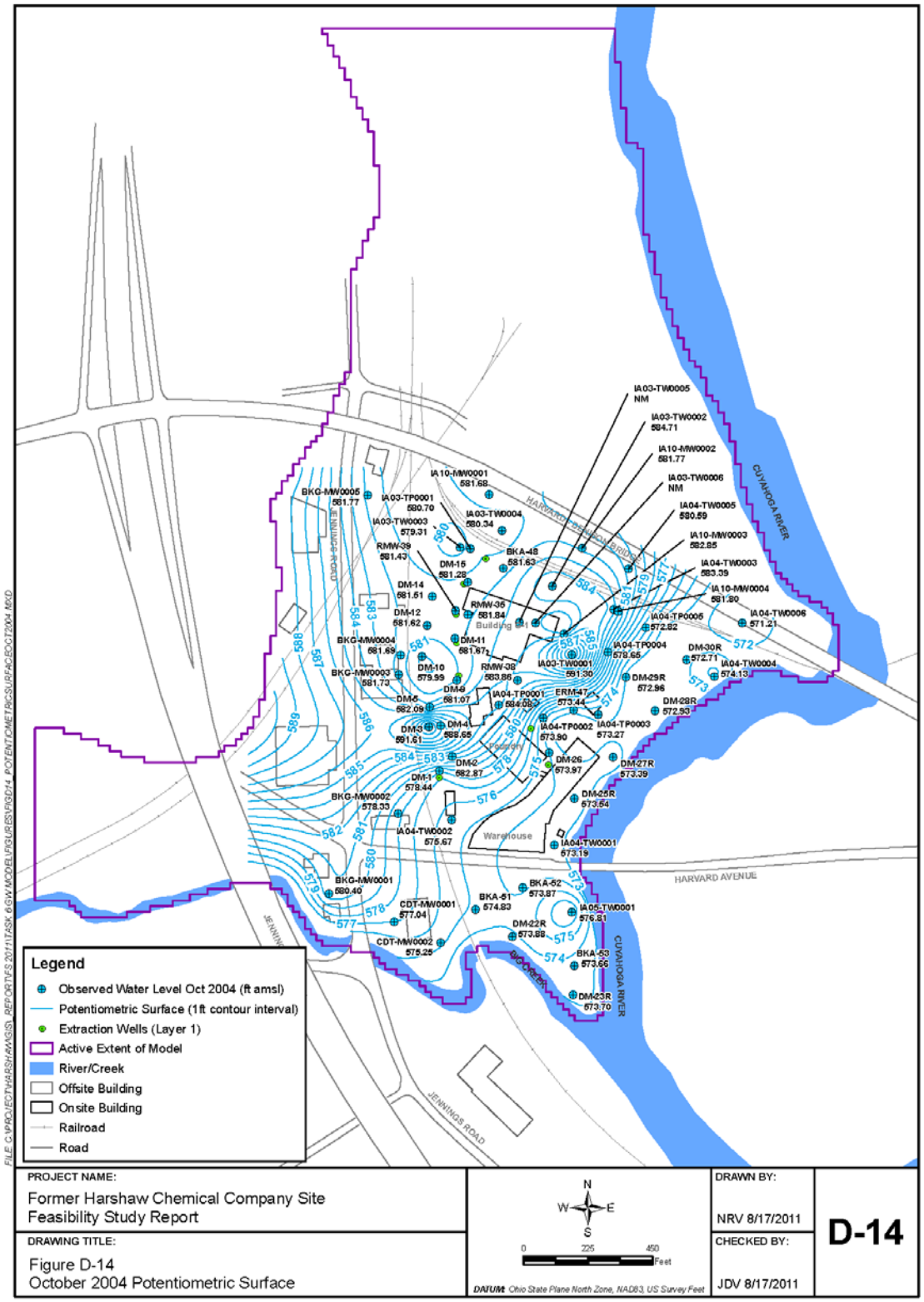

Figure D-14. October 2004 Potentiometric Surface

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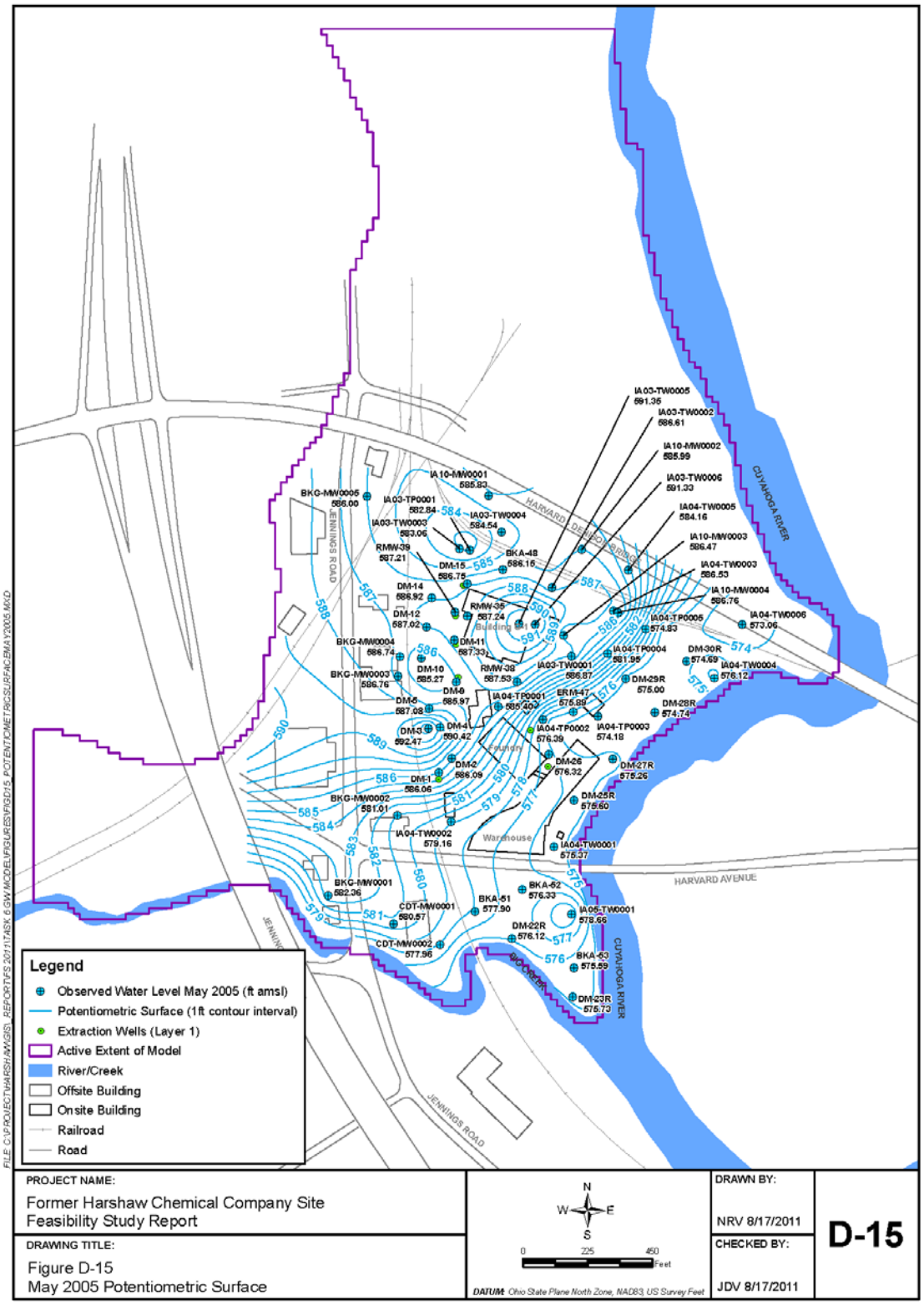

Figure D-15. May 2005 Potentiometric Surface

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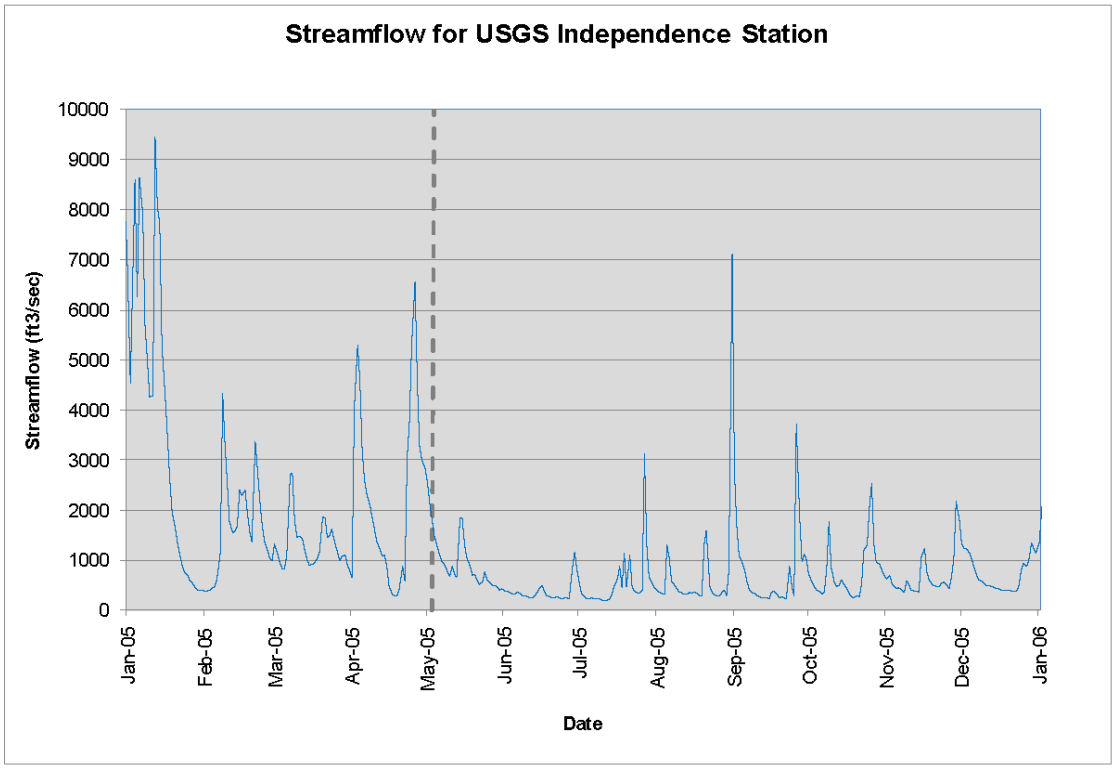

Figure D-16. Streamflow for USGS Independence Station

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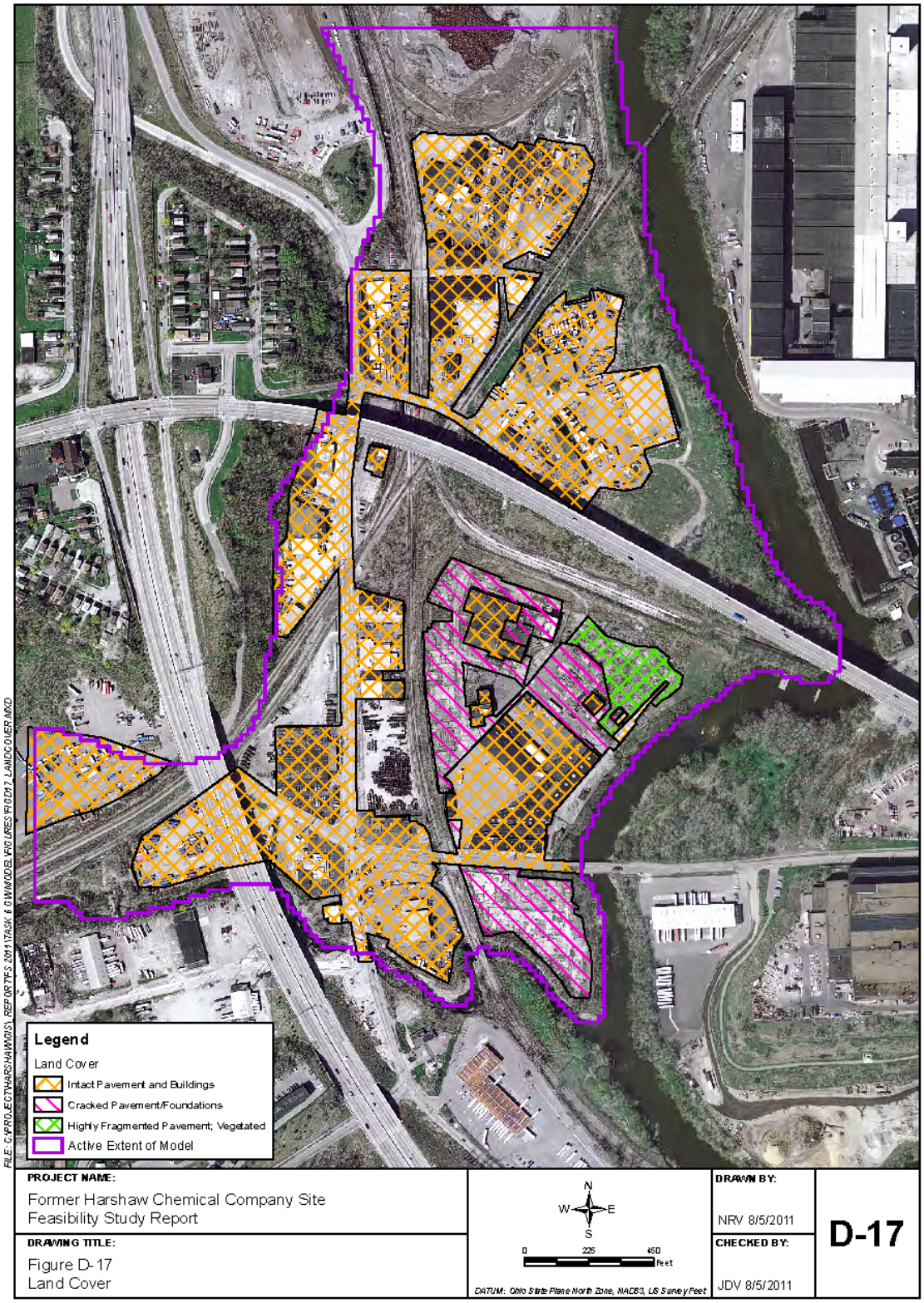

Figure D-17. Land Cover

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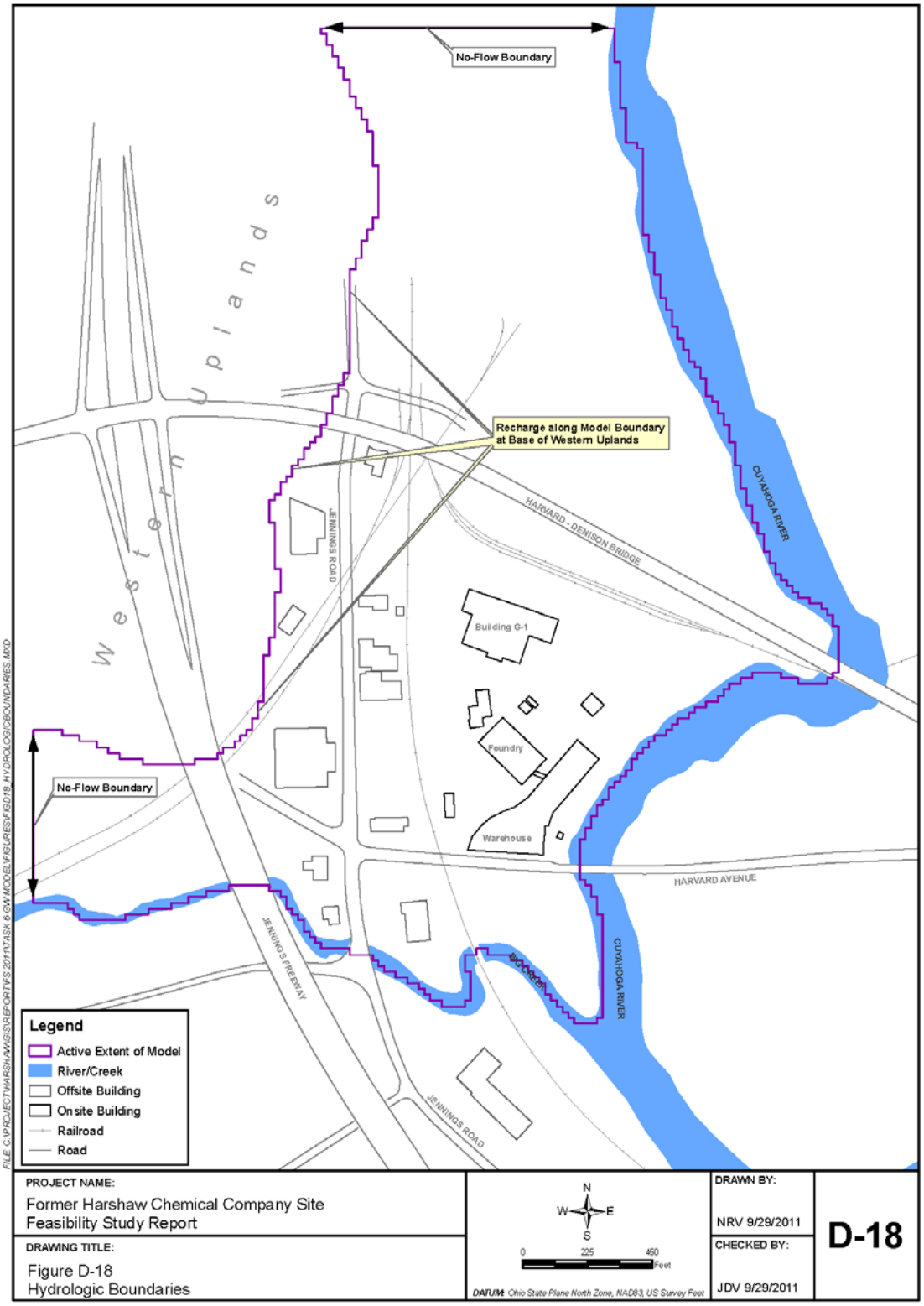

Figure D-18. Hydrologic Boundaries

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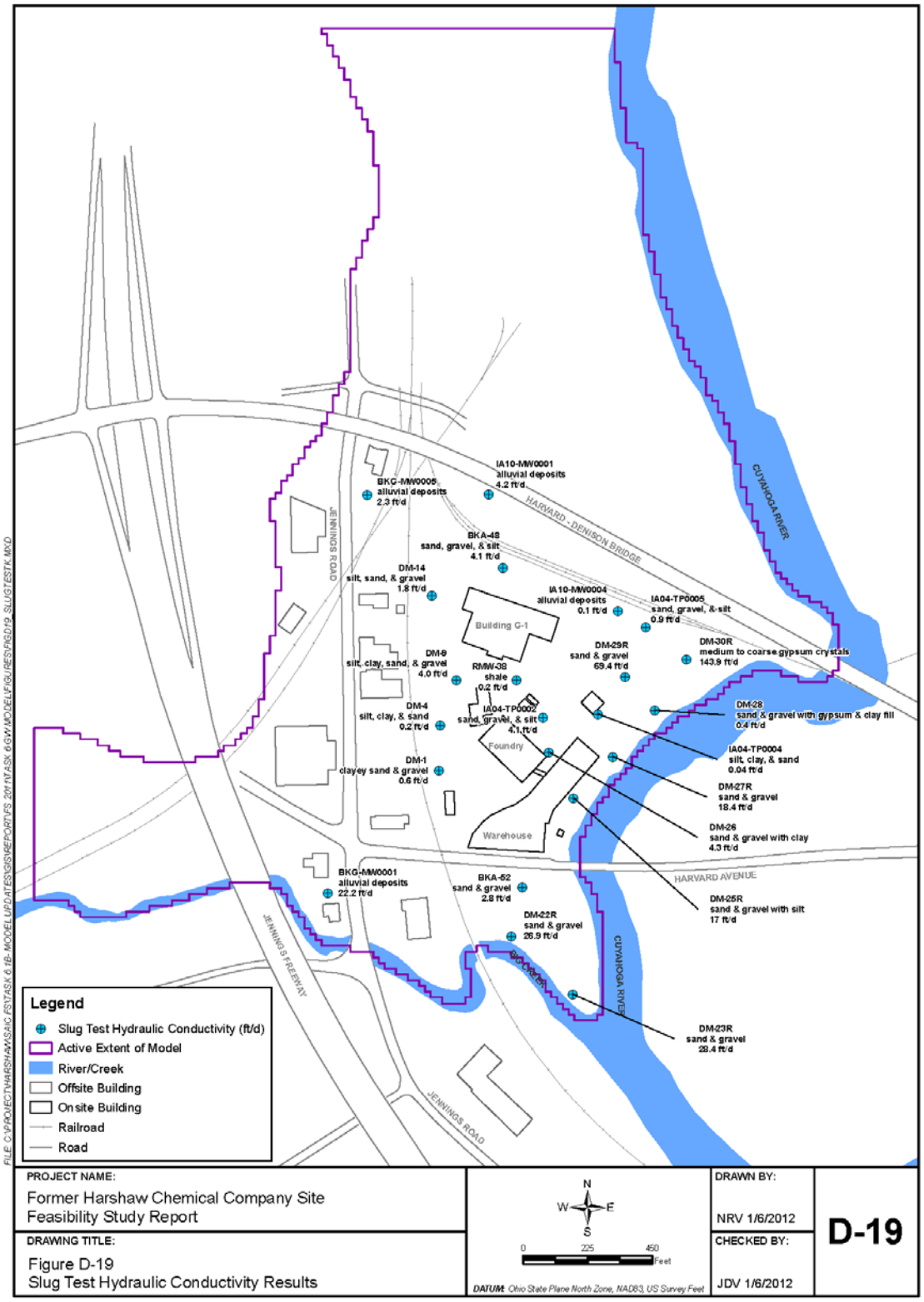

