FEASIBILITY STUDY ADDENDUM FOR THE FORMER HARSHAW CHEMICAL COMPANY SITE

CLEVELAND, OHIO

AUTHORIZED PROJECT UNDER THE
FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM
(FUSRAP)

FINAL, REVISION 0—SEPTEMBER 2018

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

µg/L	microgram(s) per Liter
AEC	Atomic Energy Commission
ARARs	applicable or relevant and appropriate requirements
As	arsenic
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cfd	cubic feet per day
CFR	Code of Federal Regulations
COC	constituent of concern
CSM	conceptual site model
DO	dissolved oxygen
DOE	United States Department of Energy
EU	exposure unit
Fe	iron
FS	feasibility study
FSA	feasibility study addendum
ft	feet
ft/day	feet per day
FUSRAP	Formerly Utilized Sites Remedial Action Program
HEC-2	Hydrologic Engineering Center Water Surface Profile System
HEC-HMS	Hydrologic Engineering Center Hydraulic Modeling System
HEC-RAS	Hydrologic Engineering Center River Analysis System
HHRA	human health risk assessment
IA	Investigative Area
ICP-MS	inductively coupled plasma mass spectrometry
kg	kilogram
KPA	Kinetic Phosphorescence Analyzer
L	liter
LLRW	low-level radioactive waste
MED	Manhattan Engineer District
MOU	memorandum of understanding
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
O&M	operation and maintenance
OU	operable unit
pCi/g	picocuries per gram
PP	proposed plan
PRG	preliminary remediation goal
RCRA	Resource Conservation and Recovery Act
ResRad	Residual Radioactivity Computer Code

ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE (CONTINUED)

RI	remedial investigation
TDS	total dissolved solids
TEDE	total effective dose equivalent
TWP	temporary well point
U	uranium
UCL	upper confidence limit
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USD	urban setting designation
VAP	voluntary action program

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	3.527396×10^{8}	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	3.70×10^{10}	becquerel	becquerel	2.703×10^{-11}	curies
rem	0.01	sievert	sievert	100	rem
rad	0.01	gray	gray	100	rads

EXECUTIVE SUMMARY

Between 1944 and 1953, the Manhattan Engineer District (MED) and Atomic Energy Commission (AEC) used the former Harshaw Chemical Company Site, 1000 Harvard Avenue, Cleveland, Ohio (see Figure 1 in Appendix A), to process various forms of uranium materials. In 1999, the United States Department of Energy (DOE) designated the Harshaw Site eligible for the Formerly Utilized Sites Remedial Action Program (FUSRAP). This program was initiated in 1974 to identify, investigate, and, if necessary remediate sites throughout the United States impacted by activities of the MED and AEC in the early years of the Nation's atomic energy and weapons program.

The United States Army Corps of Engineers (USACE), as lead federal agency responsible for cleanup of the Harshaw Site under FUSRAP, is required by Public Laws 105-245 and 106-60 to execute FUSRAP subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 42 U.S.C. 9601 et seq., as amended, and the National Oil and Hazardous Substances Pollution Contingency Plan (40 Code of Federal Regulations [CFR] 300). As part of this effort, USACE prepared a feasibility study (FS) for the Harshaw Site, *Former Harshaw Chemical Company Site Feasibility Study Report* (USACE 2012). An FS is performed to ensure appropriate remedial alternatives are developed and evaluated so relevant information about remedial action options may be presented to decision-makers, and an appropriate remedy may be selected. The USACE is responsible for ensuring the selected remedies are protective of human health and the environment and comply with applicable or relevant and appropriate requirements (ARARs). The 2012 FS addressed two operable units (OUs) at the Harshaw Site, OU-1 and OU-2 (see Figure 2 in Appendix A). This FS addendum (FSA) presents additions and changes to the 2012 FS, which include the 2014 deconstruction of Building G-1, where uranium processing had taken place. This FSA is meant to be used in conjunction with the original document and does not replace the 2012 FS.

This FSA assesses three specific data gaps identified in the completion of the FS: 1) the uncertainty in soil volume estimations due to prior site-area access limitations, 2) the risk to surface water quality posed by potential future riverbank erosion along the Cuyahoga River, and 3) the potential for release of contaminants in groundwater or soil near the former Building G-1. In addition, the FSA updates the conceptual site model (CSM) based on surface and subsurface modifications to the site since the FS. The following site work has been completed by or on behalf of USACE since the 2012 FS:

- Excavation of test pits to locate, assess, and terminate site utilities (2014)
- Performance of a geotechnical inspection and soil sampling to assess bank stability of the Cuyahoga River and Big Creek (2014)
- Deconstruction of former Building G-1 (2014)
- Advancement of soil borings and excavation of test pits to characterize soil along an abandoned rail spur north of and around the former Building G-1 (2015)

- Installation and sampling of monitoring wells and temporary well points, and sampling of groundwater from test pits to characterize contaminants in groundwater near the former Building G-1 (2015)
- Collection of groundwater and surface water samples (2015, 2016, and 2017)

In addition, the following site work was completed by others since the 2012 FS:

- Removal of storm-sewer lines from various areas of the site to preclude uncontrolled discharges to the Cuyahoga River by the BASF Corporation (2014)
- Repair of a leaking potable water supply line north to northeast of the former Building G-1 by the City of Cleveland (2014)
- Removal of a warehouse, former foundry, former boiler house, a garage, and the former hydrogen fluoride plant wastewater treatment system building from the site by the BASF Corporation (2014–2015)

This addendum includes updated information on the CSM, remedial requirements, remedial alternatives, and costs. This addendum makes the following changes to the 2012 FS due to the site work outlined above:

- Updates to the CSM
    - Incorporate soil data from new soil borings and test pits into the delineation of geologic layers (or hydrostratigraphy).
    - Incorporate sampling data from new groundwater wells and test pits and redelineate uranium contamination in the groundwater flow and contaminant-transport model.
    - Present a Cuyahoga River Watershed hydraulic modeling and riverbank erosion assessment for the banks of the Cuyahoga River and Big Creek along the site.

- Assessment of the remedial requirements for groundwater, erosion, and soil
    - The enhanced groundwater study confirmed that groundwater under OU-1 is: 1) not a source of drinking water, 2) replaceable with nearby potable surface water resources, and 3) attenuating the uranium plume beyond the former Building G-1 area. Consequently, no action is needed to address contamination in groundwater since the plume lies within an area that will not be a potential groundwater source zone.
    - Groundwater modeling predicts the uranium plume remains stable (or immobile) within the site boundary over the 1,000-year performance period. Refining the long-term transport prediction did not change the *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1* (USACE 2009) (RI), or FS findings that the groundwater plume will not affect the Cuyahoga River above drinking water standards. The USACE reevaluated the exposure point concentration for total uranium in groundwater and confirmed the preliminary remediation goals (PRGs) developed in the baseline risk assessment performed as part of the remedial investigation would not be exceeded.

- A riverbank erosion assessment was completed. It determined that future storm events will not affect groundwater and soil residuals near the former Building G-1. An increase in plume discharges to the Cuyahoga River may occur with site erosion, but it will not significantly affect river water quality.
- The volume of soil requiring treatment was reduced based on the new soil characterization data for select remedial alternatives presented in Table ES-1.

Table ES-1. Summary of Estimated Contaminated Soil and Debris Volumes To Go Off-Site

OU	Alt. Number	2012 FS Alternative Description	2012 Feasibility Study	Feasibility Study Addendum
			Total Volume (Cubic Yards, *Ex Situ*)	
OU-1	3	Complete Removal With Off-Site Disposal	25,300	5,178
	4	Complete Removal With *Ex Situ* Treatment and Off-Site Disposal	31,700	Alternative Removed
OU-2	7	Complete Removal With Off-Site Disposal	3,400	538
	8	Complete Removal with *Ex Situ* Treatment and Off-Site Disposal	4,000	Alternative Removed