Figure D-19. Slug Test Hydraulic Conductivity Results

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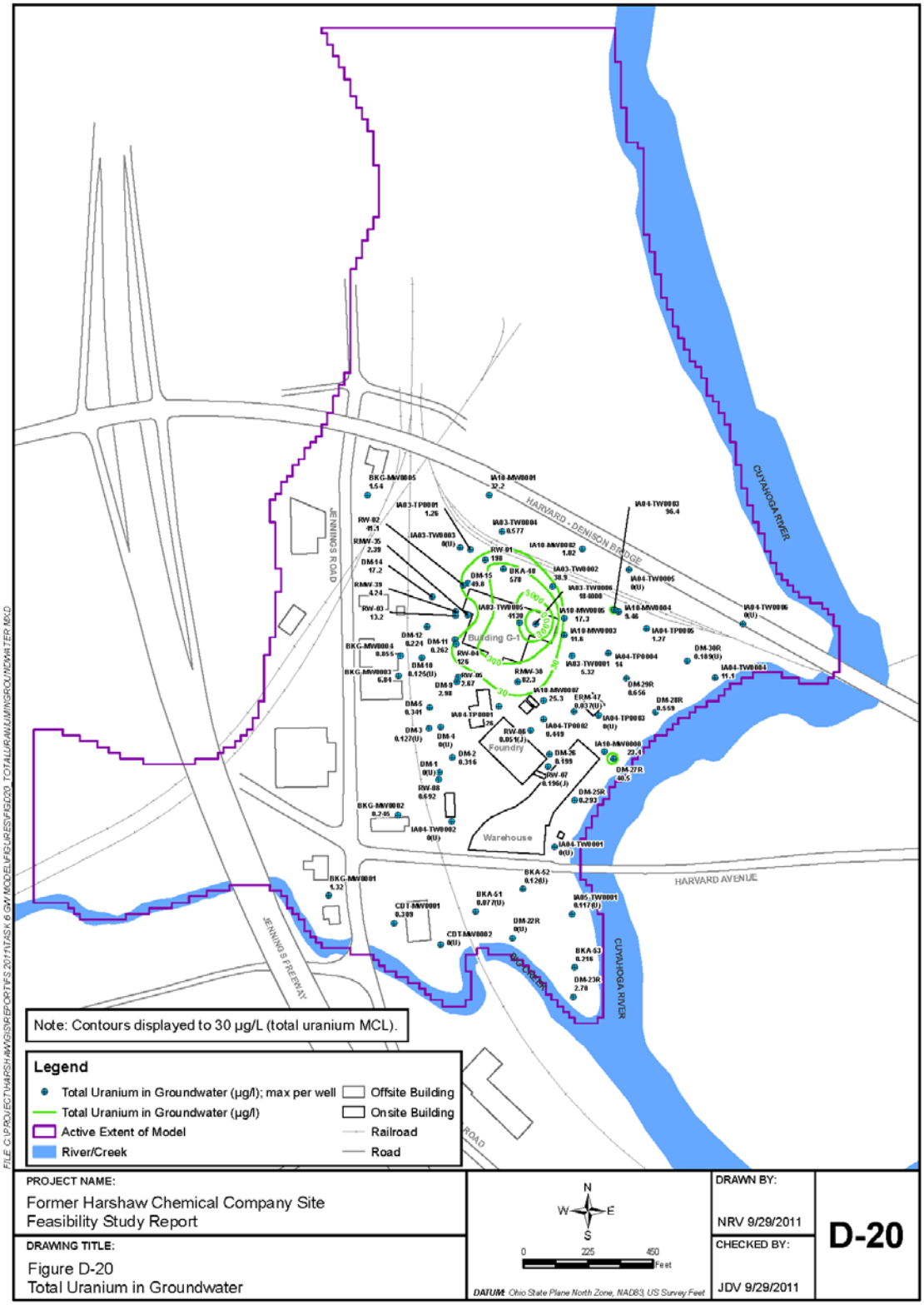

Figure D-20. Total Uranium in Groundwater

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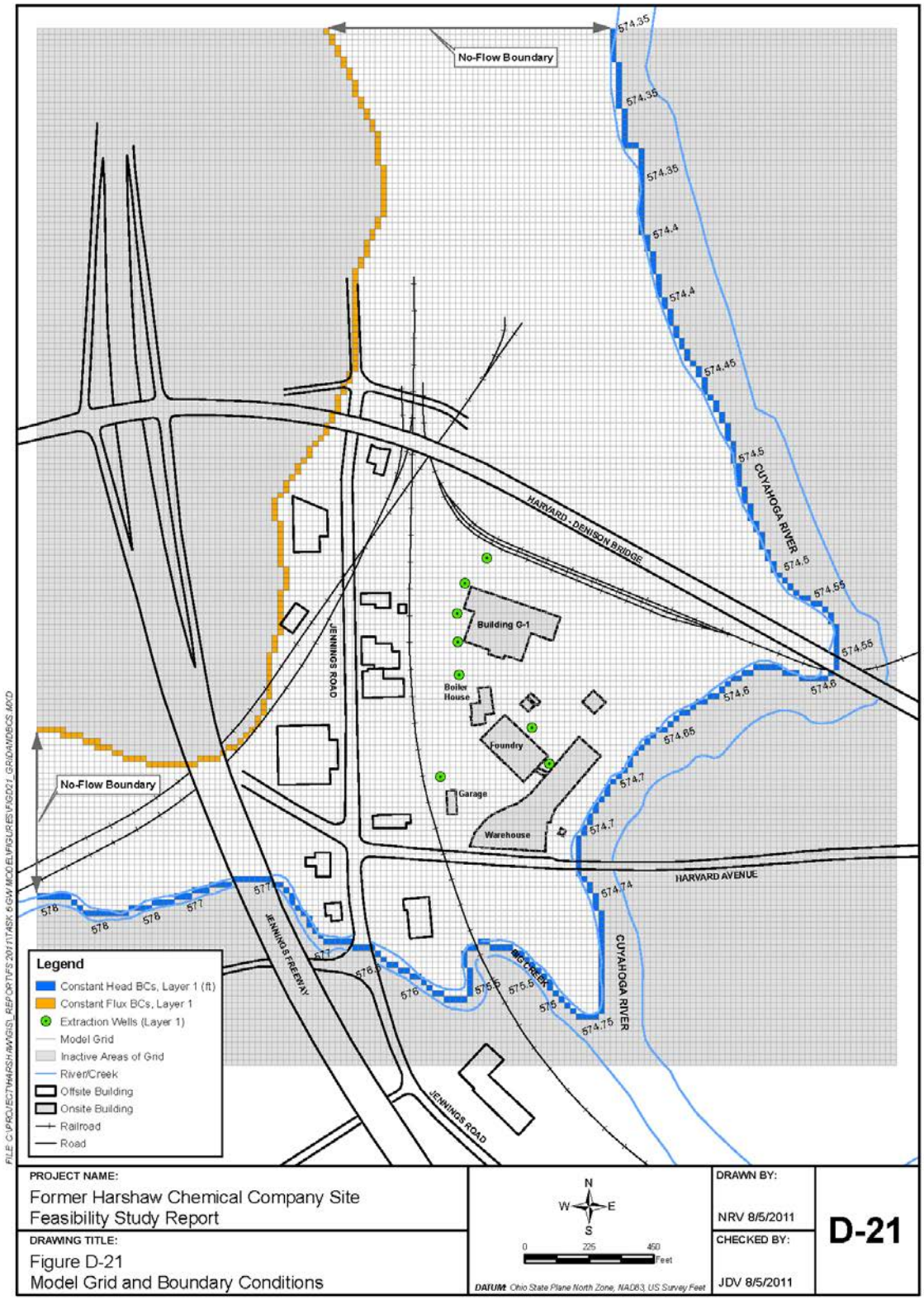

Figure D-21. Model Grid and Boundary Conditions

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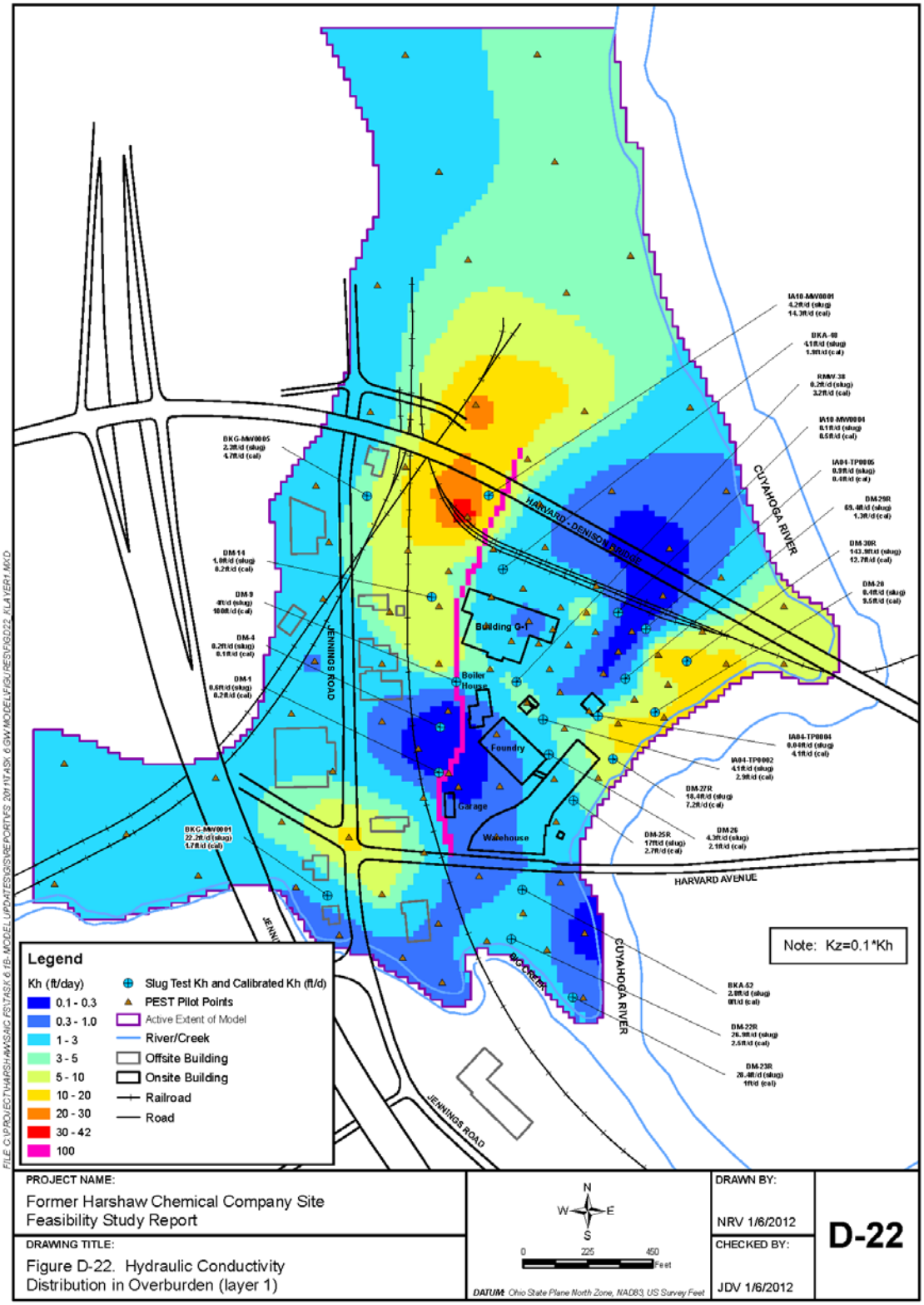

Figure D-22. Hydraulic Conductivity Distribution in Overburden (layer 1)

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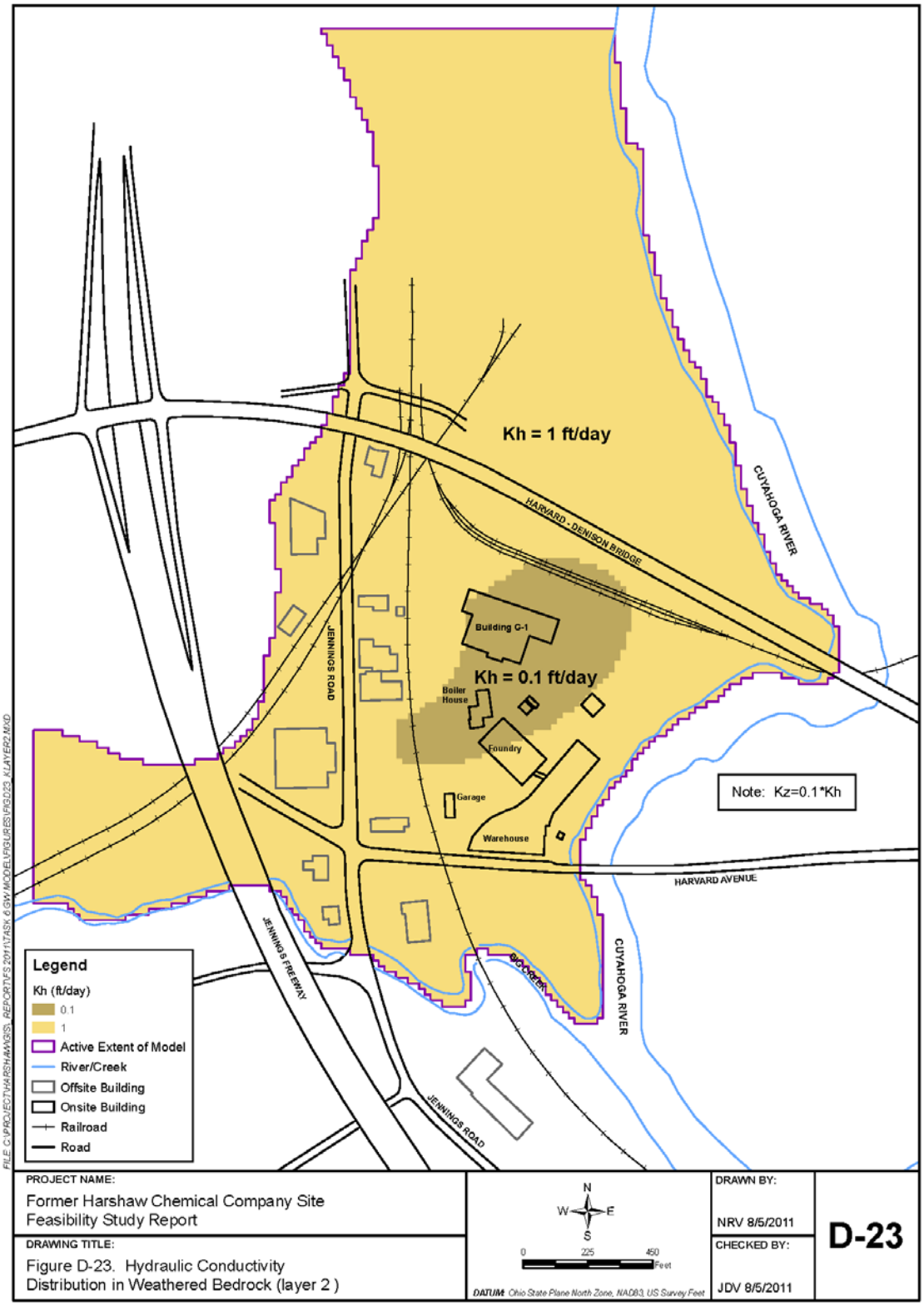

Figure D-23. Hydraulic Conductivity Distribution in Weathered Bedrock (layer 2)

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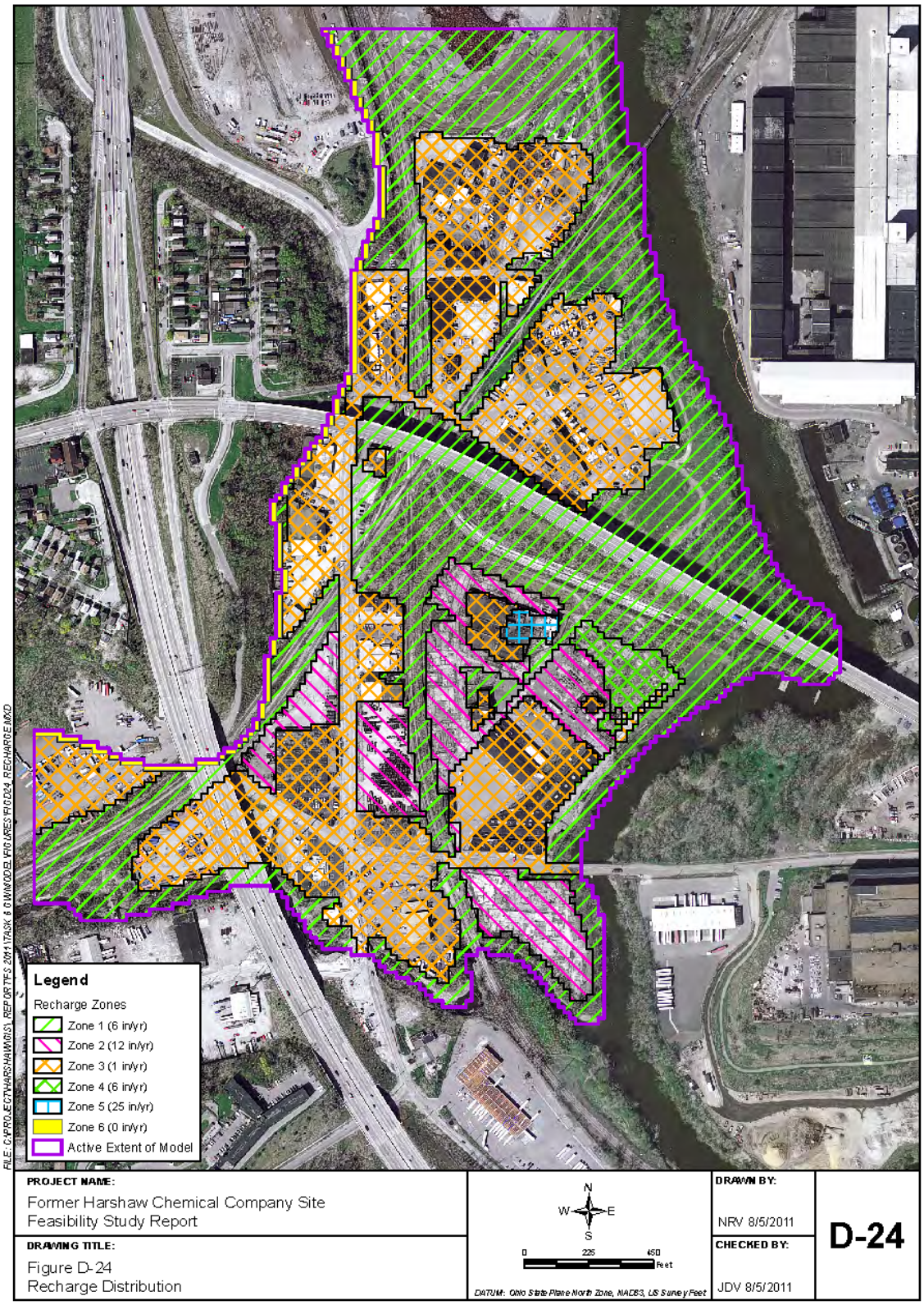

Figure D-24. Recharge Distribution

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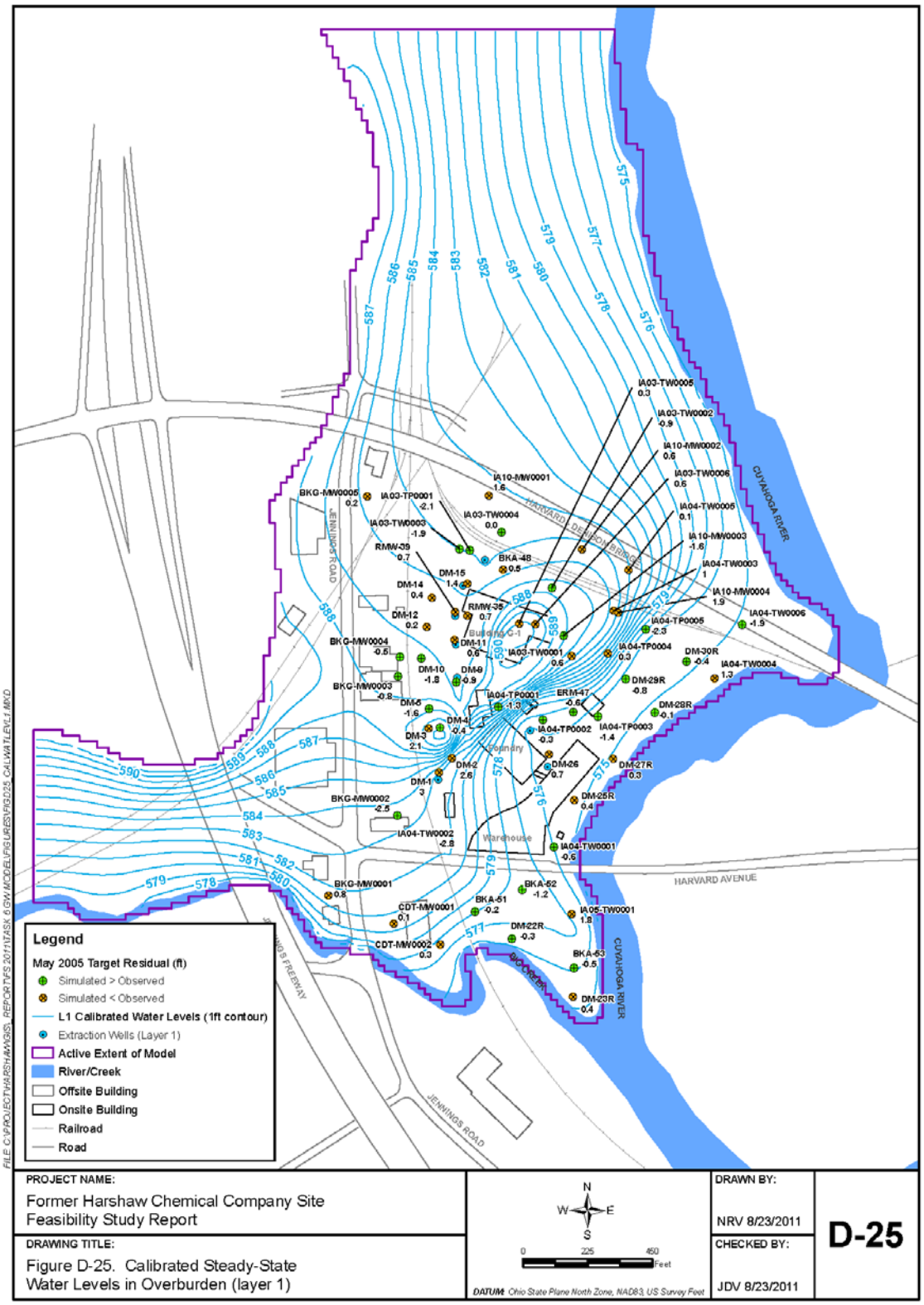

Figure D-25. Calibrated Steady-State Water Levels in Overburden (layer 1)

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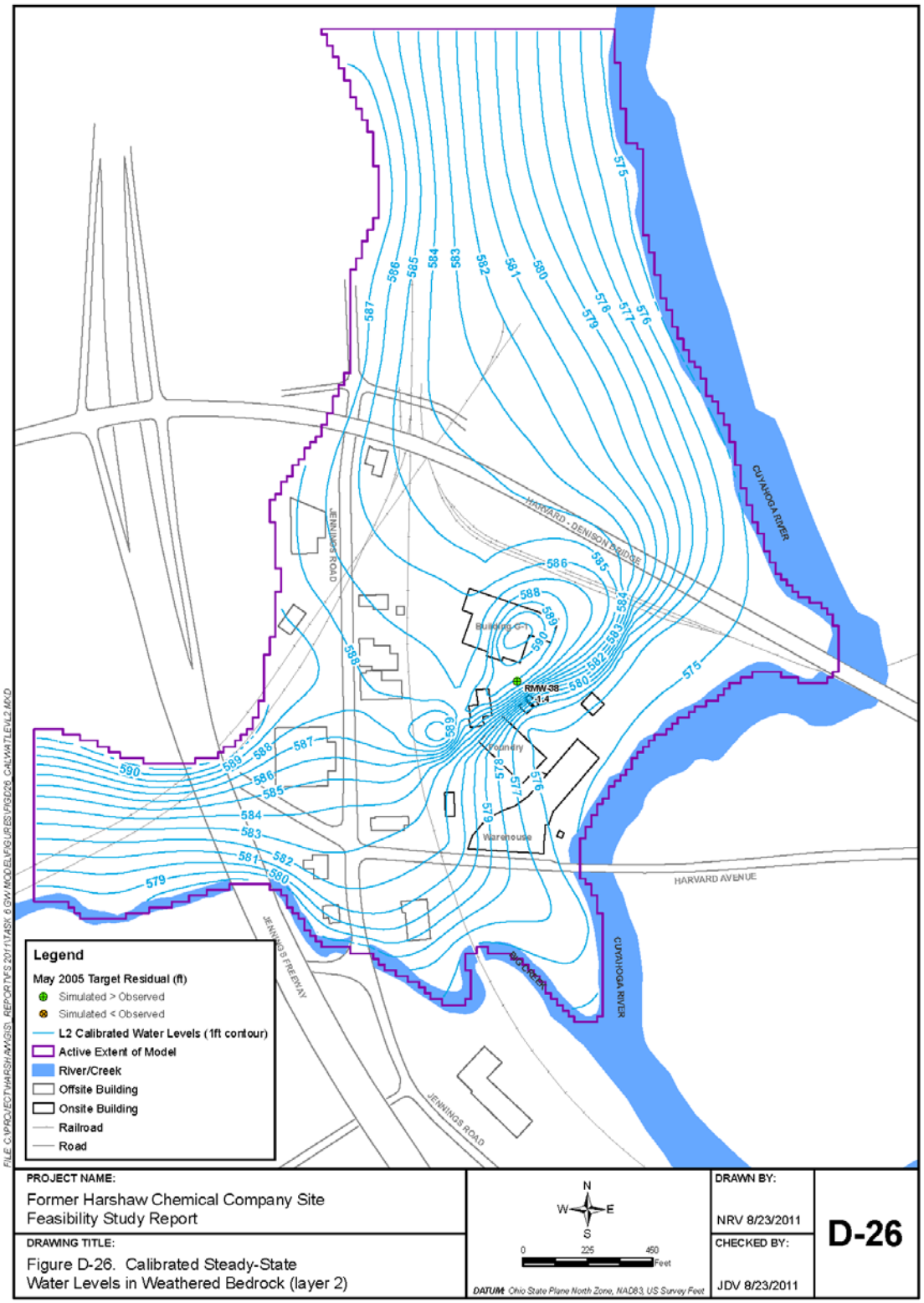

Figure D-26. Calibrated Steady-State Water Levels in Weathered Bedrock (layer 2)

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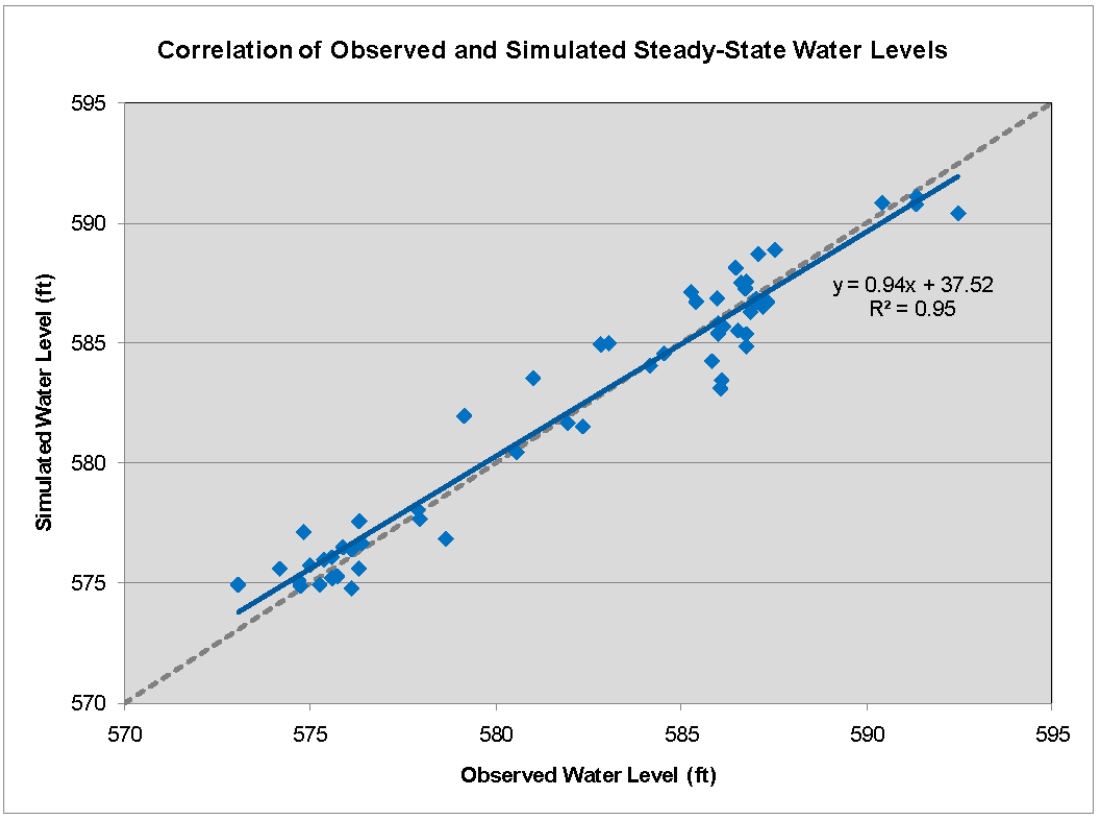

Figure D-27. Correlation of Observed and Simulated Steady-State Water Levels

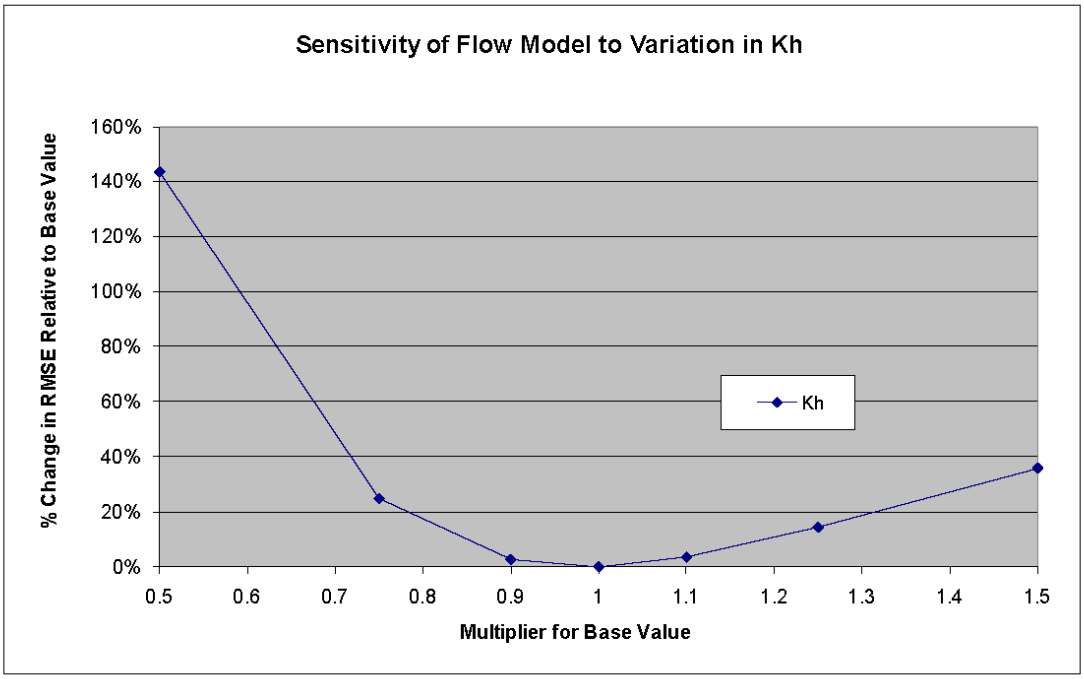

Figure D-28. Sensitivity of Flow Model to Variation in Kh

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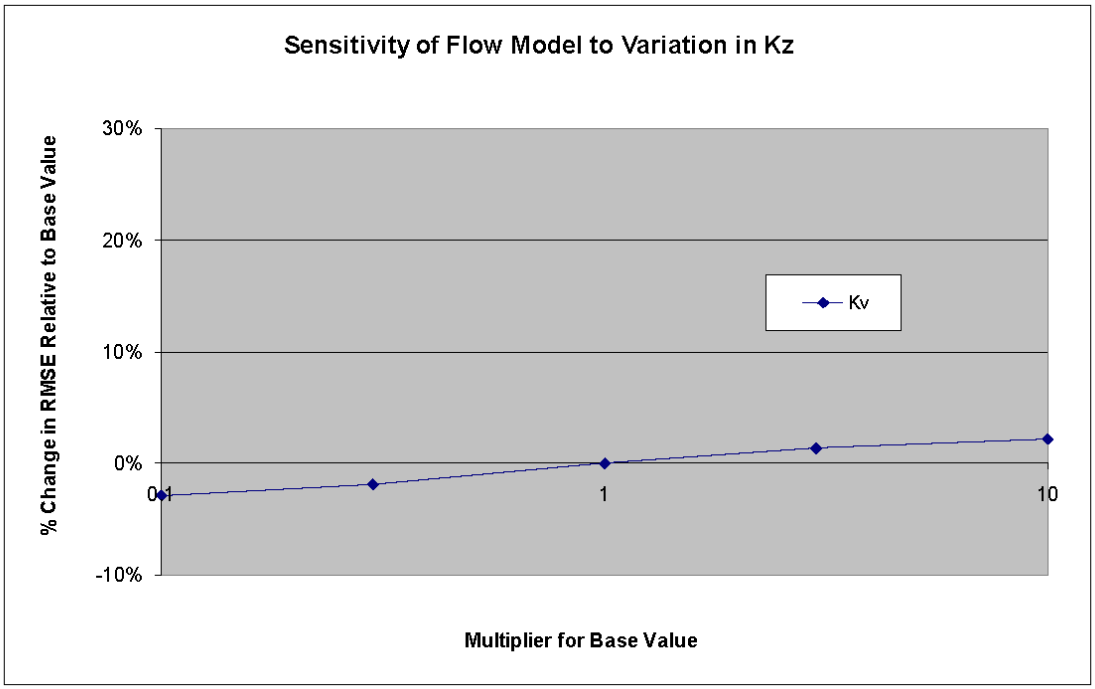

Figure D-29. Sensitivity of Flow Model to Variation in Kz

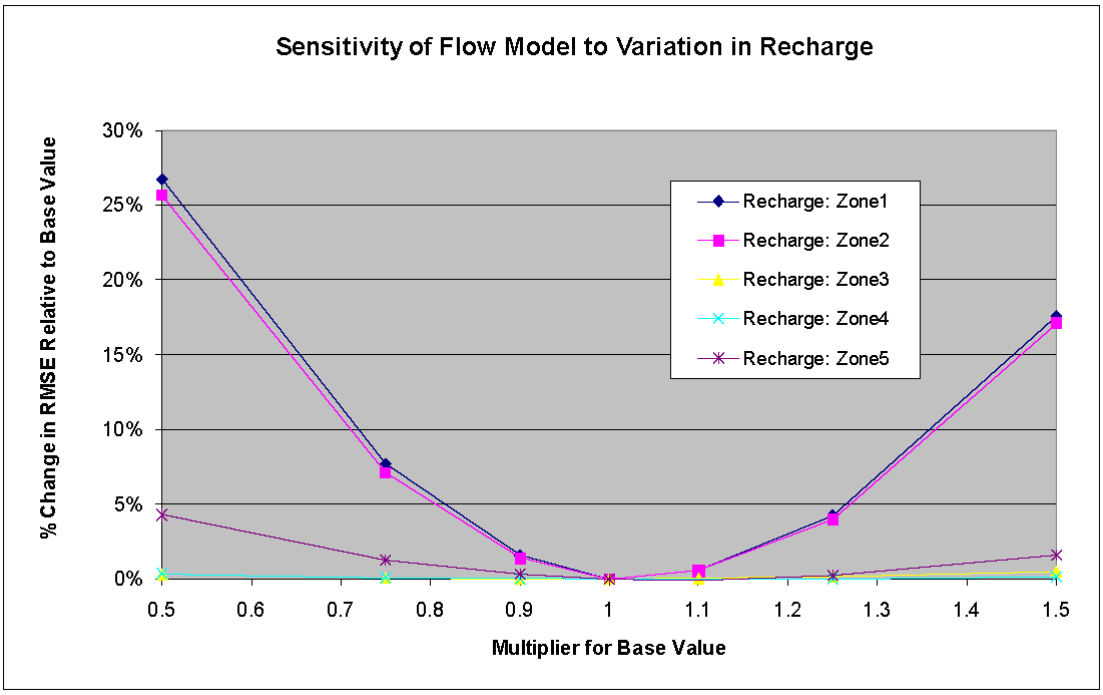

Figure D-30. Sensitivity of Flow Model to Variation in Recharge

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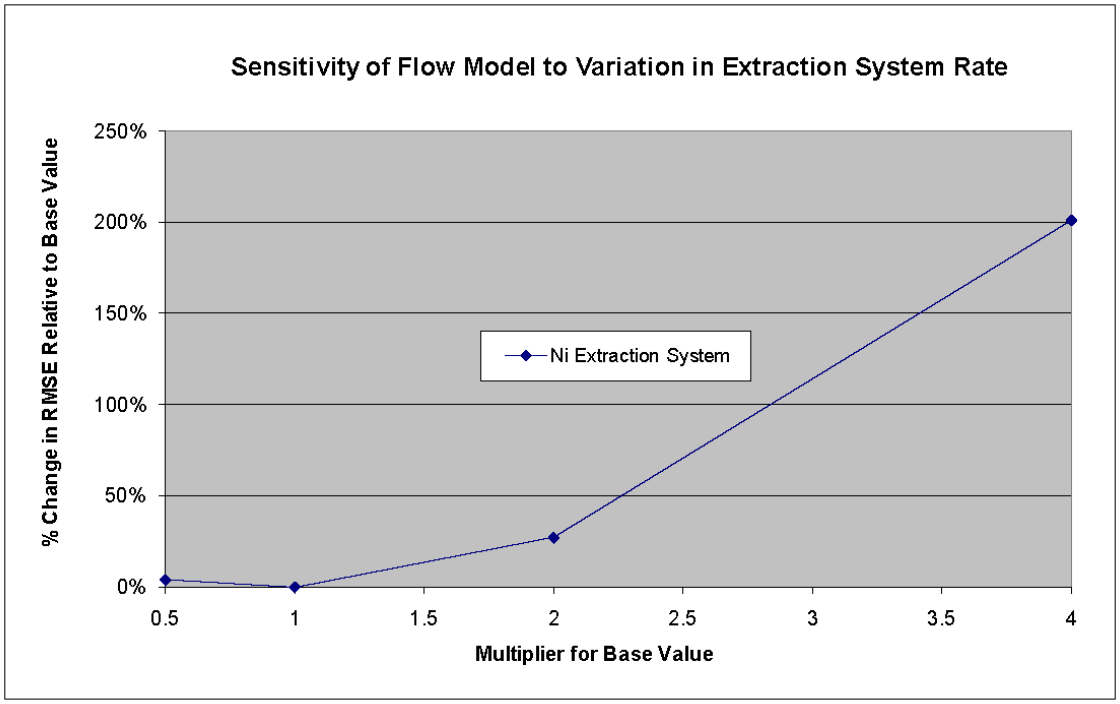

Figure D-31. Sensitivity of Flow Model to Variation in Extraction System Pumping Rate

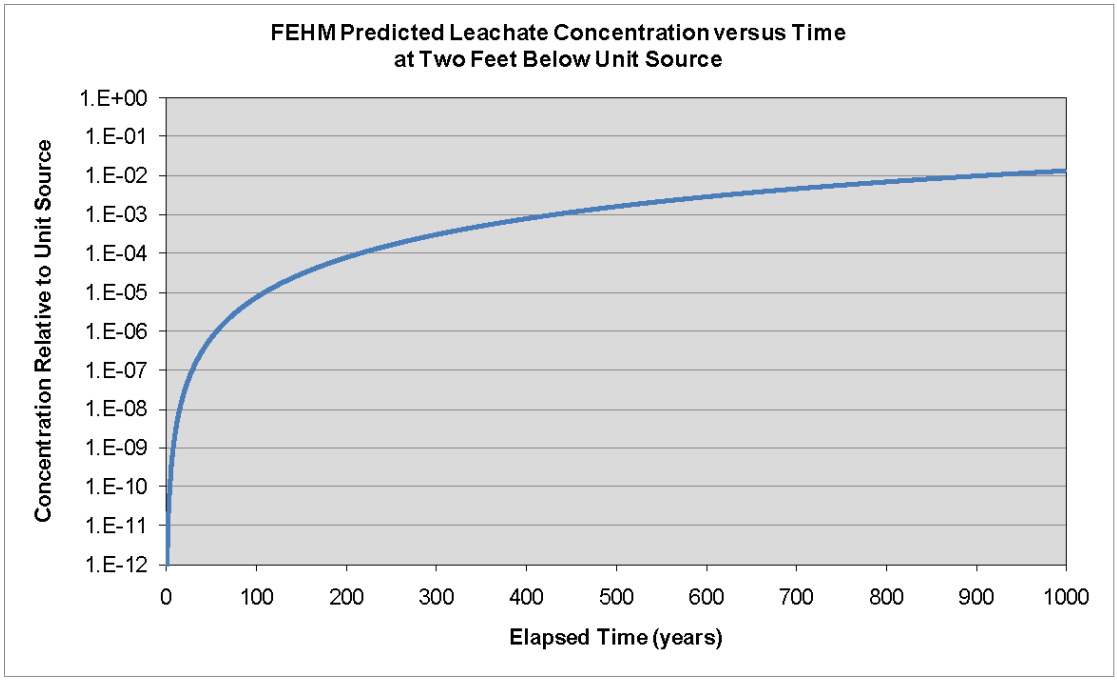

Figure D-32. FEHM Predicted Leachate Concentration versus Time at 2 ft Below Unit Source

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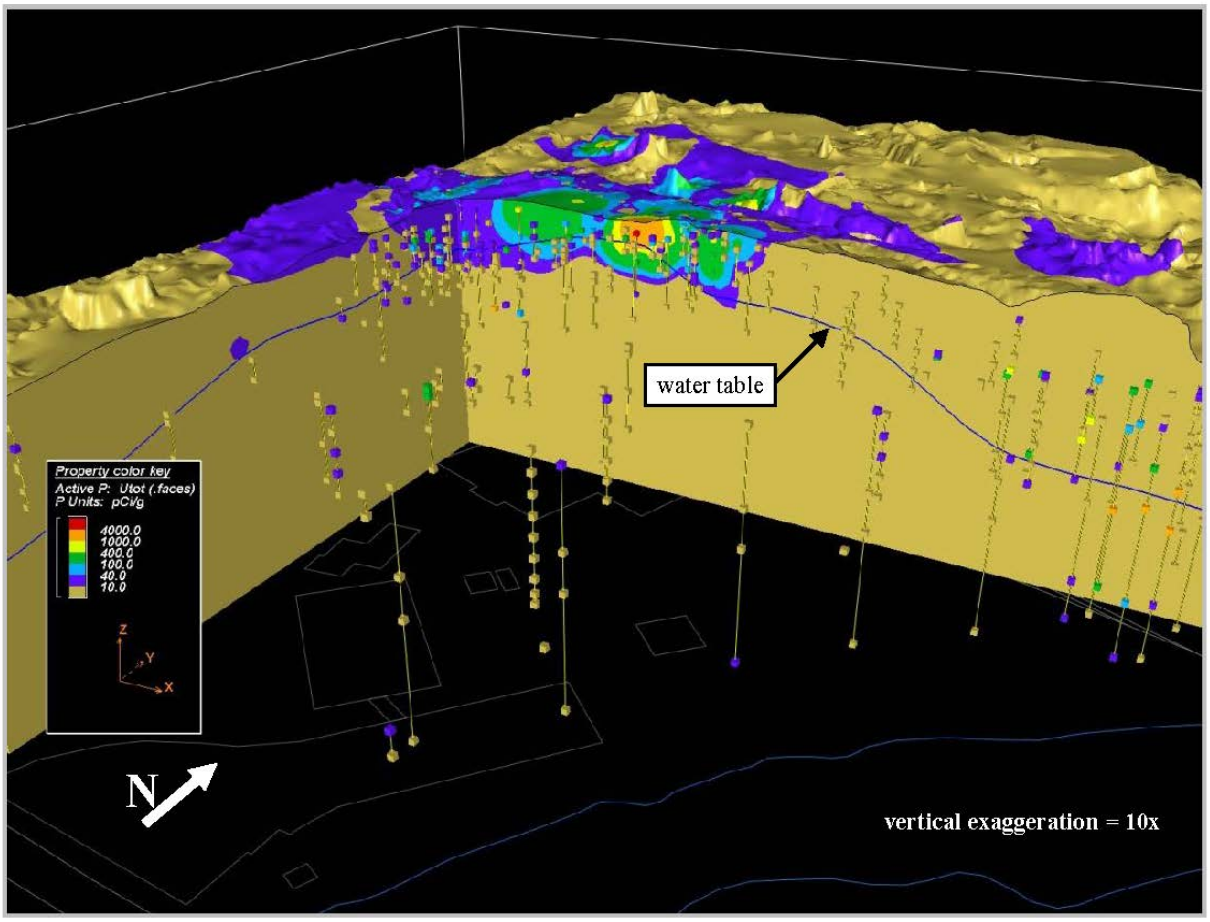

Figure D-33. 3D Model of Total Uranium in Soil

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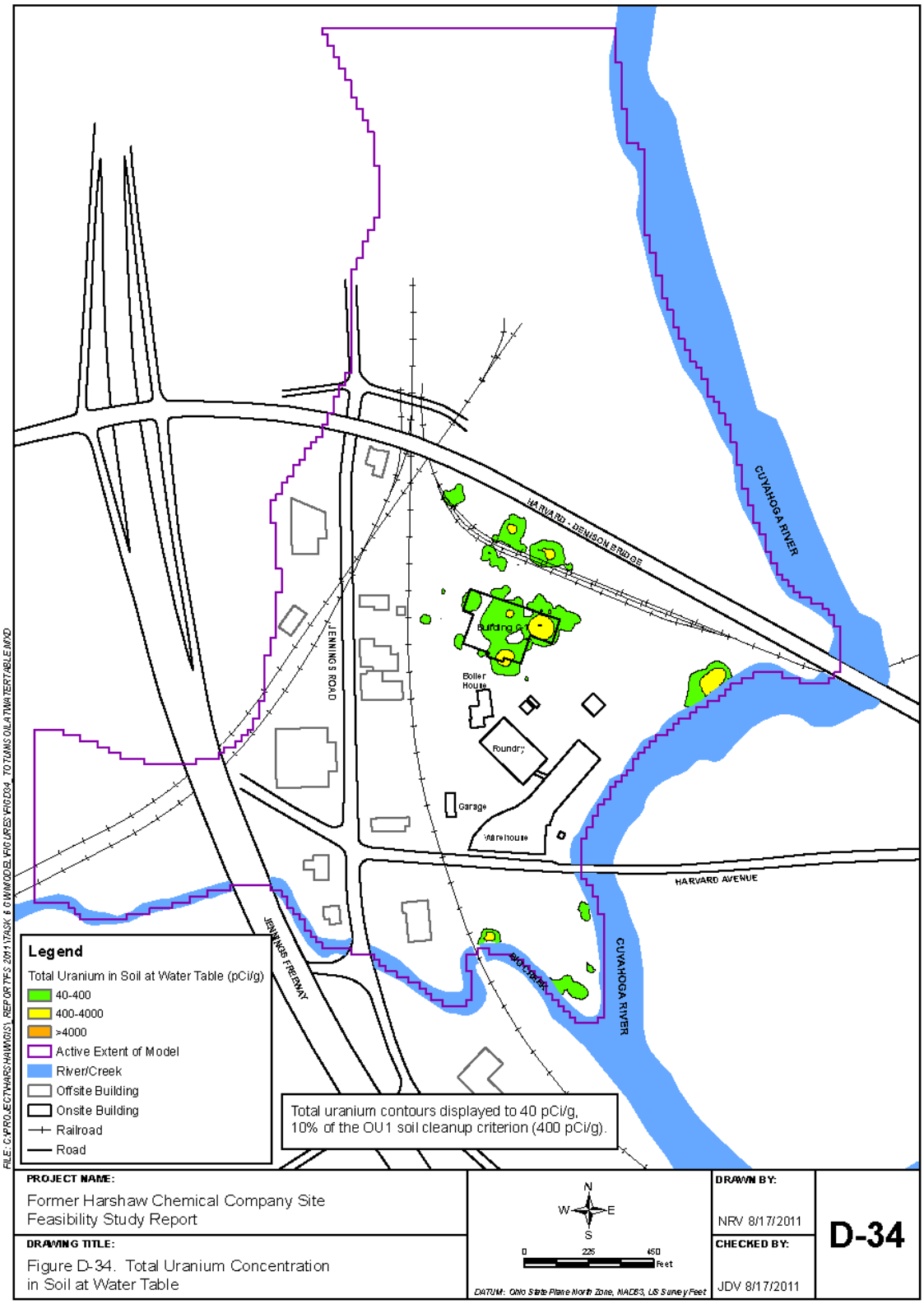

Figure D-34. Total Uranium Concentration in Soil at Water Table

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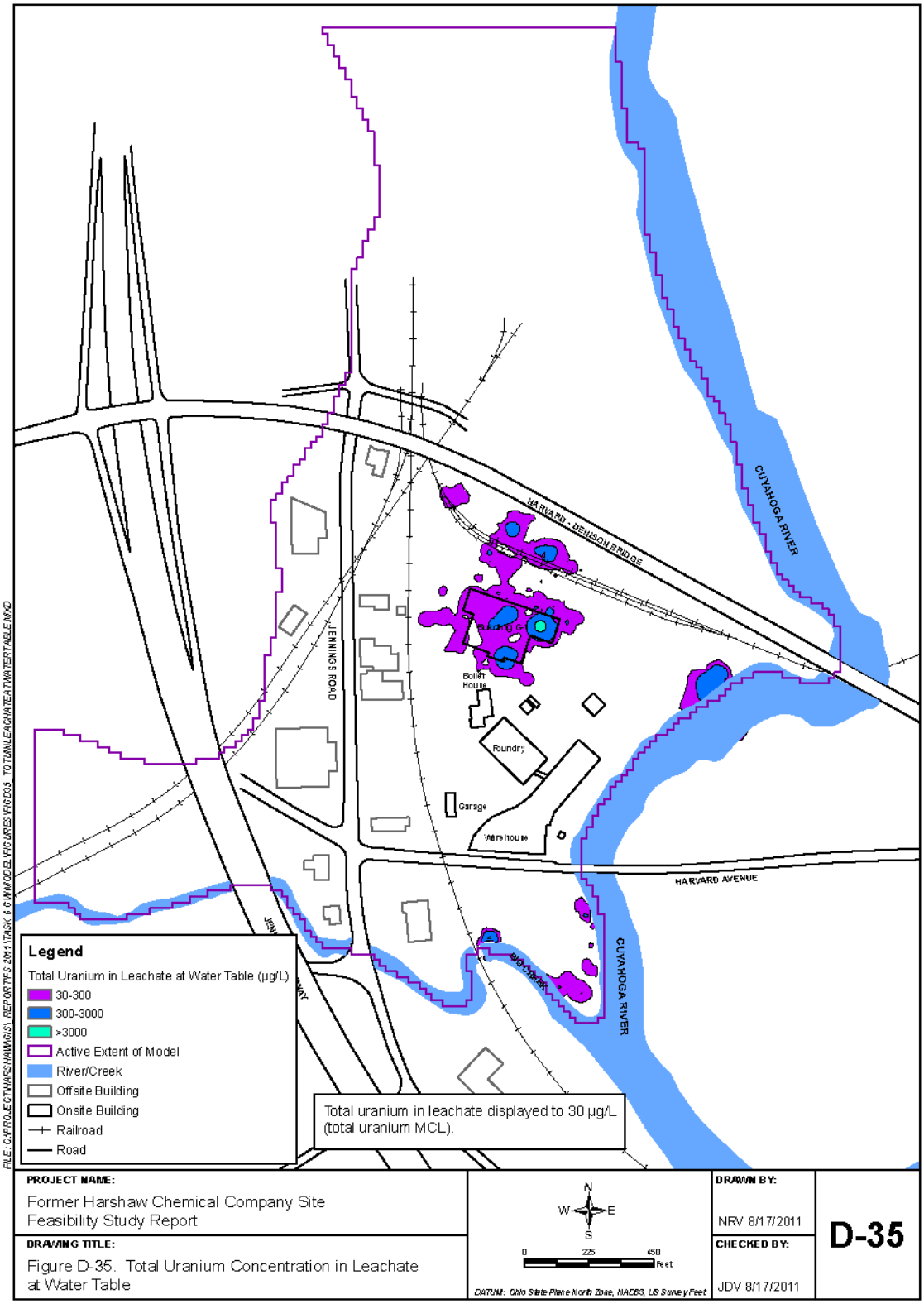

Figure D-35. Total Uranium Concentration in Leachate at Water Table

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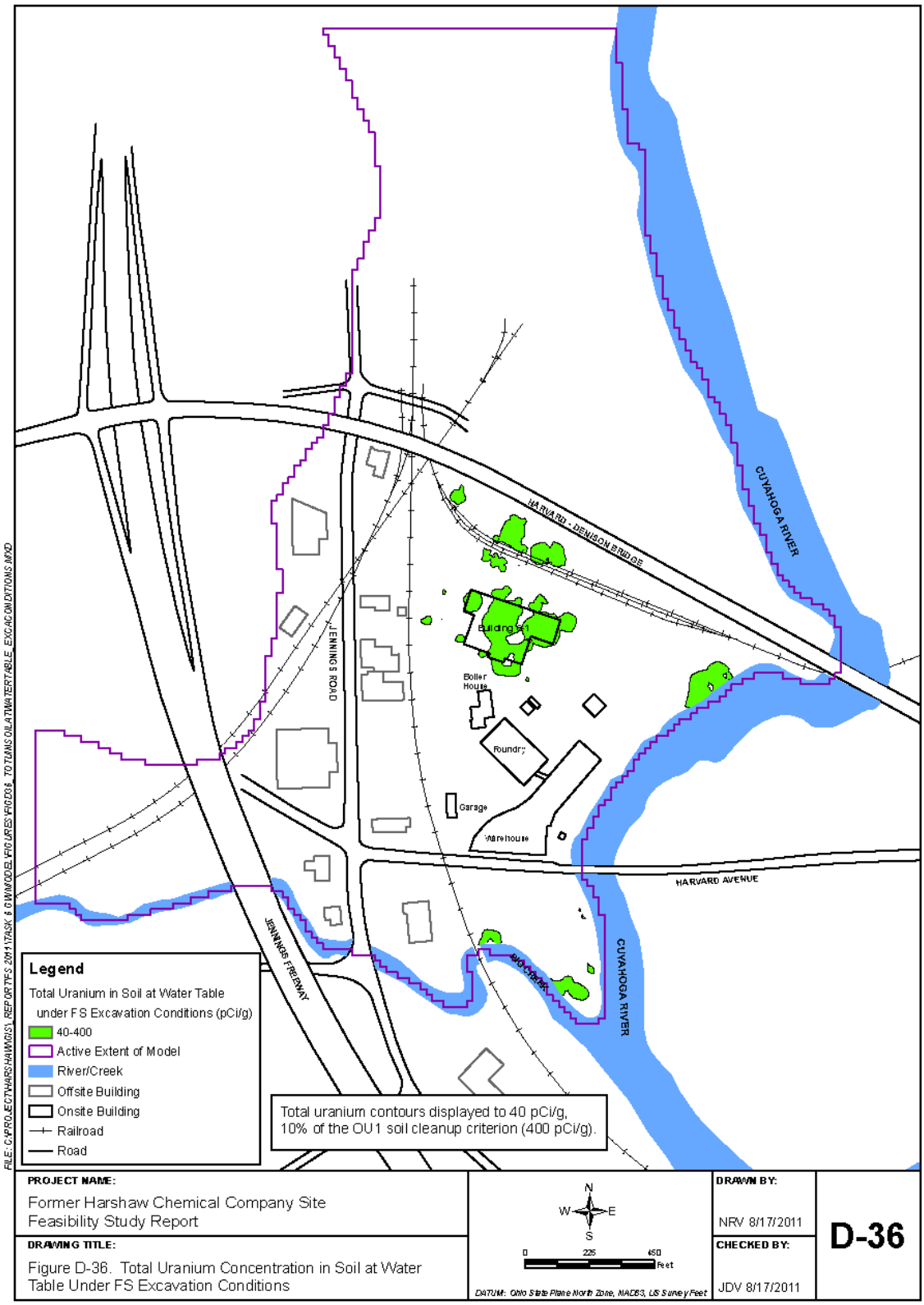

Figure D-36. Total Uranium Concentration in Soil at Water Table Under FS Excavation Conditions

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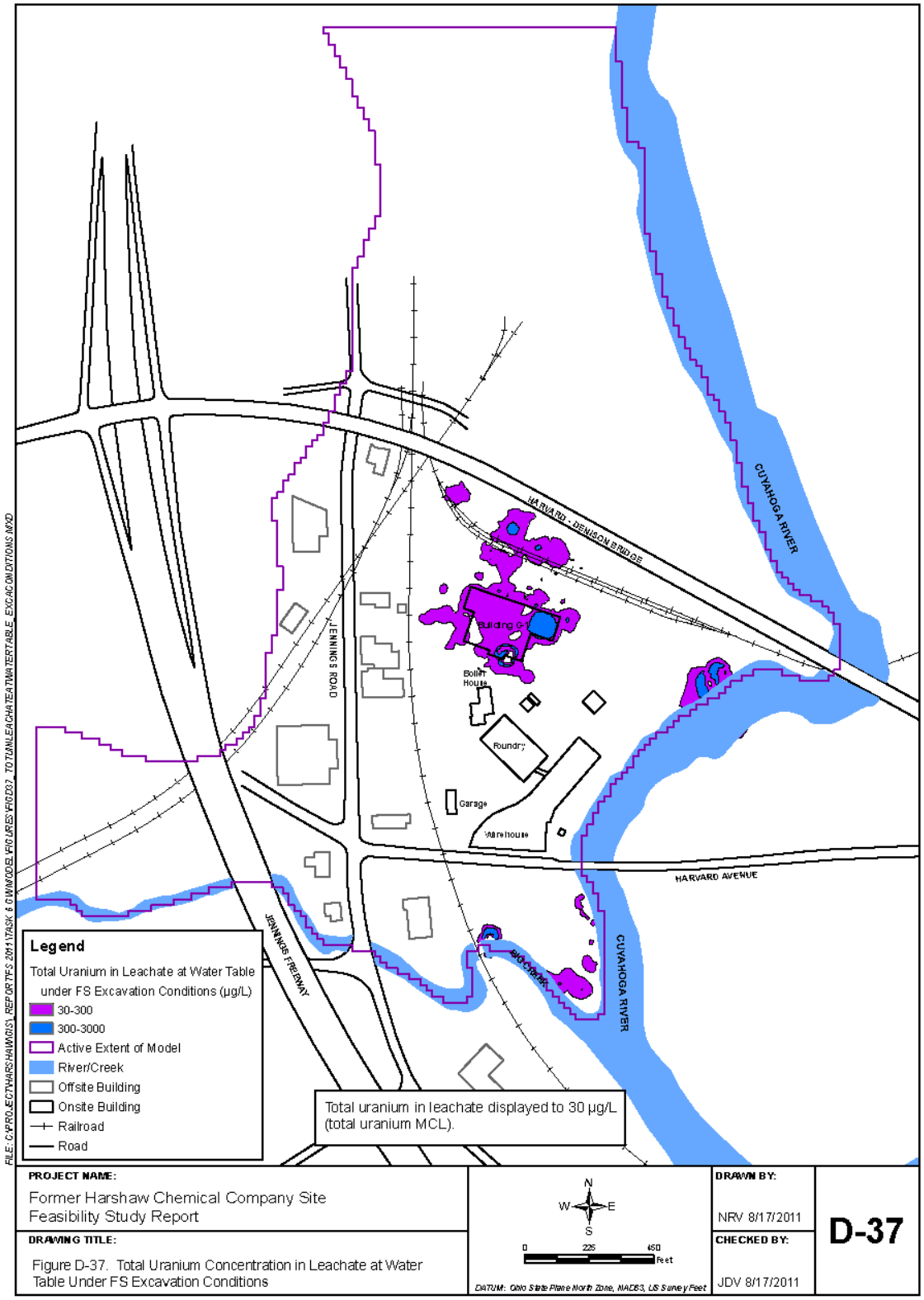

Figure D-37. Total Uranium Concentration in Leachate at Water Table Under FS Excavation Conditions

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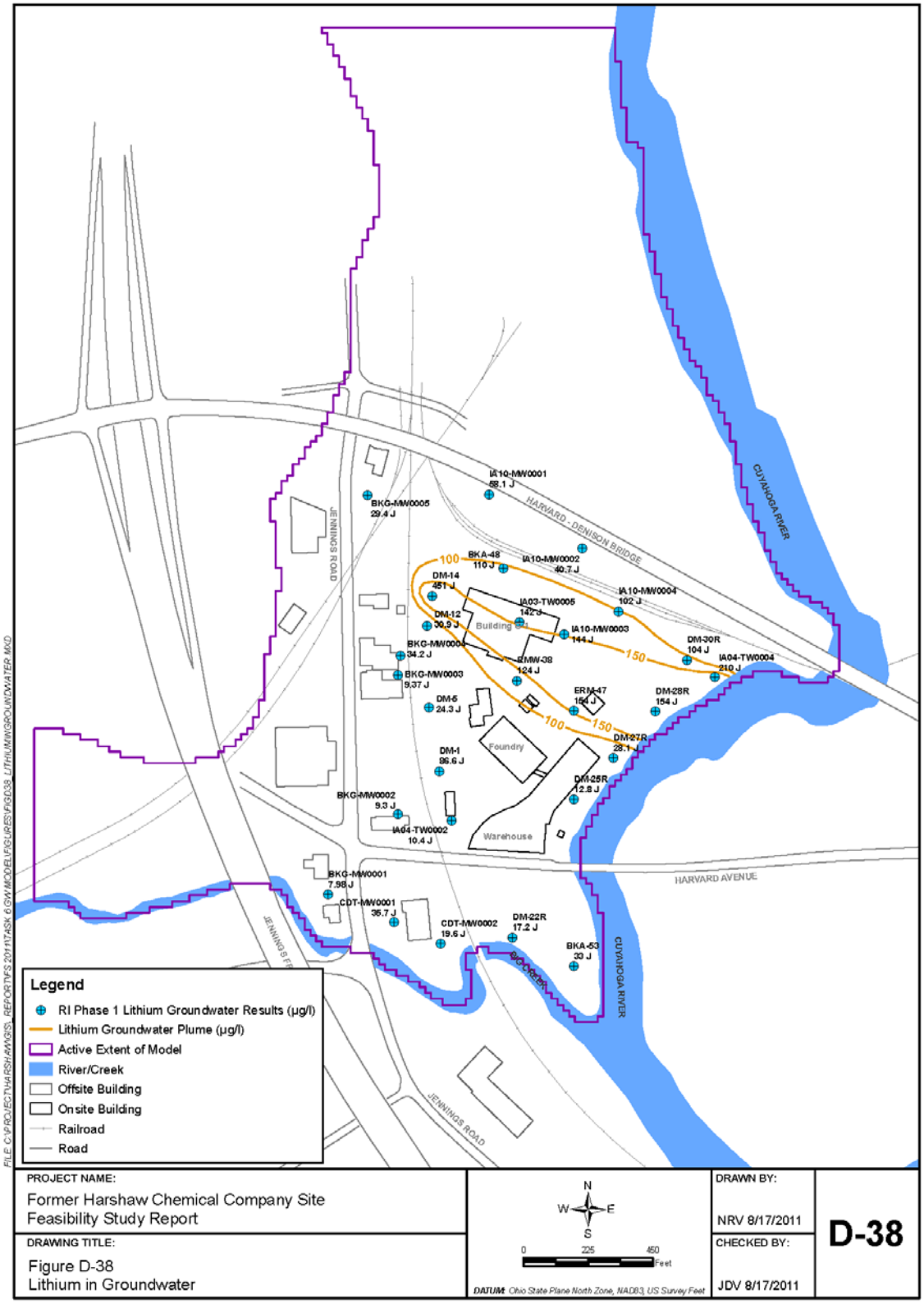

Figure D-38. Lithium in Groundwater

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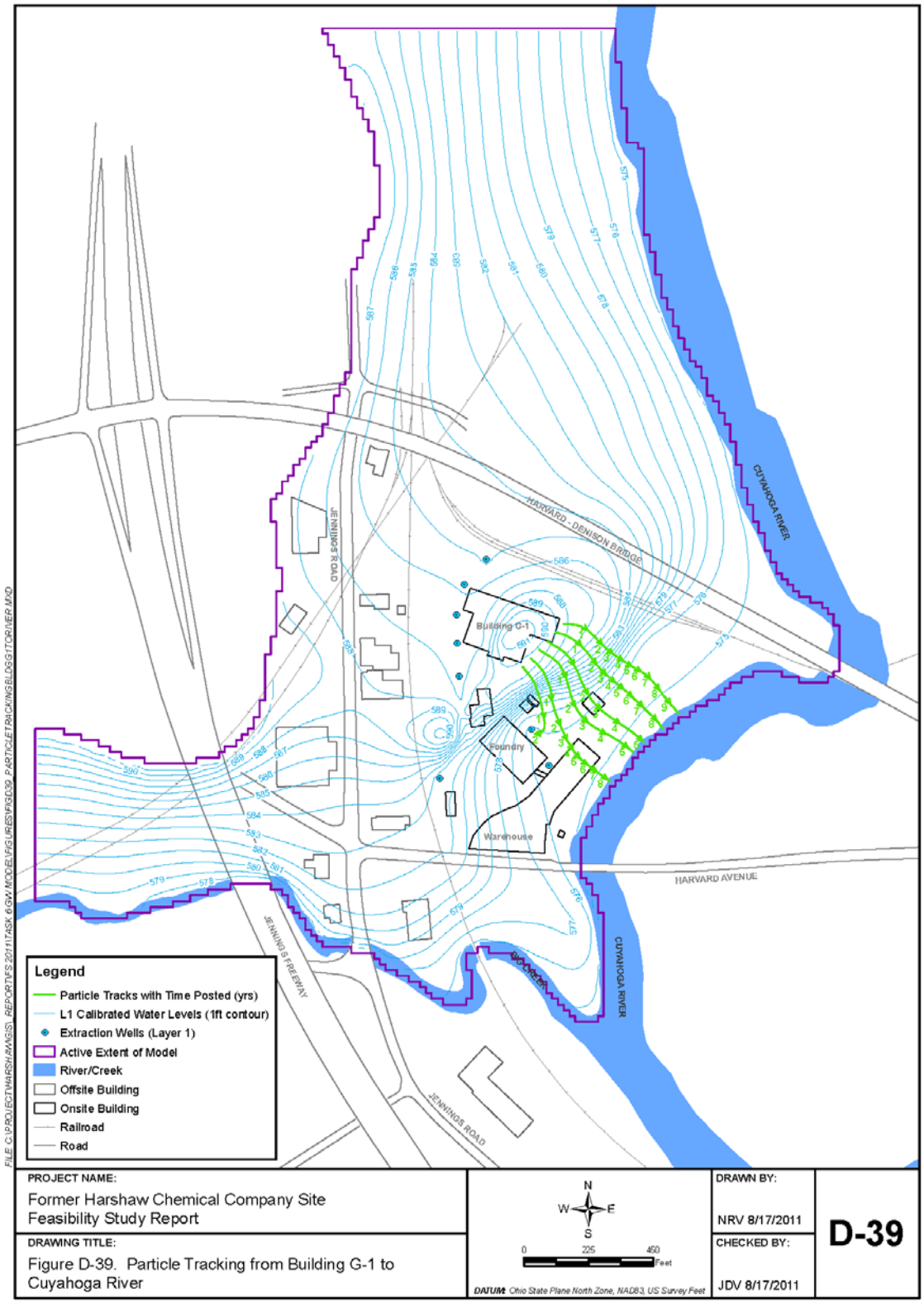

Figure D-39. Particle Tracking from Building G-1 to Cuyahoga River

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Figure D-40. Predicted Total Uranium Groundwater Plumes at 1,000 Years

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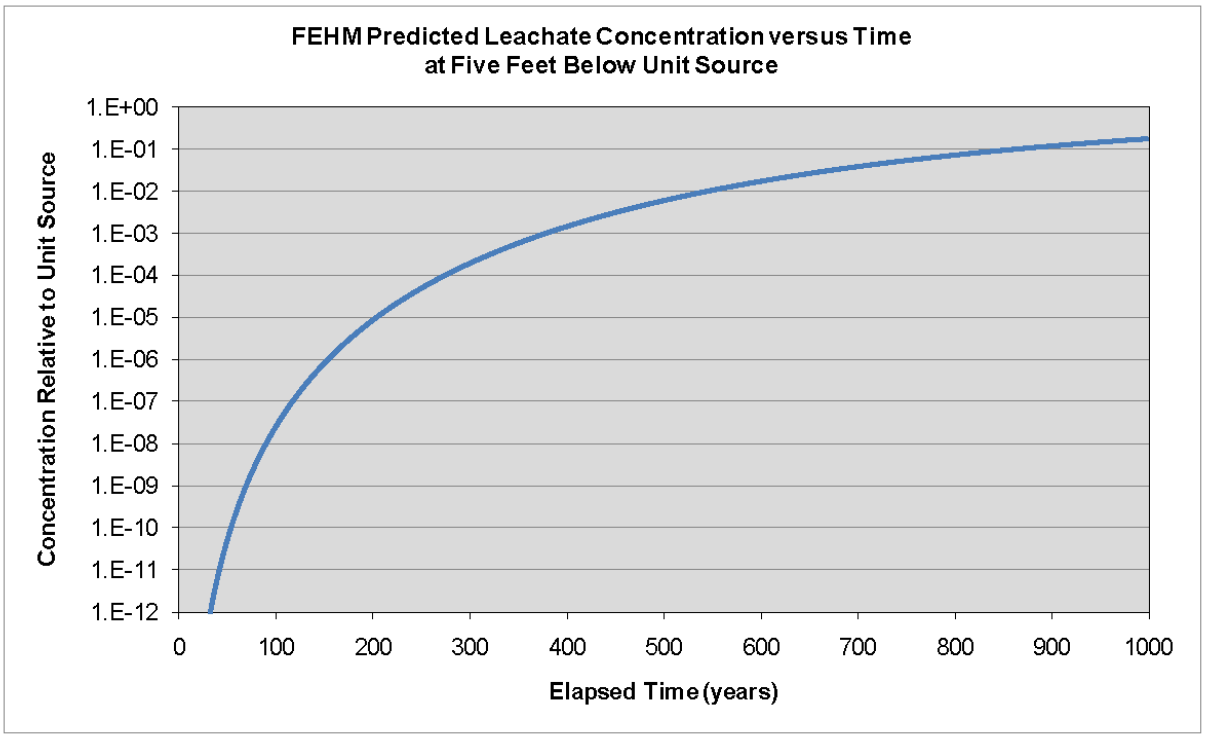

Figure D-41. FEHM Predicted Leachate Concentration versus Time at 5 ft Below Unit Source for Sensitivity Simulation (Order of Magnitude Reduction in Total Uranium K_d)

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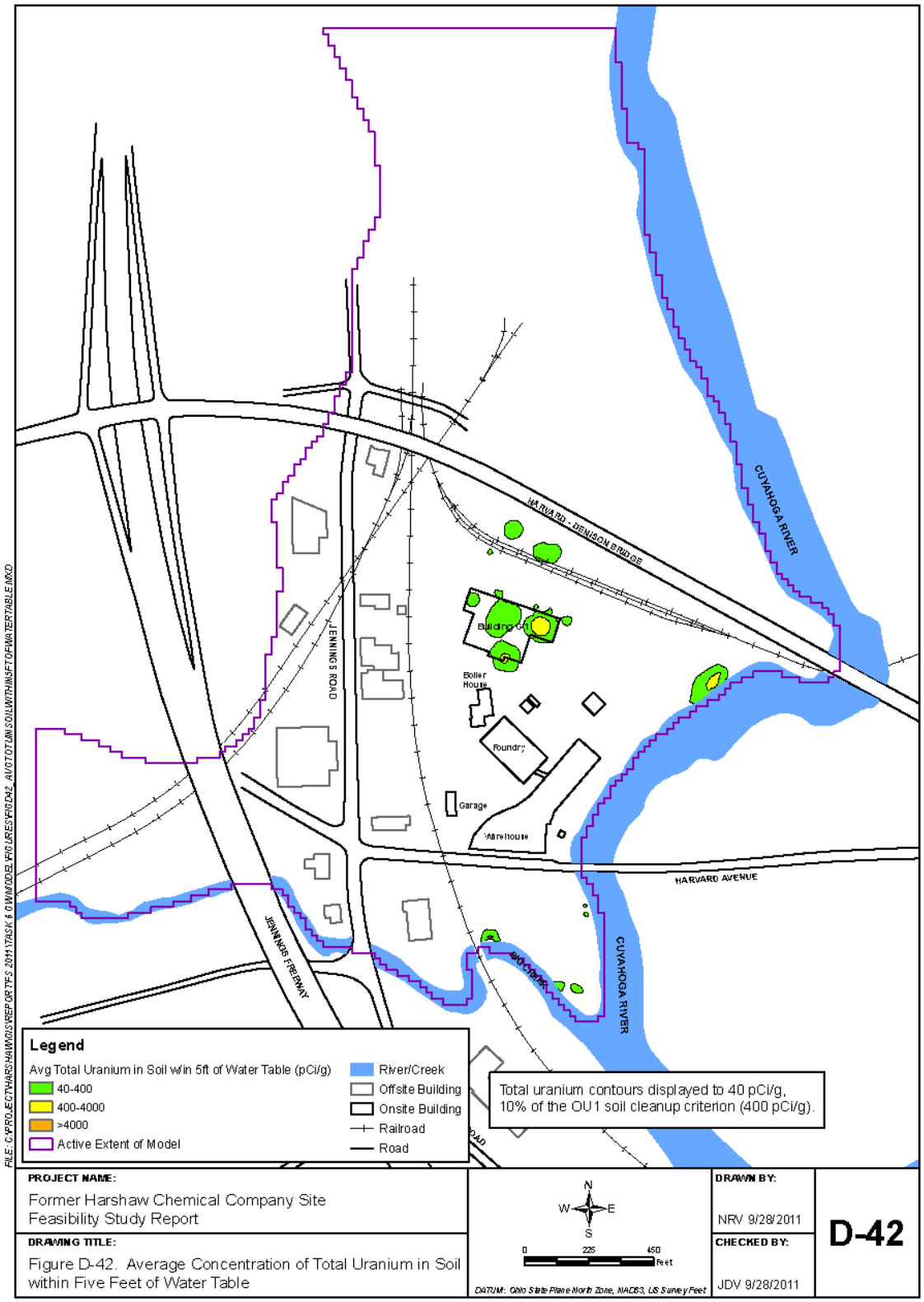

Figure D-42. Average Concentration of Total Uranium in Soil within 5 ft of Water Table

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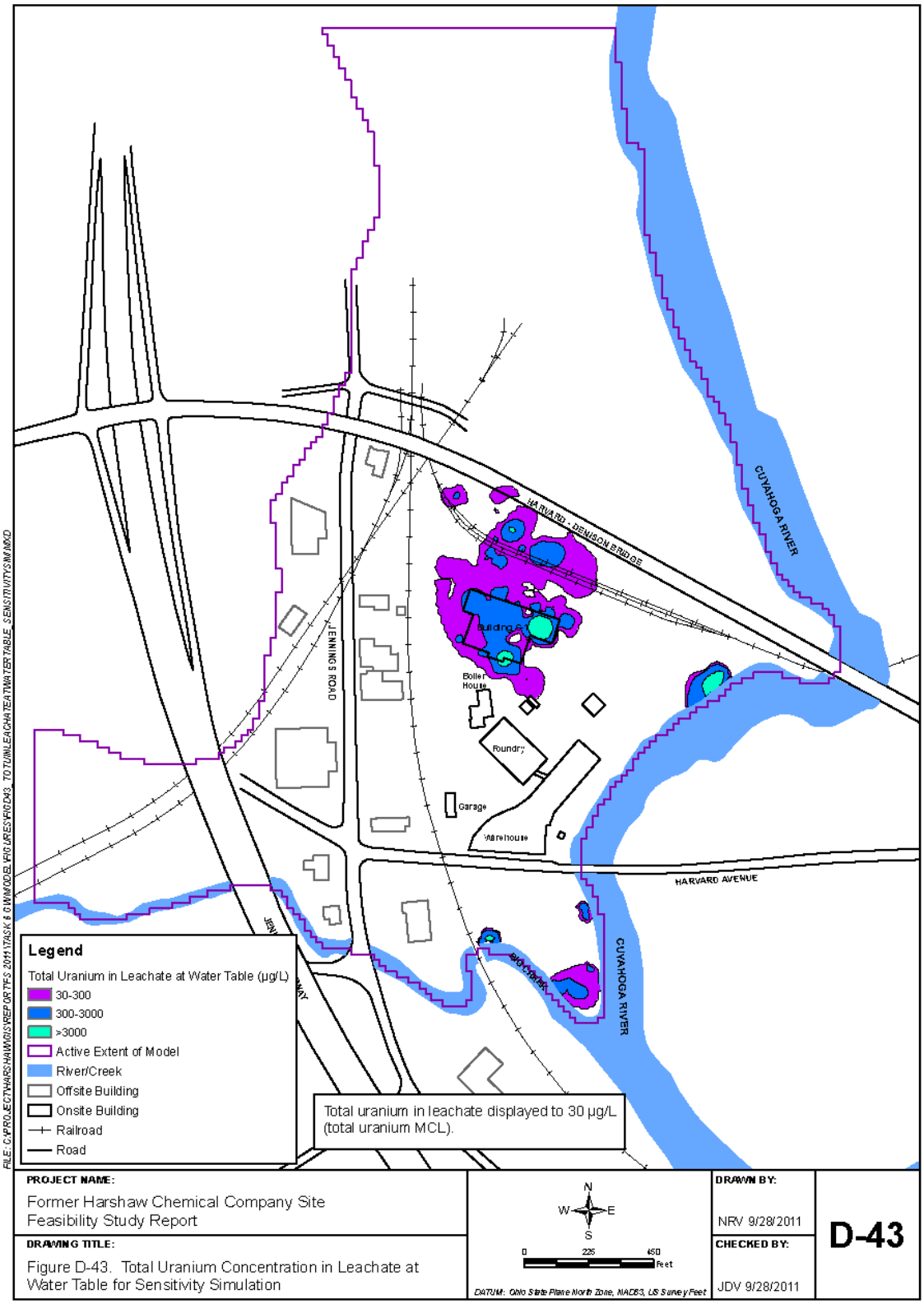

Figure D-43. Total Uranium Concentration in Leachate at Water Table for Sensitivity Simulation

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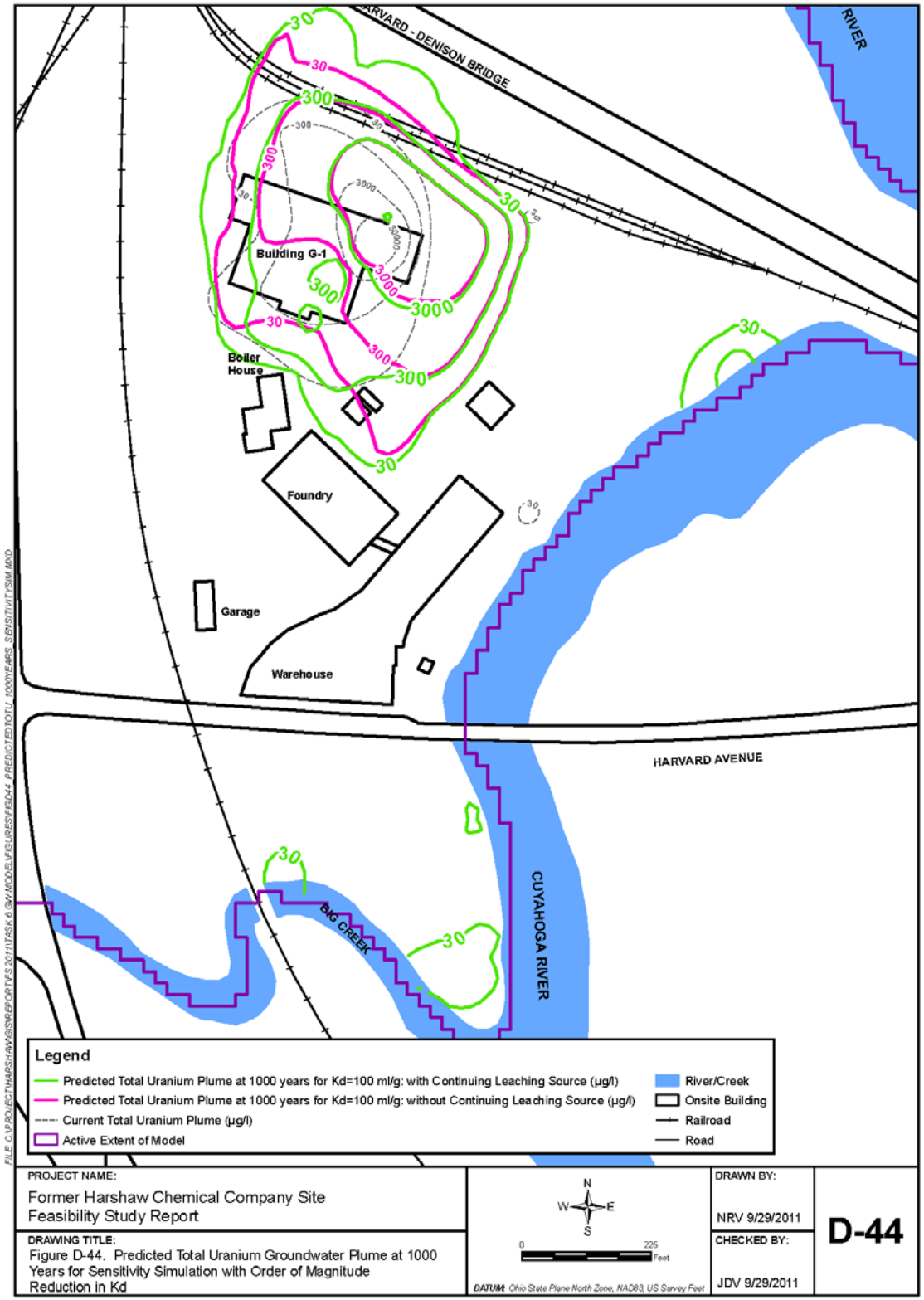

Figure D-44. Predicted Total Uranium Groundwater Plume at 1,000 Years for Sensitivity Simulation with Order of Magnitude Reduction in K_d

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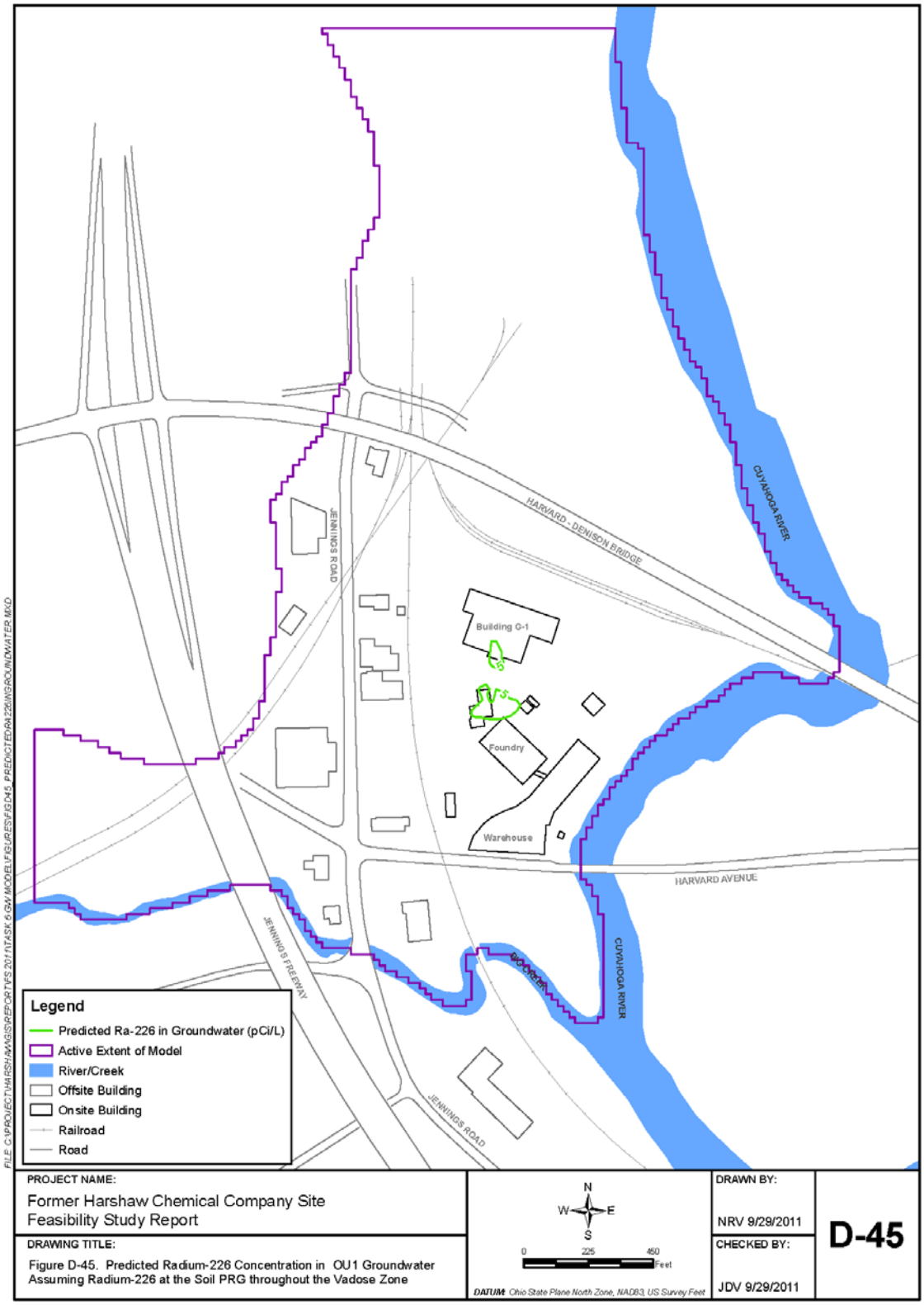

Figure D-45. Predicted Radium-226 Concentration in OU1 Groundwater Assuming Radium-226 at the Soil PRG throughout the Vadose Zone

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Attachment 1

Equilibrium Distribution Coefficients for Predictive Modeling

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2.2 THORIUM D1-4
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ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms Per Liter
ASTM	American Society for Testing and Materials
BGS	below ground surface
CEC	Cation Exchange Capacity
Ci/g	Curies Per Gram
Cs	Concentration in Soil
Cw	Concentration in Water
Eh	Oxidation-Reduction Potential
ft	Feet
FS	Feasibility Study
g	Gram
g/mole	Grams Per Mole
IA	Investigative Area
K_d	Equilibrium Distribution Coefficient
L/kg	Liters Per Kilogram
MCL	Maximum Contaminant Level
MED	Manhattan Engineer District
meq	Milliequivalent
mg/kg	Milligrams Per Kilogram
mg/L	Milligrams Per Liter
mL/g	Milliliters Per Gram
mV	Millivolt
pCi/µg	picoCuries per Microgram
pCi/g	picoCuries per Gram
pCi/L	picoCuries per Liter
Ra-222	Radium-222
Ra-226	Radium-226
R_f	Retardation Factor
RI	Remedial Investigation
Th-230	Thorium-230
Th-232	Thorium-232
U-235	Uranium-235
U-238	Uranium-238
USEPA	United States Environmental Protection Agency

1. INTRODUCTION

The affinity of uranium, radium, and thorium to sorb to soil at the Former Harshaw Chemical Company Site must be assessed to support the Harshaw site Feasibility Study (FS). This information is used in predicting potential impacts to groundwater from residual contamination for the various FS alternatives. It is also used in assessing whether soil remediation goals are protective of groundwater. Sorption of contaminants to geologic media at environmental sites is characterized using equilibrium distribution coefficients (K_d). This attachment provides a discussion of K_d development for the Harshaw site.

The K_d is independent of the isotopic form of a given element; it is a function instead of the molecular form and interactions with the environment. Thus, for example, a single thorium K_d will be developed which will then be used for both thorium-230 and thorium-232.

In general, K_d values are developed for contaminated sites using a combination of literature and available site-specific data. Literature data are presented first in this attachment to provide a context for the subsequent discussion of available site-specific data. The literature discussion establishes the following key points:

- Uranium mobility depends upon valence state, with U(IV) immobile and U(VI) potentially mobile. The U(VI) K_d is most dependent upon pH, mineralogy, and carbonate concentration.
- The thorium K_d is most dependent on pH, with thorium relatively immobile at near-neutral pH. Thorium precipitates at concentrations above the Harshaw site thorium background.
- The radium K_d (for which limited data exists) can be assessed using strontium as a surrogate and is most dependent upon pH and cation exchange capacity (CEC) (clay content).

The discussion of site-specific data, which follows the literature discussion, establishes K_d recommendations for uranium, thorium, and radium based on data including observed soil and groundwater concentrations and groundwater conditions such as oxidation-reduction potential (Eh) and pH.

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2. LITERATURE DATA

2.1 URANIUM

The mobility of uranium in the subsurface is dependent first upon the valence state of uranium (USEPA 1999). U(IV) compounds prevail under very low oxygen conditions and are relatively immobile due to precipitation from solution. When uranium is present as U(IV), an arbitrarily large K_d can be assigned to simulate its lack of mobility in groundwater.

Under aerobic conditions, U(VI) compounds dominate. U(VI), in contrast to U(IV), has a broad range of mobility which is dependent on several factors. In a large scale analysis of K_d values collected for U(VI) in multiple media, the United States Environmental Protection Agency (USEPA) (1999) concluded that pH, mineralogy, and dissolved carbonate concentrations are the most important factors influencing the sorption behavior of U(VI). The impact of each of these factors upon U(VI) sorption is described by USEPA (1999) as follows:

- Sorption of U(VI) by soil and single-mineral phases is low at pH values less than 3, increases rapidly with increasing pH from pH 3 to 5, reaches a maximum in adsorption in the pH range from pH 5 to 8, and then decreases with increasing pH values greater than 8.

- Sorption of U(VI) is greater for soil containing larger percentages of iron oxide minerals and mineral coatings and/or clay minerals, and less for soil dominated by quartz and feldspar minerals.

- Sorption of U(VI) at neutral to alkaline (high) pH conditions decreases with increasing dissolved carbonate concentration.

Table 1 provides U(VI) K_d ranges based on pH. For any given pH, the U(VI) K_d values vary over a large range (generally three to six orders of magnitude).

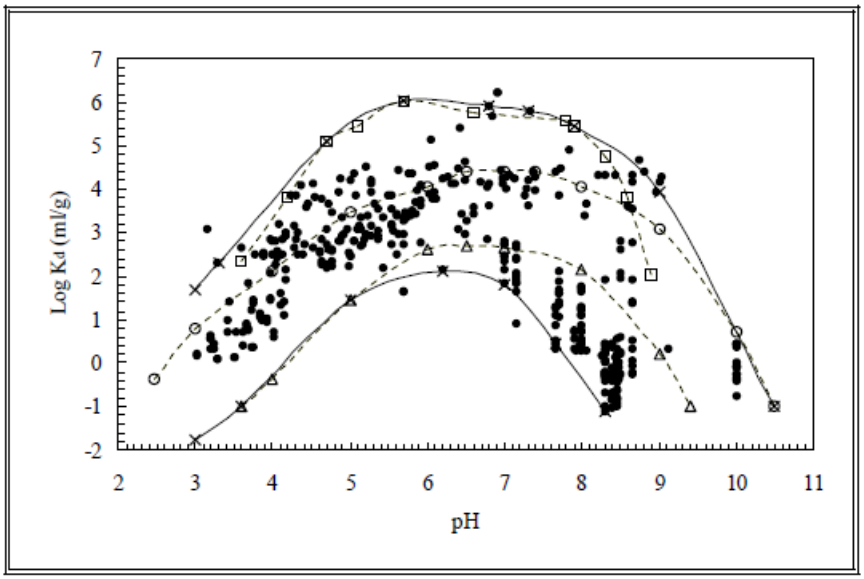
Table 1. U(VI) K_d Ranges Based on pH

	pH							
K_d (mL/g)	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Minimum	<1	0.4	25	100	63	0.4	<1	<1
Maximum	32	5,000	16,000	1,000,000	630,000	250,000	7,900	5

Source: United States Environmental Protection Agency 1999.
K_d = Equilibrium Distribution Coefficient
mL/g = Milliliters Per Gram

The data from which Table 1 was developed are displayed in Figure 1, which plots log(K_d) versus pH. The open triangles and the connecting dashed line at/near the bottom of the dataset represent K_d values for quartz over a range of pH conditions. These provide a lower bound for most of the K_d dataset, with the K_d measurements occurring below this line derived from Hanford sediment, which have significant quantities of quartz and feldspar. The open squares and circles (also connected by dashed lines, which together bound the high K_d end of the dataset) represent K_d values for ferrihydrite and kaolinite (a clay mineral) over a range of pH conditions. Between these single mineral phase extremes lie most of the data for soil and rock material. For a pH between 6.5 and 7.0 (consistent with the Harshaw site groundwater), most of these data fall within the log(K_d) range of 3 to 4 (K_d of 1,000 to 10,000 mL/g). These considerations narrow the likely U(VI) K_d range expected at the Harshaw site relative to the four order of magnitude range at neutral pH suggested in Table 1. The Harshaw site unconsolidated soil are varied mineralogically (containing clay minerals, quartz,

feldspar), and therefore are also expected to fall in the middle range of uranium K_d data defined by most of the soil and rock data in the USEPA study.



Source: United States Environmental Protection Agency 1999.

Figure 1. U(VI) K_d Values Used for Development of Table 1

2.2 THORIUM

In the same study cited above for uranium, USEPA compiled data for multiple K_d analyses for thorium. This study concluded that:

- Thorium sorption occurs at concentrations less than 1E-9 M, while precipitation occurs above 1E-9 M; and

- Thorium sorption can be estimated directly by soil pH.

For thorium concentrations below 1E-9M and for pH between 4 and 8, K_d can be estimated by the following equation:

$$\text{Log (Th } K_d) = -0.13 + 0.69(\text{pH})$$

Using a molecular weight of 520 g/mol [molecular weight of dominant aqueous thorium species, $Th(HPO_4)_3^{2-}$], 1E-9 M corresponds to 0.52 µg/L. Using a specific activity of 2.2E-7 Ci/g for naturally occurring thorium, 0.52 µg/L is equivalent to 0.11 pCi/L. Thus the thorium solubility limit of 1E-9M [based on the solubility of $Th(OH)_4$ at pH 5.5] corresponds to 0.11 pCi/L.

Background concentrations for thorium-230, thorium-230 (dissolved), thorium-232, and thorium-232 (dissolved) in groundwater at the Harshaw site are 0.42, 0.72, 0.057, and 0.0 pCi/L, respectively (Table 8-7 of SAIC 2009). Accounting for local variation in pH and geochemical parameters, if thorium is expected to precipitate at 0.11 pCi/L, then thorium in the Harshaw site groundwater is at its solubility limit. Additional loading of thorium into the system due to anthropogenic sources would not increase its concentration in groundwater.

Near or below the thorium background concentration (i.e., the thorium solubility limit), the thorium K_d is estimated to be 27,000 mL/g, using the preceding thorium versus pH regression equation and a site-specific pH of 6.6. This pH represents the mean of all pH readings in site monitoring wells under equalized conditions during sampling and well development from a dataset including Remedial Investigation (RI) Phases 1 and 2, and 2008-2010 annual monitoring events.

2.3 RADIUM

In an analysis of available data, USEPA (2004) determined that insufficient data were available to develop reliable data ranges or generate lookup tables for radium. However, USEPA expects that radium sorption affinities for various media will be somewhat greater than that of strontium, for which extensive studies and data exist. Table 2 provides a K_d lookup for strontium based on pH and CEC/clay content. At near-neutral pH and clay content by weight at or above 20% (conditions consistent with the Harshaw site), a strontium K_d of 200 to 1600 mL/g is predicted, with radium sorption expected to be somewhat greater.

Table 2. K_d values for Strontium[1] based upon pH and CEC/Clay Content

	CEC (meq/100g) / Clay content (wt.%)								
	3 / <4			**3 – 10 / 4 – 20**			**10 – 50 / 20 - 60**		
	pH			**pH**			**pH**		
K_d (mL/g)	**<5**	**5 - 8**	**8 - 10**	**<5**	**5 - 8**	**8 – 10**	**<5**	**5 - 8**	**8 - 10**
Minimum	1	2	3	10	15	20	100	200	300
Maximum	40	60	120	150	200	300	1,500	1,600	1,700

[1]Strontium is used here as a surrogate for radium.
Source: United States Environmental Protection Agency 1999
CEC = Cation Exchange Capacity
g = Gram
K_d = Equilibrium Distribution Coefficient
meq = milliequivalent
mL/g = Milliliters Per Gram

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3. SITE-SPECIFIC DATA

3.1 URANIUM

As stated earlier in the literature data discussion, the mobility of uranium in the subsurface is dependent first upon the valence state of uranium. U(IV) precipitates from solution and is therefore relatively immobile, while U(VI) remains in solution and has a wide potential mobility range. MINTEQA2 modeling conducted for the RI (SAIC 2009) indicated that Eh was the primary driver governing the valence state of uranium at the Harshaw site. Groundwater well-specific MINTEQA2 modeling of August 24th, 2004, geochemical data predicted the following uranium valence states moving southeast from Building G-1 (a primary uranium release area) downgradient to the Cuyahoga River (Figure 2 presents the well locations):

- **BKA-48:** At an Eh of -19 millivolts (mV), uranium is predicted to be present in the immobile U(IV) valence state at BKA48.

- **RMW-38:** At an Eh of 5 mV, uranium is predicted to be speciated equally between the immobile U(IV) valence state and the potentially mobile U(VI) state.

- **DM-27R:** At an Eh of 163 mV, uranium is predicted to be present entirely in the potentially mobile U(VI) state.

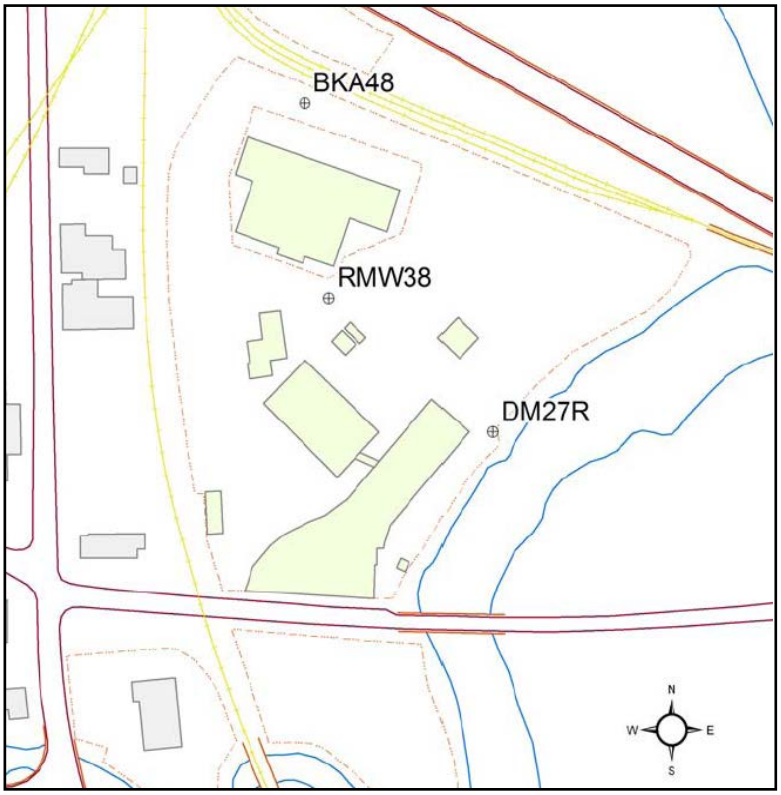

Figure 2. Well Locations used for Well-Specific MINTEQA2 Modeling

However, a review of all currently available Eh data for Harshaw (Table 3) reveals the Eh results from the August 2004 sampling event (from which Eh values were drawn for the well-specific MINTEQA2 modeling) are generally low with respect to the remaining sampling events. Ignoring the August 2004 event, the Harshaw site Eh results still exhibit temporal and spatial variability. Nonetheless, these results generally exceed 100 mV site-wide. For clarity, results in Table 3 that are between 0 and 100 mV are bordered by bold lines, while negative results are shaded gray. Uranium is predicted to be present entirely as U(VI) above an Eh of roughly 100 mV (the MINTEQA2 Eh sensitivity analysis conducted for the RI identified a transition point between an Eh of 56 and 135 mV). Thus, it is reasonable to conclude from available Eh data (neglecting the August 2004 Eh dataset) and previous MINTEQA2 speciation modeling that uranium is generally present site-wide as potentially mobile U(VI) and not as immobile U(IV). Consistent with this conclusion, dissolved oxygen results are generally near or above 0.5 mg/L site-wide, also indicating an oxidizing environment (Jurgens, et al., 2009) favoring U(VI) over U(IV).

Table 3. Harshaw Site Eh Results

	Eh (mV)							
Well ID	**May/June 2003**	**July 2003**	**Aug/Sept 2003**	**Nov 2003**	**Aug 2004**	**Aug 2008**	**Aug 2009**	**June 2010**
BKA-48	348	176	-	-	-19	283	486	315
BKA-51	253	-	-	-	-	-	-	-
BKA-52	255	-	-	-	-	-	-	-
BKA-53	173	195	-	-	-1	79	-	-
BKG-MW0001	-	-	-	209	130	-	-	-
BKG-MW0002	-	-	-	224	317	-	-	-
BKG-MW0003	-	-	-	250	107	320	-	-
BKG-MW0004	-	-	-	181	-62	-	-	-
BKG-MW0005	-	-	-	154	-33	-	-	150
CDT-MW0001	-	-	208	-	31	-	-	-
CDT-MW0002	-	-	223	-	206	-	-	-
DM-1	383	99	-	-	-	-	-	-
DM-3	367	-	-	-	-	-	-	-
DM-4	359	-	-	-	-	-	-	-
DM-5	309	-	100	-	-	-	-	-
DM-9	389	-	-	-	119	-	-	-
DM-10	329	-	-	-	-	-	-	-
DM-11	284	-	-	-	185	-	-	-
DM-12	198	142	-	-	-	-	-	-
DM-14	353	-	433	-	-	-	-	143
DM-15	182	-	-	-	128	112	-	144
DM-22R	220	190	-	-	-	-	-	-
DM-23R	197	-	-	-	91	-	-	87
DM-25R	115	215	-	-	120	-	-	-
DM-26	312	-	-	-	80	-	-	-
DM-27R	442	-	92	-	163	-	-	-
DM-28R	302	123	-	-	-92	-	-	-
DM-29R	250	-	-	-	114	156	-	-
DM-30R	210	-	175	-	113	-	-	-

Table 3. Harshaw Site Eh Results (continued)

Well ID	Eh (mV)							
	May/June 2003	July 2003	Aug/Sept 2003	Nov 2003	Aug 2004	Aug 2008	Aug 2009	June 2010
ERM-47	200	-	230	-	-	-72	-	-
IA03-TP0001	-	-	-	-	-15	-	-	-
IA03-TW0001	-	-	-	-	-	287	451	304
IA03-TW0002	-	-	-	-	253	-	491	-
IA03-TW0004	-	-	-	-	120	83	-	-
IA03-TW0005	-	-	-	-	154	-	-	-
IA03-TW0006	-	-	-	-	144	-	-	-
IA04-TP0001	-	-	-	-	375	281	394	387
IA04-TP0002	-	-	-	-	-19	-	-	-
IA04-TP0003	-	-	-	-	-12	-	-	-
IA04-TP0004	-	-	-	-	58	193	145	177
IA04-TP0005	-	-	-	-	-56	169	-	-
IA04-TW0004	-	-	-	-	-94	162	-	-
IA10-MW0001	-	-	-	220	108	-23	-30	25
IA10-MW0002	-	-	-	229	-41	164	-	157
IA10-MW0003	-	-	-	-	192	310	-	-
IA10-MW0004	-	-	-	309	-56	269	458	243
IA10-MW0005	-	-	-	-	-	-	270	174
IA10-MW0007	-	-	-	-	-	-	167	221
IA10-MW0008	-	-	-	-	-	-	-	293
IA10-MW0014	-	-	-	-	-	-	-	127
IA10-MW0017	-	-	-	-	-	-	-	356
IA10-MW0018	-	-	-	-	-	-	-	282
RMW-35	309	-	-	-	156	-	-	-
RMW-38	373	215	-	-	5	224	175	236
RMW-39	317	-	-	-	-	-	-	-

= Eh results less than 0 mV

= Eh results between 0 and 100 mV

"-" = Eh data not collected

Note: Eh values calculated from field ORP values plus 200 mV (assumes field instrumentation uses Ag/AgCl, 4 M KCl reference electrode).

Eh = Oxidation-Reduction Potential

mV = Millivolt

Given that uranium is expected to be speciated primarily, if not entirely, as potentially mobile U(VI), site-specific U(VI) sorption must be considered. In the remaining discussion, references to uranium are specifically to U(VI). The affinity of uranium to sorb to the Harshaw site soil was assessed in the RI (SAIC 2009) using American Society for Testing and Materials (ASTM) test method D4646-87. Three native soil samples were analyzed and results ranging from 6.8 to 29.5 mL/g are presented as the K_d in the RI (Table 7-9 of SAIC 2009). However, the test method used yields a 24-hour distribution ratio (24-h Rd) rather than an *equilibrium* distribution coefficient (K_d), as indicated in the following excerpt from Section 5 of ASTM Test Method D4646-87 (ASTM 1987):

"This test method is meant to allow for a rapid (24-h) index of a geomedia's sorption affinity for given chemicals …. A large number of samples may be run … to determine a comparative ranking of those samples….Due to this time constraint, the final (24-h) concentration should not be confused with that of an equilibrium or steady-state concentration."

Since the method involves contacting chemical-containing water with clean soil and net movement is thus from the aqueous to the sorbed phase, the concentration in water (Cw) will be higher and the concentration in soil (Cs) will be lower under non-equilibrium than under equilibrium conditions. Thus, if equilibrium is not reached during the 24-hour test period, the 24-h Rd (24-h Cs/Cw) will underestimate the K_d (equilibrium Cs/Cw). Consistent with this, the 24-h Rd values fall at the low end of the uranium K_d ranges from literature data.

Evaluating the total uranium 24-h Rd values (Table 7-9 of SAIC 2009) against site-specific total uranium background values (both of which were developed using native soil) highlights the point that the 24-h Rd values underestimate uranium K_d for the Harshaw site. In industrial soil background samples [0-13 ft (0-4 m) collected immediately west of the Harshaw site, the mean total uranium is 5.5 mg/kg. An expected groundwater background value in equilibrium with the soil can be estimated from Cs/K_d. If the 24-h Rd (~10 mL/g) is treated as K_d, then the expected groundwater background concentration would be approximately 0.55 mg/L (Cs divided by K_d, or 5.5 mg/kg divided by ~10 L/kg). However, this is over 300 times greater than the total uranium groundwater background of 0.0016 mg/L, which was developed from groundwater samples co-located with the soil background samples. This clearly illustrates that the uranium 24-h Rd values in the RI should not be treated as K_d values.

In addition, the "expected" groundwater background of 0.55 mg/L calculated above for illustration exceeds the total uranium maximum contaminant level (MCL) of 0.03 mg/L by a factor of ~20. Thus, if the 24-h Rd's (Table 7-9 of SAIC 2009) are treated as K_d values, groundwater at the entire Harshaw site would be expected to exceed the total uranium MCL by 20 times due solely to background total uranium in soil. Accordingly, the total uranium 24-h Rd values provide only a lower bound on the K_d, and should not be treated as a K_d for predictive modeling.

In the absence of laboratory-derived site-specific K_d values, field-derived K_d values were developed from co-located groundwater and soil samples. If these co-located samples are assumed to be in equilibrium with one another, then K_d can be estimated from the Cs divided by the concentration in water (Cs/Cw). At a number of Harshaw site locations, soil samples were first collected prior to installing monitoring wells. These include five industrial background locations west of the Harshaw site and four locations in Investigative Area (IA)-10. Table 4 presents these co-located well and boring pairs. At all of these locations the deepest soil sample is approximately 8-10 ft (2.4-3 m) below ground surface (BGS), coinciding with the upper portion of the well screened interval. Thus, it is reasonable to assume that groundwater and soil sample pairs taken at these locations are in equilibrium, and Cs/Cw can then be used to estimate K_d. These co-located well and boring pairs occur both in the old fill and in the native overburden units, as shown in Table 4. The field-derived K_d will be examined for differences that may be attributable to differing overburden units.

Uranium is expected to be present as U(VI) at these co-located well and boring pairs (and site-wide in general) based on previously-discussed Eh data and the MINTEQA2 modeling from the RI. Therefore, from a uranium valence state standpoint, field-derived U(VI) K_d values can be developed from these locations and extended to site-wide U(VI) fate and transport.

Table 4. Co-located Monitoring Well and Soil Boring Pairs

Monitoring Well	Soil Boring	Overburden Unit of Deepest Soil Sample
BKG-MW0001	BKG-SB0002	Old Fill
BKG-MW0002	BKG-SB0005	Old Fill
BKG-MW0003	BKG-SB0008	Old Fill
BKG-MW0004	BKG-SB0011	Old Fill
BKG-MW0005	BKG-SB0014	Old Fill
IA10-MW0001	IA10-MW0001	Native
IA10-MW0002	IA10-MW0002	Native
IA10-MW0003	IA10-MW0003	Native
IA10-MW0004	IA10-MW0004	Old Fill

The soil uranium results for the co-located well and boring pairs are presented in Table 5. Total uranium results are calculated from isotopic results for uranium-235 (U-235) and uranium-238 (U-238), with the latter being the overwhelming driver (consistent with RI total uranium calculations, uranium isotopes are assumed to be present in naturally occurring proportions; the formulas used to calculate soil total uranium appear in the footnote to Table 5). For the four IA10 locations and one background location (BKG-SB0005), U-235 and U-238 are both non-detect ("U" qualified). Using a total uranium Cs value calculated from non-detect isotopic results may overestimate the term Cs/Cw, which would provide a non-conservative field-derived total uranium K_d. Therefore, these locations were not used to develop the Cs/Cw term. For the remaining four background locations (BKG-SB0002, -SB0008, -SB0011, -SB0014), U-238 was detected and the calculated total uranium value in soil was used to derive field K_d values from Cs/Cw.

Table 5. Uranium Results in Soil at Stations where Monitoring Wells were Subsequently Installed

Station	Top Depth (ft)	Bottom Depth (ft)	Parameter	Result (pCi/g)	Data Qualifier
BKG-SB0002	7.7	9.7	Total Uranium	3.94	
	7.7	9.7	U-235	0.06	U
	7.7	9.7	U-238	1.93	
BKG-SB0005	8	10	Total Uranium	3.03	
	8	10	U-235	0.21	U
	8	10	U-238	1.48	U
BKG-SB0008	8	10	Total Uranium	3.60	
	8	10	U-235	0.09	J
	8	10	U-238	1.76	
BKG-SB0011	8	10	Total Uranium	3.58	
	8	10	U-235	0.13	
	8	10	U-238	1.75	
BKG-SB0014	7.5	9.5	Total Uranium	4.03	
	7.5	9.5	U-235	0.16	U
	7.5	9.5	U-238	1.97	J
IA10-MW0001	8	10	Total Uranium	4.34	
	8	10	U-235	-0.01	U
	8	10	U-238	2.12	U
IA10-MW0002	8	10	Total Uranium	5.14	
	8	10	U-235	0.30	U
	8	10	U-238	2.51	U
IA10-MW0003	8	10	Total Uranium	3.71	
	8	10	U-235	-0.14	U
	8	10	U-238	1.81	U
IA10-MW0004	8	10	Total Uranium	4.06	
	8	10	U-235	0.75	U
	8	10	U-238	1.99	U

Note: Consistent with RI methods, total uranium values were calculated from isotopic gamma spectroscopy analyses under the assumption that uranium feed material processed at the site during historical operations was natural, non-enriched uranium. The following formulas were used, with all units pCi/g:

1) If neither U-238 nor U-235 results are qualified, then:
   total uranium = (U-238 * 2.0) + U-235
2) If U-235 is non-detect or estimated ("U" or "J" qualified), or if both U-238 and U-235 are non-detects ("U" qualified), then:
   total uranium = (U-238 * 2.0) + (U-238 * 0.046)

ft = Feet
pCi/g = PicoCuries Per Gram
U-235 = Uranium-235
U-238 = Uranium-238

For the four monitoring well locations corresponding to BKG-SB0002, -SB0008, -SB0011, -SB0014, (BKG-MW0001, -MW0003, -MW0004, and -MW0005, respectively), Table 6 presents the total uranium results in groundwater over time. For these wells, non-detects ("U" flagged results) have a zero result assigned in the Harshaw database, and these records are therefore excluded from Table 6. The results presented in Table 6 have no qualifiers in the Harshaw database. Two of the date-specific results in Table 6 represent averages of duplicate analyses for that date, and the remaining date-specific results represent a single analysis for that date. Average concentrations are calculated for both total uranium and total uranium (dissolved) for each

well. The maximum of these two averages is presented in the rightmost column. Use of the maximum as Cw will tend to underestimate the term Cs/Cw, providing a conservative field-derived uranium K_d.

Table 6. Uranium Results in Groundwater at Monitoring Wells Co-located with Selected Soil Stations

Station	Parameter	Total Uranium Concentration in Groundwater (µg/L)					
		Nov 2003	**Aug 2004**	**Aug 2008**	**Aug 2009**	***Average***	***Max of Averages***
BKG-MW0001	Tot U	1.31	0.797			*1.05*	*1.05*
	Tot U (dissolved)	1.38	0.668			*1.02*	
BKG-MW0003	Tot U	6.84	4.34	5	5.19	*5.34*	*6.18*
	Tot U (dissolved)	6.7	5.65			*6.18*	
BKG-MW0004	Tot U	0.481	0.855			*0.67*	*0.67*
	Tot U (dissolved)	0.47	0.431			*0.45*	
BKG-MW0005	Tot U	0.3965				*0.40*	*0.40*
	Tot U (dissolved)	0.282				*0.28*	

µg/L = Micrograms Per Liter

Table 7 presents the total uranium results for co-located groundwater and soil sample pairs (Tables 5 and 6) and the calculated Cs/Cw for these sample pairs. The Cs/Cw values are presented graphically in Figure 3. The Cs/Cw values range from 855 to 15,000 mL/g. Because lower K_d values will provide more conservative predictions of contaminant transport, it is recommended that a value near the low end of this Cs/Cw range be selected to use as the K_d. Given the uncertainty in these estimates, an order of magnitude value of 1,000 mL/g is recommended. This is consistent with literature data, which ranges from roughly 100 to 1,000,000 mg/L at the near-neutral pH conditions present at the Harshaw site. Moreover, closer consideration of that literature data had narrowed the likely range to 1,000 to 10,000 mL/g. Thus, the field-derived U(VI) K_d values for the Harshaw site are conservatively near the lower end of the expected range from literature data.

Since all of the field-derived uranium K_d values in Table 7 and Figure 3 are developed from soil samples taken in the old fill, a comparison of field-derived K_d values across the overburden units is not possible. However, given the generally similar overall composition of the overburden units (glacial tills, whether reworked or not), it is reasonable to assume similar K_d values across the overburden units. During vadose and saturated zone transport simulations, sensitivity simulations with varying K_d values will be conducted to examine the effect upon transport predictions.

Table 7. Field-Derived Uranium K_d from Co-located Groundwater and Soil Sample Pairs

Parameter	Soil Station	Cs[1] (pCi/g)	Co-located Monitoring Well	Cw[2] (µg/L)	Cw (pCi/L)[3]	K_d as Cs/Cw (mL/g)	Overburden Unit of Soil Sample
Total Uranium	BKG-SB0002	3.94	BKG-MW0001	1.05	0.72	5,500	Old Fill
	BKG-SB0008	3.60	BKG-MW0003	6.18	4.21	855	Old Fill
	BKG-SB0011	3.58	BKG-MW0004	0.67	0.45	7,900	Old Fill
	BKG-SB0014	4.03	BKG-MW0005	0.40	0.27	15,000	Old Fill

[1] Cs = concentration in soil
[2] Cw = concentration in water
[3] Groundwater concentrations are converted from units of µg/L to pCi/L using the specific activity of naturally-occurring uranium (0.681 pCi/µg)
µg/L = Micrograms Per Liter
K_d = Equilibrium Distribution Coefficient
mL/g = Milliliters Per Gram
pCi/µg = PicoCuries Per Microgram
pCi/L = PicoCuries Per Liter

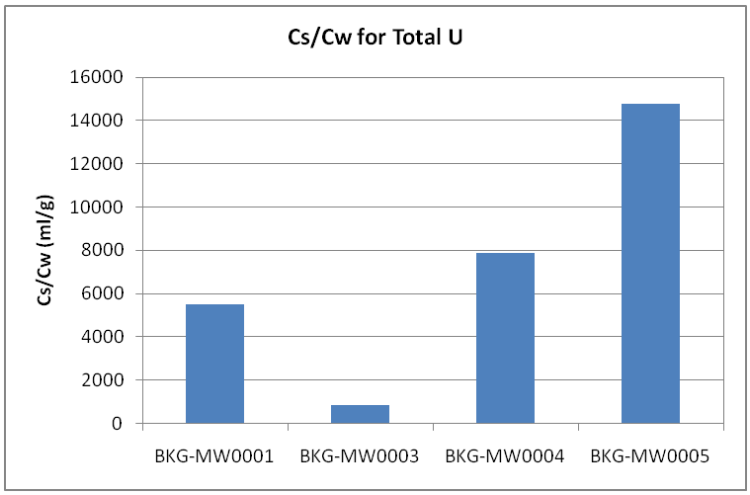

Figure 3. Field-Derived Uranium K_d from Co-located Groundwater and Soil Sample Pairs

3.2 THORIUM

Site-specific tests have not been conducted to assess the affinity of thorium to sorb to the Harshaw site soil. As previously discussed, the thorium solubility limit is roughly equal to the thorium background. As a result, additional loading of thorium into the system would not increase the concentration in groundwater (since precipitation would result). However, to supplement this literature information, a similar approach was followed as with uranium. Namely, field-derived thorium K_d values were developed from Cs/Cw for co-located groundwater and soil samples.

The soil thorium results for these co-located samples are presented in Table 8. Thorium-230 is non-detect ("U" qualified) for the four IA10 locations. Using a non-detect Cs value may overestimate the term Cs/Cw, which would provide a non-conservative indication of the thorium K_d. Therefore, these locations were not used to develop the term Cs/Cw. The remaining locations were used to develop the term Cs/Cw in order to provide an indication of the thorium K_d.

Table 8. Thorium Results in Soil at Stations where Monitoring Wells were Subsequently Installed

Station	Top Depth (ft)	Bottom Depth (ft)	Parameter	Method	Result (pCi/g)	Qual
BKG-SB0002	7.7	9.7	Th-230	EML HASL 300, 4.5.2.3	1.01	
	7.7	9.7	Th-232	GSS	1.27	
BKG-SB0005	8	10	Th-230	EML HASL 300, 4.5.2.3	1.57	
	8	10	Th-232	GSS	1.29	
BKG-SB0008	8	10	Th-230	EML HASL 300, 4.5.2.3	1.34	
	8	10	Th-232	GSS	1.13	
BKG-SB0011	8	10	Th-230	EML HASL 300, 4.5.2.3	1.34	
	8	10	Th-232	GSS	1.49	
BKG-SB0014	7.5	9.5	Th-230	EML HASL 300, 4.5.2.3	1.41	
	7.5	9.5	Th-232	GSS	1.47	
IA10-MW0001	8	10	Th-230	GSS	3.27	U
	8	10	Th-232	GSS	1.32	
IA10-MW0002	8	10	Th-230	GSS	-0.21	U
	8	10	Th-232	GSS	1.35	
IA10-MW0003	8	10	Th-230	GSS	3.70	U
	8	10	Th-232	GSS	1.18	
IA10-MW0004	8	10	Th-230	GSS	5.22	U
	8	10	Th-232	GSS	1.12	

ft = Feet
pCi/g = PicoCuries Per Gram
Th-230 = Thorium-230
Th-232 = Thorium-232

Table 9 presents the thorium results in groundwater over time for the monitoring well locations corresponding to the soil stations in Table 8. For the four IA10 monitoring wells, only thorium-232 and not thorium-230 results are presented, consistent with the preceding discussion regarding excluding thorium-232 from calculation of the Cs/Cw term for these four locations. The majority of thorium results in Table 9 are non-detect. Using a non-detect Cw value may underestimate the term Cs/Cw, which would provide a conservative indication of the thorium K_d. Therefore, these locations were retained to develop field-derived K_d values. Average concentrations are calculated for thorium-230, thorium-230 (dissolved), thorium-232, and thorium-232 (dissolved) for each well. The maximum of these two averages is presented in the rightmost column. Use of the maximum as Cw tends to underestimate the term Cs/Cw, which provides a conservative thorium K_d.

Table 9. Thorium Results in Groundwater at Monitoring Wells Co-located with Selected Soil Stations

Station	Parameter	Thorium Concentration in Groundwater (pCi/L)						
		Nov 2003	Aug 2004	Jul 2007	Aug 2008	Aug 2009	Average	Maximum of Averages
BKG-MW0001	Th-230	0.206 U	0.511 U	0.181 U			0.299	0.299
	Th-230 (diss.)	0.0995 U	0.47 U	0.3 J			0.290	
	Th-232	0.00035 U	0.229 U	0.034 U			0.088	0.117
	Th-232 (diss.)	0.0559 U	0.238 U	0.058 U			0.117	
BKG-MW0002	Th-230	1.04 U	0.531 U	0.42 J			0.664	0.664
	Th-230 (diss.)	0.124 U	0.65 U	0.115 J			0.296	
	Th-232	0.112 U	-0.0727 U	0.042 U			0.027	0.027
	Th-232 (diss.)	0.0084 U	-0.381 U	0.016 U			-0.119	
BKG-MW0003	Th-230	0.27 U	0.315 U	0.124 J	0.0819 U	-0.00736	0.157	0.262
	Th-230 (diss.)	0.727 U	-0.136 U	0.196 J			0.262	
	Th-232	0.0887 U	-0.0145 U	0.042 U	-0.0075 U	-0.00025	0.022	0.023
	Th-232 (diss.)	0.0413 U	-0.0189 U	0.046 U			0.023	
BKG-MW0004	Th-230	0.431 U	0.266 U				0.349	0.907
	Th-230 (diss.)	1.25 U	0.563 U				0.907	
	Th-232	-0.0017 U	0 U				-0.001	0.166
	Th-232 (diss.)	0.187 U	0.144 U				0.166	
BKG-MW0005	Th-230	0.355 U	0.456 U	0.096 J			0.302	0.382
	Th-230 (diss.)	0.3265 U	0.721 J	0.099 J			0.382	
	Th-232	0.0462 U	0.28 U	0.057 J			0.128	0.128
	Th-232 (diss.)	0.01 U	0.0772 U	0.011 U			0.033	
IA10-MW0001	Th-232	0.0175 U	0.0886 U	0.049 J	0.0318 U	0.0011	0.038	0.038
	Th-232 (diss.)	0.139 U	-0.0333 U	0.009 U			0.038	
IA10-MW0002	Th-232	0.0796 U	0.0739 U	0.002 U	0.0359 U	0.00882	0.040	0.103
	Th-232 (diss.)	0.0271 U	0.253 U	0.028 U			0.103	
IA10-MW0003	Th-232	0.0357 U	0.103 U				0.069	0.069
	Th-232 (diss.)	0.0496 U					0.050	
IA10-MW0004	Th-232	0.0734 U	0.00277 U	0.021 U	-0.0319 U	0.0215	0.017	0.046
	Th-232 (diss.)	0.00044 U	0.0965 U	0.042 U			0.046	

pCi/L = PicoCuries per Liter
Th-230 = Thorium-230
Th-232 = Thorium-232

Table 10 presents the thorium results for co-located groundwater and soil sample pairs (shown in Tables 8 and 9) and the calculated Cs/Cw for these sample pairs. The Cs/Cw values are presented graphically in Figure 4. The Cs/Cw values range from 1,480 to 5,110 mL/g for thorium-230 and from 9,000 to 49,700 mL/g for thorium-232. The values for thorium-232 are roughly an order of magnitude greater than those for thorium-230 because the non-detect Cw results for thorium-232 are roughly an order of magnitude less than those for thorium-230 (Table 9). The sorption characteristics are independent of isotopic form, and so the results based upon the groundwater non-detect results that reflect greater analytical sensitivity (i.e., those for thorium-232) provide the more accurate understanding of Cs/Cw. Because lower K_d values will provide more conservative predictions of contaminant transport, it is recommended that a value near the low end of the thorium-232 Cs/Cw range (8,996 to 49,704 mL/g) be selected to use as the K_d. Given the uncertainty in these estimates, an order of magnitude value of 10,000 mL/g is recommended. This K_d is developed based upon thorium samples in groundwater that are roughly at the thorium solubility limit (~0.1 pCi/L). At and below this concentration, the thorium versus pH regression equation from literature suggests a thorium K_d of 27,000 mL/g, consistent with the 10,000 mL/g field-derived K_d. Above the thorium solubility limit, precipitation is expected. If the K_d construct were applied to this range, an arbitrarily high K_d (e.g., 1E+6 mL/g) could be selected. However, to be conservative and to simplify forthcoming analyses, it is recommended that 10,000 mL/g be used as the thorium K_d regardless of thorium concentration.

The field-derived K_d values for thorium-232 (the preferred thorium K_d values, as described above) in Table 10 and Figure 4 are developed from soil samples taken in both the old fill and the native overburden. Differences in the field-derived K_d values due to different overburden units are not apparent. Therefore, the same K_d (10,000 mL/g) is recommended for use in all overburden units (and in the weathered bedrock units as well, given the thorium solubility limit constraint).

Table 10. Field-Derived Thorium K_d from Co-located Groundwater and Soil Sample Pairs

Parameter	Soil Station	Cs[1] (pCi/g)	Co-located Monitoring Well	Cw[2] (pCi/L)	K_d as Cs/Cw (mL/g)	Overburden Unit of Soil Sample
Th-230	BKG-SB0002	1.01	BKG-MW0001	0.299	3,370	Old Fill
	BKG-SB0005	1.57	BKG-MW0002	0.664	2,370	Old Fill
	BKG-SB0008	1.34	BKG-MW0003	0.262	5,110	Old Fill
	BKG-SB0011	1.34	BKG-MW0004	0.907	1,480	Old Fill
	BKG-SB0014	1.41	BKG-MW0005	0.382	3,690	Old Fill
Th-232	BKG-SB0002	1.27	BKG-MW0001	0.117	10,800	Old Fill
	BKG-SB0005	1.29	BKG-MW0002	0.027	47,600	Old Fill
	BKG-SB0008	1.13	BKG-MW0003	0.023	49,700	Old Fill
	BKG-SB0011	1.49	BKG-MW0004	0.166	9,000	Old Fill
	BKG-SB0014	1.47	BKG-MW0005	0.128	11,500	Old Fill
	IA10-MW0001	1.32	IA10-MW0001	0.038	34,600	Native
	IA10-MW0002	1.35	IA10-MW0002	0.103	13,100	Native
	IA10-MW0003	1.18	IA10-MW0003	0.069	17,000	Native
	IA10-MW0004	1.12	IA10-MW0004	0.046	24,300	Old Fill

[1] Cs = concentration in soil
[2] Cw = concentration in water
mL/g = Milliliters Per Gram
pCi/g = PicoCuries Per Gram
pCi/L = PicoCuries Per Liter
Th-230 = Thorium-230
Th-232 = Thorium-232

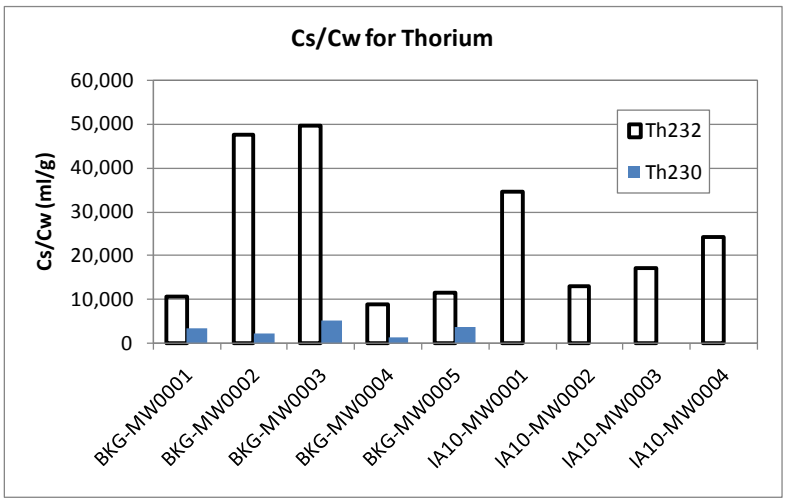

Figure 4. Field-Derived Thorium K_d from Co-located Groundwater and Soil Sample Pairs

3.3 RADIUM

Site-specific tests have not been conducted to assess the affinity of radium to sorb to the Harshaw site soil. As previously discussed, literature data indicate an approximately two order of magnitude range of potential K_d values for radium. To narrow this range, a similar approach was followed as with uranium. Namely, field-derived radium K_d values were developed from Cs/Cw for co-located groundwater and soil samples. The soil radium results for these co-located samples are presented in Table 11.

Table 11. Radium Results in Soil at Stations where Monitoring Wells were Subsequently Installed

Station	Top Depth (ft)	Bottom Depth (ft)	Parameter	Method	Result (pCi/g)	Data Qualifier
BKG-SB0002	7.7	9.7	RA-226	GSS	1.31	
BKG-SB0005	8	10	RA-226	GSS	1.37	
BKG-SB0008	8	10	RA-226	GSS	1.11	
BKG-SB0011	8	10	RA-226	GSS	1.54	
BKG-SB0014	7.5	9.5	RA-226	GSS	1.36	
IA10-MW0001	8	10	RA-226	GSS	1.37	
IA10-MW0002	8	10	RA-226	GSS	1.45	
IA10-MW0003	8	10	RA-226	GSS	1.27	
IA10-MW0004	8	10	RA-226	GSS	1.03	

ft = Feet
pCi/g = PicoCuries Per Gram

Table 12 presents the radium results in groundwater over time for the monitoring well locations corresponding to the soil stations in Table 11. Several radium results in Table 12 are non-detect. Using a non-detect Cw value may underestimate the term Cs/Cw, which would provide a conservative indication of the radium K_d. Therefore, these locations were retained to develop the term Cs/Cw. Average concentrations are calculated for both radium-226 and radium-222 (dissolved) for each well. The maximum of these two

averages is presented in the rightmost column. Again, use of the maximum as Cw will tend to underestimate the term Cs/Cw, which would provide a conservative indication of the radium K_d.

Table 12. Radium Results in Groundwater at Monitoring Wells Co-located with Selected Soil Stations

Station	Parameter	Radium Concentration in Groundwater (pCi/L)					
		Aug 2004	Jul 2007	Aug 2008	Aug 2009	Average	Maximum of Averages
BKG-MW0001	RA-226	0.775 J	0.67 J			0.7225	0.893
	RA-226 (diss.)	0.776 J	1.01			0.893	
BKG-MW0002	RA-226	0.832 J	1.03			0.931	0.94
	RA-226 (diss.)		0.94 J			0.94	
BKG-MW0003	RA-226	0.163 U	0.23 J	0.89	0.18	0.37	0.37
	RA-226 (diss.)		0.27 J			0.27	
BKG-MW0004	RA-226	0.325 U				0.325	0.325
	RA-226 (diss.)	0.202 U				0.202	
BKG-MW0005	RA-226	1.5	2.38			1.94	2.29
	RA-226 (diss.)		2.29			2.29	
IA10-MW0001	RA-226	0.974	0.46 J	0.751	0.5745	0.69	0.69
	RA-226 (diss.)		0.55 J			0.55	
IA10-MW0002	RA-226	1.25	1.29	1.2	0.187	0.99	0.99
	RA-226 (diss.)	0.642	0.79 J			0.716	
IA10-MW0004	RA-226	0.085 U	0.21 J	0.908	0.569	0.443	0.443
	RA-226 (diss.)		0.191 J			0.191	

pCi/L = PicoCuries Per Liter

Table 13 presents the radium results for co-located groundwater and soil sample pairs (from Tables 11 and 12) and the calculated Cs/Cw for these sample pairs. The Cs/Cw values are presented graphically in Figure 5. The Cs/Cw values range from 593 to 4,730 mL/g, with seven of the eight values greater than 1,460 mL/g. Because lower K_d values will provide more conservative predictions of contaminant transport, it is recommended that a value near the low end of the Cs/Cw range be selected to use as the K_d. Given the uncertainty in these estimates, an order of magnitude value of 1,000 mL/g is recommended. This is consistent with literature data, which indicates a radium K_d is somewhat greater than the strontium K_d of 200 to 1600 mL/g for clay content and pH conditions at the Harshaw site.

The field-derived K_d values for radium in Table 13 and Figure 5 are developed from soil samples taken in both the old fill and the native overburden. Differences in the field-derived K_d values due to different overburden units are not apparent. Therefore, the same K_d (1,000 mL/g) is recommended for use in all overburden units.

Table 13. Field-Derived Radium K_d from Co-located Groundwater and Soil Sample Pairs

Parameter	Soil Station	Cs[1] (pCi/g)	Co-located Monitoring Well	Cw[2] (pCi/L)	K_d as Cs/Cw (mL/g)	Overburden Unit of Soil Sample
RA-226	BKG-SB0002	1.31	BKG-MW0001	0.89	1,470	Old Fill
	BKG-SB0005	1.37	BKG-MW0002	0.94	1,460	Old Fill
	BKG-SB0008	1.11	BKG-MW0003	0.37	3,040	Old Fill
	BKG-SB0011	1.54	BKG-MW0004	0.33	4,730	Old Fill
	BKG-SB0014	1.36	BKG-MW0005	2.29	593	Old Fill
	IA10-MW0001	1.37	IA10-MW0001	0.69	1,980	Native
	IA10-MW0002	1.45	IA10-MW0002	0.98	1,480	Native
	IA10-MW0004	1.03	IA10-MW0004	0.44	2,330	Old Fill

[1] Cs = concentration in soil
[2] Cw = concentration in water
mL/g = Milliliters Per Gram
pCi/g = PicoCuries Per Gram
pCi/L = PicoCuries Per Liter
RA-226 = Radium-226

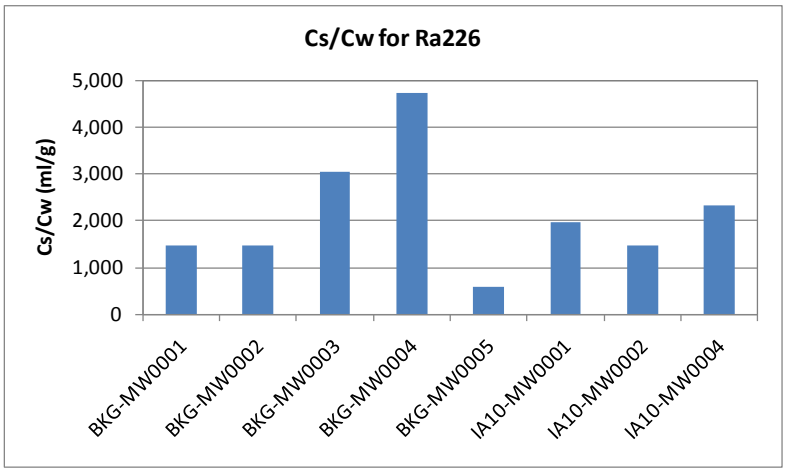

Figure 5. Field-Derived Radium K_d from Co-located Groundwater and Soil Sample Pairs

4. SUMMARY AND IMPLICATIONS

Recommended K_d values for the Harshaw site include the following:

- Uranium – 1,000 mL/g
- Thorium – 10,000 mL/g
- Radium – 1,000 mL/g

These field-derived K_d values were developed from analysis of co-located groundwater and soil samples and are consistent with literature data as follows:

- **Uranium:** Literature data suggest a possible K_d range from roughly 100 to 1,000,000 mL/g at the near-neutral pH conditions present at the Harshaw site. The extremes of this K_d range represent sorption on single mineral phases: quartz and feldspar on the low end of the K_d range, and ferrihydrite and kaolinite (a clay mineral) on the high end. Closer consideration of the literature data for soil and rock narrowed the likely uranium K_d range for the Harshaw site to 1,000 to 10,000 mL/g, given the varied mineralogy of Harshaw site unconsolidated soil.

- **Thorium:** Literature data indicate a thorium K_d of approximately 27,000 mL/g at the near-neutral pH conditions present at the Harshaw site, for groundwater concentrations at or below the thorium solubility limit (near background).

- **Radium:** Literature data indicate a radium K_d somewhat greater than the strontium K_d of 200 to 1600 mL/g for clay content and pH conditions at the Harshaw site. Strontium is recommended to be used as a surrogate for radium (USEPA 2004).

Uranium is expected to be present in the potentially mobile U(VI) valence state site-wide and not in the immobile U(IV) state. Therefore, from a uranium valence state standpoint, it is reasonable to extend site-wide the field-derived U(VI) K_d values developed from available co-located groundwater and soil sample locations.

For a given site with elevated levels of uranium and radium, it is generally the case that the uranium K_d is less than the radium K_d. The K_d values developed herein for Harshaw are the same for uranium and radium (1,000 mL/g). To address the possibility that the total uranium K_d for Harshaw is overestimated, sensitivity transport simulations with decreased total uranium K_d will be conducted to examine the effect upon transport predictions.

The recommended K_d values for uranium, thorium, and radium correspond to contaminant transport retardation factors (R_f) of roughly 1E+4, 1E+5, and 1E+4, respectively. The travel velocity of these contaminants in the saturated zone would be reduced by these factors relative to the groundwater flow velocity. If the above total uranium K_d had prevailed since contaminant release at Harshaw, insignificant lateral migration of total uranium would have occurred in the saturated zone since its release. However, at the time of total uranium release, the K_d was likely much lower due to discharge of process acids in the same areas. Together with the widespread contaminant release mechanisms discussed in Appendix D, this lower K_d in the past helps to explain the current extent of total uranium in groundwater.

Figure D-20 (see main portion of Appendix D) presents the interpreted total uranium plume in Operable Unit-1 groundwater. Above-background results are generally confined to the immediate vicinity of Building

G-1, a primary source area. Impacts to wells north/northeast of Building G-1 are coincident with Building G-2 and the associated high-security storage yard (Manhattan Engineer District [MED] material laydown areas) to the north (between the building and railroad tracks). Analysis of aerial photos for the RI suggests the prior presence in these areas of significant quantities of MED material, which were likely more highly contaminated than what is now observed on-site. Although a gross removal of the material was conducted during historical site operations, soil and groundwater residuals help to explain the current contaminant distribution. The above-background results along the Cuyahoga River are consistent with the use of contaminated fill along the river bank.

Similarly, the recommended K_d values suggest insignificant leaching of these contaminants. If these K_d values are accurate, they imply that contaminant must have reached observed locations in groundwater not by leaching from the surface, but by other mechanisms. Possible mechanisms include direct release to the saturated zone via building drains, sewer systems, and contaminant burial.

The uranium K_d lower limit of approximately 10 mL/g (indicated by the non-equilibrium 24-hour distribution ratio testing done in the RI) equates to an R_f of approximately 100. This R_f is sufficiently high that very little lateral saturated zone transport or vertical vadose zone leaching of uranium would have occurred from the time of release until the present. Thus, even at this lower uranium K_d limit established using laboratory data, uranium must have reached the groundwater by the type of mechanisms noted above, and groundwater 'plumes' are more likely a series of isolated occurrences of groundwater contamination associated with corresponding contaminant releases at or very near those locations.

The recommended K_d values will be applied uniformly across all overburden units, given the generally similar overall composition of the overburden units (glacial tills, whether reworked or not). The similarity in field-derived K_d values for the old fill and native overburden for radium and thorium (where data permitted a comparison) supports this approach. Finally, the same K_d values are recommended for use in the weathered bedrock. For both uranium and radium, sorption is strongly dependent upon pH and clay minerals. The shale bedrock at the Harshaw site is the Chagrin Member of the Ohio Shale Formation (SAIC 2009), which consists primarily of clayshale and mudshale (Lewis 1988). Clay minerals in the shale weathered bedrock will provide similar sorption sites as in the overburden units. Also, similar pH conditions are expected in the weathered bedrock as in the overburden, and this is borne out by neutral pH readings at the weathered bedrock well RMW-38.

The data available for developing field-derived K_d values generally reflect near-background concentrations. As such, it is possible that at higher contaminant concentrations, sorption may not be as great (i.e., contaminant sorption may be non-linear). This applies for uranium and radium but not for thorium, whose solubility limit is near background. However, the consistency of the field-derived uranium and radium K_d values with available literature data suggests that lower sorption at higher contaminant concentrations may not be a significant concern.

To assess the impact of uncertainty in K_d, sensitivity transport simulations with varying K_d values will be conducted to examine the effect upon transport predictions.

5. REFERENCES

ASTM (American Society for Testing and Materials) 1987. *Standard Test Method for 24-h Batch-Type Measurement of Contaminant Sorption by Soils and Sediments*. American Society for Testing and Materials. D 4646-87 (Reapproved 2001).

Lewis 1988. *Late Devonian and Early Mississippian Distal Basin-Margin Sedimentation of Northern Ohio*. Ohio Journal of Science 88 (1): 23-39, 1988. Accessed April 2011 at https://kb.osu.edu/dspace/bitstream/handle/1811/23236/V088N1_023.pdf

Jurgens, et al., 2009. Bryant C. Jurgens, Peter B. McMahon, Francis H. Chapelle, and Sandra M. Eberts. *An Excel® Workbook for Identifying Redox Processes in Ground Water*. USGS Open File Report 2009-1004.

SAIC (Science Applications International Corporation) 2009. *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1, December 2009*. Contract No: W912P4-04-D-0001.

USEPA (United States Environmental Protection Agency) 1999. *Understanding Variation in Partition Coefficient, Kd, Values. Volume II: Review of Geochemistry and Available Kd Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (3H), and Uranium*. EPA 402-R-99-004B. http://www.epa.gov/rpdweb00/docs/kdreport/vol2/402-r-99-004b.pdf. August 1999.

USEPA 2004. *Variation in Partition Coefficient, Kd, Values. Volume II: Review of Geochemistry and Available Kd Values for Americium, Arsenic, Curium, Iodine, Neptunium, Radium and Technetium. EPA 402-R-04-002C*. http://www.epa.gov/rpdweb00/docs/kdreport/vol3/402-r-04-002c.pdf. July 2004.

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Attachment 2

Development and Application of FEHM Leaching Model

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ACRONYMS AND ABBREVIATIONS

FEHM	Finite Element Heat and Mass
ft	Feet
ft/day	Feet Per Day
in/year	Inches Per Year
K_d	Equilibrium Distribution Coefficient
m^2/s	Square Meters Per Second
m	Meter
mL/g	Milliliters Per Gram

1. INTRODUCTION

Residual contamination in the vadose zone may provide a continuing source of contamination to groundwater via leaching. This attachment documents the development and application of a vadose zone leaching model to support assessment of this contaminant leaching potential. The Los Alamos Finite Element Heat and Mass (FEHM) code (v3.0) was used for this analysis. A description of this code and the rationale for selection are presented in Appendix D, Section 4.

2. MODEL DEVELOPMENT

A one-dimensional FEHM model was developed to simulate vertical flow and transport in the vadose zone. The horizontal and vertical discretization of the model domain are shown in Figure 1. The plan (x,y) dimensions of the column are 3 ft by 3 ft (1 m by 3 m). This area is divided into nine cells, each measuring 1 ft by 1 ft (0.3 m by 0.3 m). Vertically, the model is 20 ft (6.1 m) in depth and is divided into 40 layers. The elevation of the bottom of the model corresponds to the water table, and a saturation of 1.0 is set as a boundary condition there.

The horizontal and vertical hydraulic conductivities are specified as 1 ft/day and 0.1 ft/day (0.3 m/day and 0.03 m/day), respectively. Recharge is the primary transport mechanism for the vertical leaching of contamination through the soil column. A recharge rate of 10 inches per year (25.4 cm per year) (consistent with rates described in Appendix D, Section 5.1.4) is used for this analysis. Model input parameters are provided in Table 1.

Table 1. FEHM Model Input Parameters

Input Parameter	Value
Boundary conditions	
Top of model (recharge)	10 inches/year (25.4 cm/year)
Bottom of model (saturation)	1
Van Genuchten model parameters for unsaturated zone	
Inverse air entry head	1.6 m^{-1}
Power in formula	1.4
Molecular dispersion	1×10^{-9} m^2/s
Longitudinal dispersivity	1×10^{-30} m
Transverse dispersivity	1×10^{-30} m
Decay	Conservatively assumed no decay
Linear sorption (K_d)	1,000 mL/g
Hydraulic conductivity	1 ft/day (horizontal) (0.3 m/day) 0.1 ft/day (vertical) (0.03 m/day)

ft/day = Feet Per Day
K_d = Equilibrium Distribution Coefficient
m^2/s = Square Meters Per Second
m = meters
mL/g = Milliliters Per Gram

3. MODEL APPLICATION

A steady-state flow solution was simulated prior to simulating contaminant transport. The predicted nodal saturations above the groundwater table ranged from 0.813 at the surface (top of the column) to 0.953 just above the water table (Figure 2). Contaminant transport was simulated for a period of 1,000 years under these steady state flow conditions. The contaminants considered for simulation of leaching (total uranium, thorium-230, thorium-232, and radium-226) all have high equilibrium distribution coefficient (K_d) values at the Harshaw site, as described in Attachment 1 to Appendix D. Given this, a simplified approach was adopted to model leaching of contamination from the vadose zone to the groundwater table. Total uranium (with the lowest K_d of 1,000 mL/g) was selected for simulation. A total uranium source of unit strength was specified at the top of the column (in the recharge flux), and this source was conservatively held constant for the entire 1,000-year simulation period. The predicted total uranium concentration in pore water at various depths was then monitored over time. After 1,000 years, predicted vertical migration of total uranium is minimal, as shown in Figure 3 which presents concentration versus depth at 1,000 years. At 2 ft (0.6 m) below the unit source, the concentration versus time is shown in Figure 4. After 1,000 years, the pore water concentration is still only about 1% of the unit source concentration in the recharge flux. These results indicate that leaching of total uranium is minimal over the 1,000-year transport period, and only the vadose zone contamination at or extremely near the water table will impact the leaching to the saturated zone.

A sensitivity simulation was executed with the K_d reduced from 1,000 mL/g to 100 mL/g. The predicted concentration versus depth below the unit source at 1,000 years is presented in Figure 5. The leaching reflected in Figure 5 is significantly greater relative to that in Figure 3. However, in an absolute sense, Figure 5 still indicates very limited leaching. Figure 6 presents the concentration versus time at 5 ft (1.5 m) below the unit source. As shown, the predicted concentration after 1,000 years is only about 0.2, or 20% of the unit source concentration. Relative to the baseline simulation above, this indicates that a larger vertical interval of approximately 5 ft (1.5 m) above the water table influences leaching over the 1,000-year simulation period.

4. SUMMARY

The FEHM model simulations using a constant source concentration predict that total uranium will migrate only a few feet vertically over the 1,000-year simulation period. This prediction is controlled by the high total uranium K_d (1,000 mL/g) at the Harshaw site. A sensitivity simulation demonstrated that total uranium migration is still very limited with the K_d reduced from 1,000 mL/g to 100 mL/g. These simulation results are used to specify continuing source from contaminant leaching, as described in Section 6.1.4 and Section 6.3.3 of Appendix D.

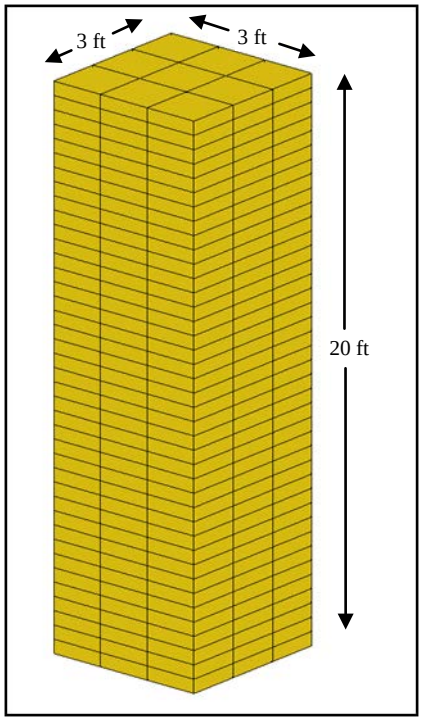

Figure 1. FEHM Model Discretization

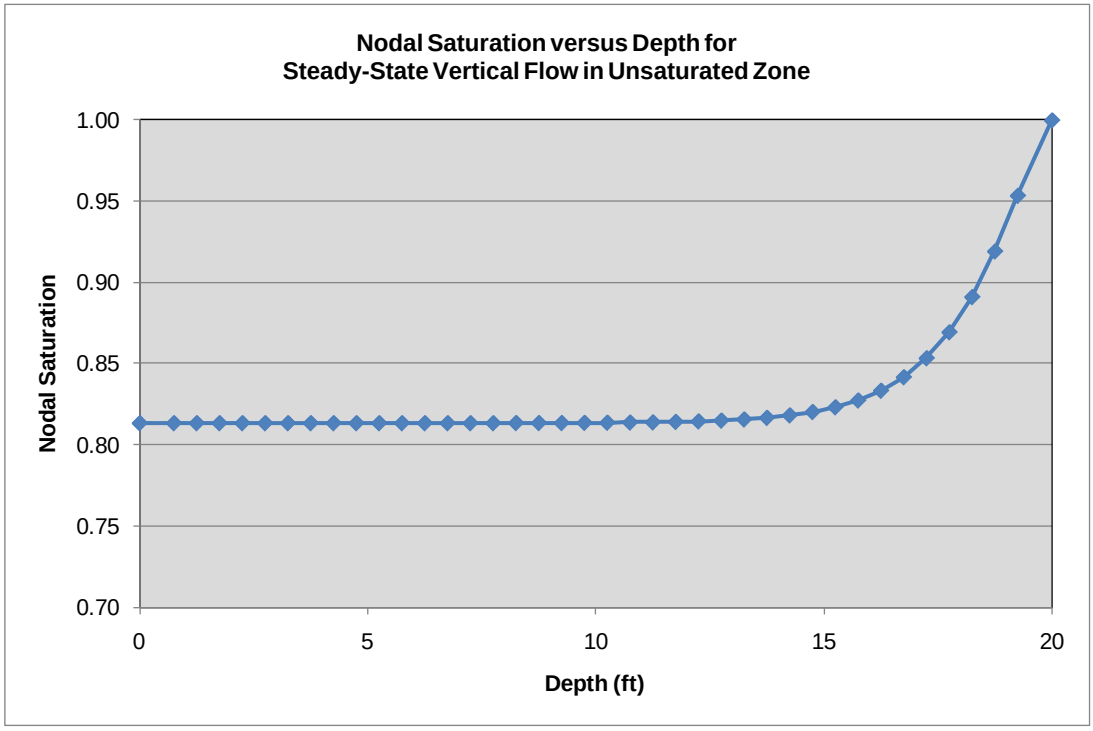

Figure 2. FEHM Predicted Nodal Saturation versus Depth for Steady-State Vertical Flow in Unsaturated Zone

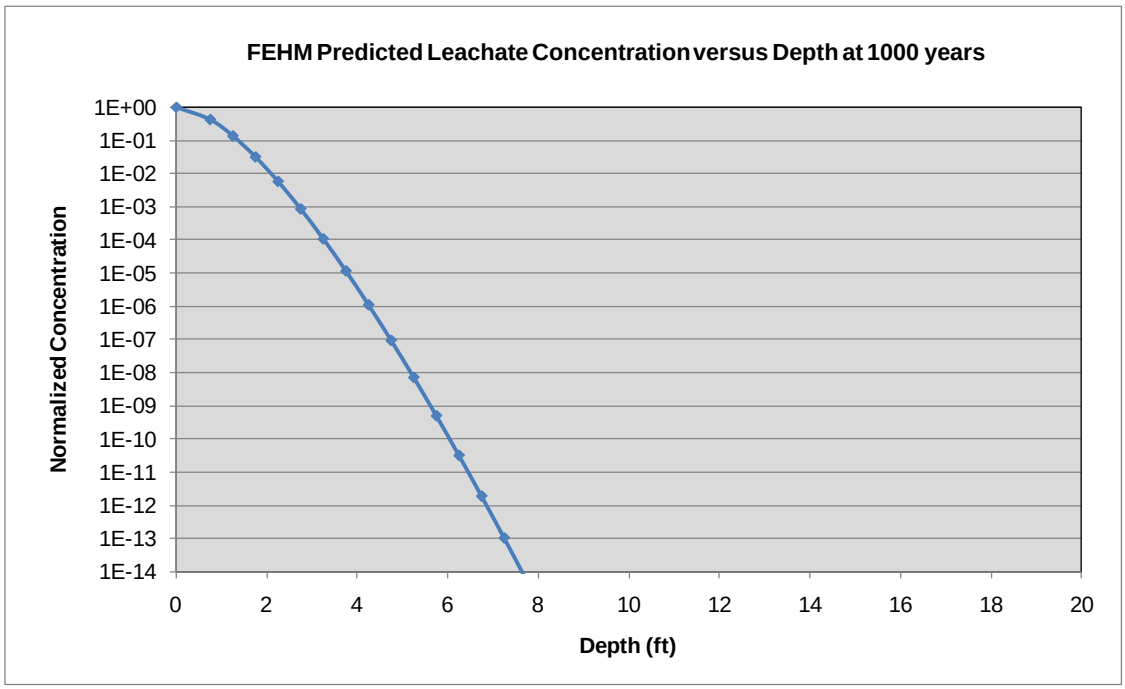

Figure 3. FEHM Predicted Leachate Concentration versus Depth at 1,000 Years

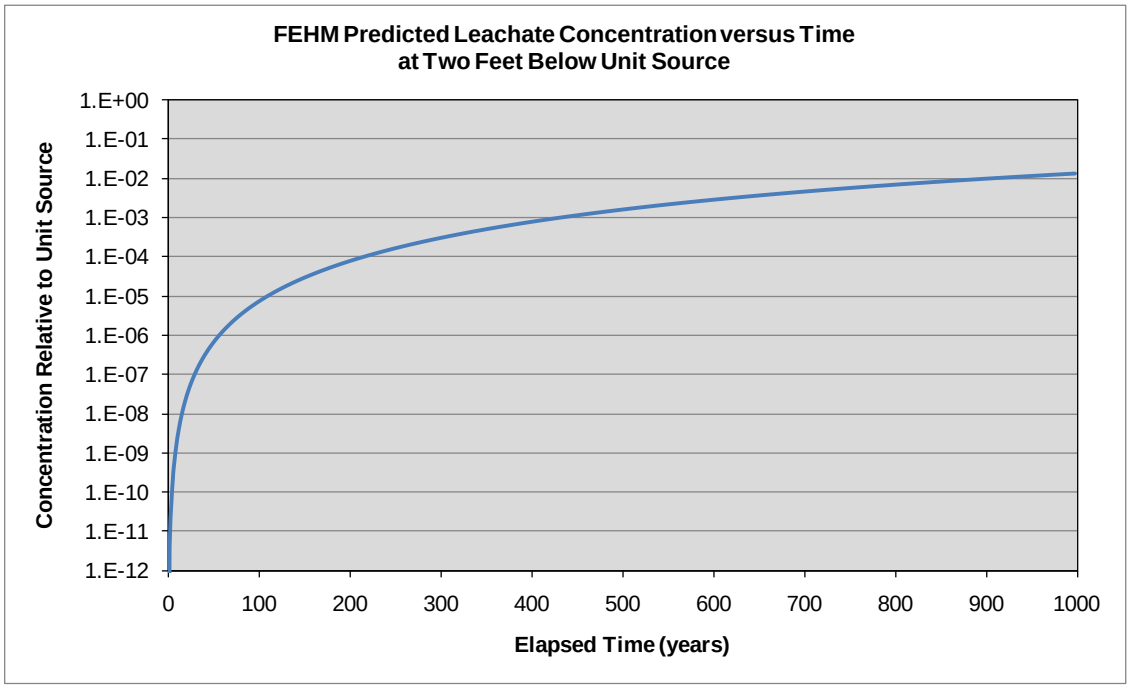

Figure 4. FEHM Predicted Leachate Concentration versus Time at 2 ft Below Unit Source

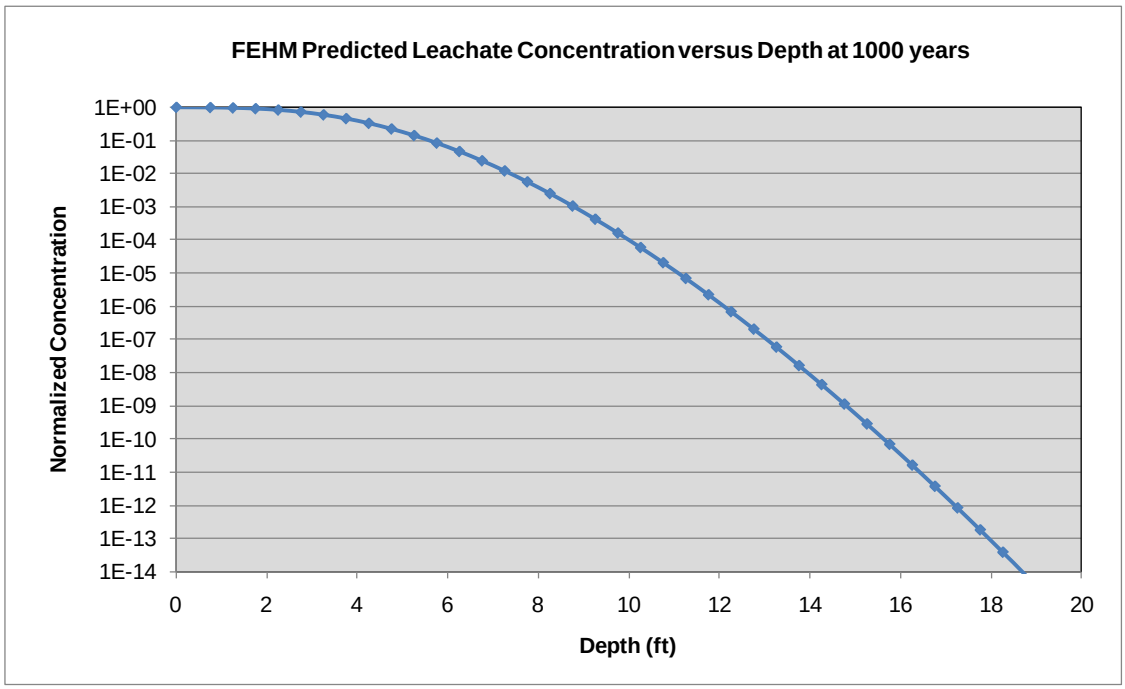

Figure 5. FEHM Predicted Leachate Concentration versus Depth at 1,000 Years for Sensitivity Simulation (order of magnitude reduction in total uranium K_d)

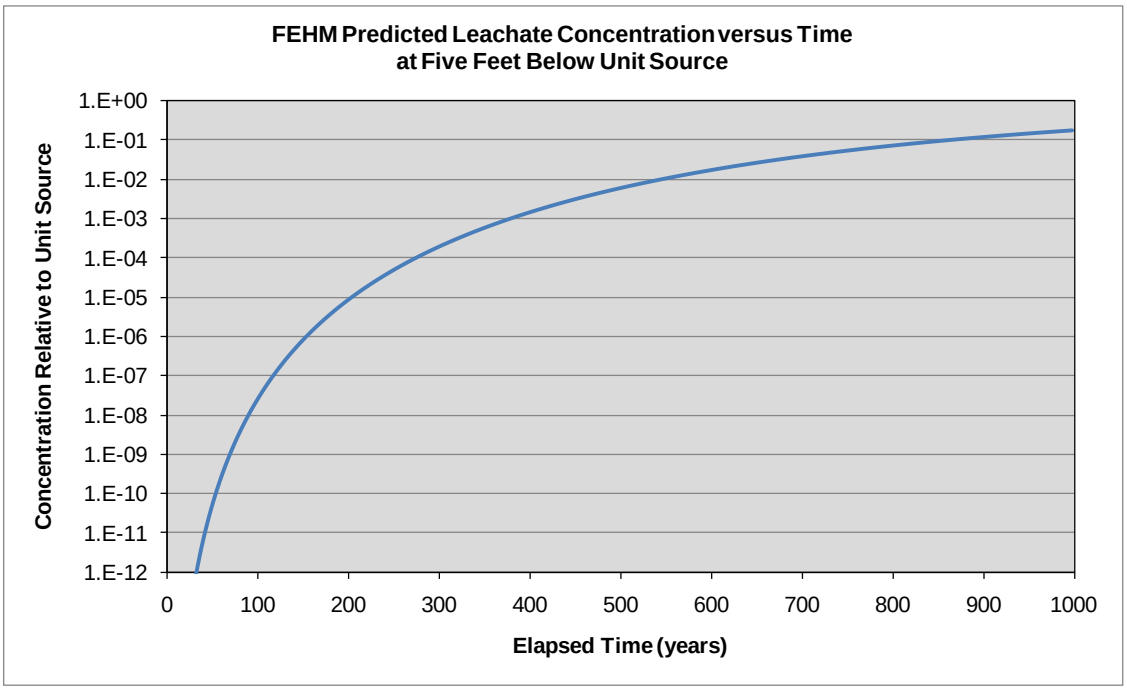

Figure 6. FEHM Predicted Leachate Concentration versus Time at 5 ft Below Unit Source for Sensitivity Simulation (order of magnitude reduction in total uranium K_d)

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