- Modifications to the remedial alternatives presented in Table ES-2
    - Alternatives 3 and 7—Complete Removal With Off-Site Disposal—were revised to allow the remediation contractor to select the disposal/treatment method of excavated soil. This modification caused Alternatives 4 and 8— Complete Removal With Ex Situ Treatment and Off-Site Disposal–to be redundant. Accordingly, Alternatives 4 and 8 were removed from consideration.
    - The costs and details associated with the deconstruction of former Building G-1 were removed from Alternative 3—Complete Removal With Off-Site Disposal (OU-1).
    - The decontamination of the warehouse, the former foundry, the former boiler house, a garage, and the former hydrogen fluoride plant wastewater treatment system building were removed from Alternative 3—Complete Removal With Off-Site Disposal (OU-1)
    - The volume of soil exceeding preliminary remediation goals was reduced based on the new soil characterization for Alternative 3 (OU-1) and Alternative 7 (OU-2).

Table ES-2. Summary of Remedial Alternatives

Operable Unit	Alternative	2012 Feasibility Study Components	Feasibility Study Addendum Components
OU-1	1 – No Action	None	None
	2 – Limited Action and Land Use Controls	Deconstruction of Building G-1, off-site disposal of Building G-1 debris, bank stabilization, land use controls, and site monitoring	Land use controls and site monitoring
	3 – Complete Removal with Off-Site Disposal	Excavation of impacted soil exceeding the preliminary remediation goals, off-site disposal, deconstruction of Building G-1 and off-site disposal, decontamination of site buildings	Excavation of impacted soil exceeding the preliminary remediation goals, and off-site soil disposal
	4 – Complete Removal with *Ex Situ* Treatment and Off-Site Disposal	Excavation of impacted soil exceeding the preliminary remediation goals, *ex situ* treatment, off-site soil disposal, deconstruction of Building G-1 and off-site disposal, decontamination of site buildings	Remedial alternative removed from consideration
OU-2	5 – No Action	None	None
	6 – Limited Action and Land Use Controls	Land use controls and site monitoring	Land use controls and site monitoring
	7 – Complete Removal with Off-Site Disposal	Excavation of impacted soil exceeding the preliminary remediation goals and off-site disposal	Excavation of impacted soil exceeding the preliminary remediation goals and off-site disposal
	8 – Complete Removal with *Ex Situ* Treatment and Off-Site Disposal	Excavation of impacted soil exceeding the preliminary remediation goals, *ex situ* treatment, off-site soil disposal	Remedial alternative removed from consideration

- Updates to the remedial alternative cost estimates are presented in Table ES-3. Cost estimates decreased for OU-1 mainly due to the removal of costs associated with the deconstruction of site buildings and the reduction in contaminated soil volumes. Other factors affecting the cost estimates were revised contingencies and the increase of unit costs to 2016 dollars.

Table ES-3. Cost Summary for Remedial Alternatives

Operable Unit	Alternative	Capital Cost	Operation & Maintenance	Total Non-Discounted Cost	Discounted O&M Cost[a]	Total Present Value Cost
2012 Feasibility Study						
OU-1	1	$0	$0	$0	$0	$0
	2	$11,320,378	$1,086,179	$56,604,601	$1,086,179	$12,406,557
	3	$55,034,232	$151,694	$61,829,592	$151,694	$55,185,927
	4	$76,257,108	$153,639	$83,139,588	$153,639	$76,410,747
OU-2	5	$0	$0	$0	$0	$0
	6	$1,400,265	$868,310	$36,047,405	$828,310	$2,228,575
	7	$6,617,430	$0	$6,617,430	$0	$6,617,430
	8	$9,562,520	$0	$9,562,520	$0	$9,562,520
Feasibility Study Addendum						
OU-1	1	$0	$0	$0	$0	$0
	2	$4,545,926	$58,649,922	$63,195,848	$1,640,322	$6,186,258
	3	$32,551,854	$8,077,821	$40,629,675	$232,148	$32,784,001
	4	Removed				
OU-2	5	$0	$0	$0	$0	$0
	6	$2,420,176	$40,396,171	$42,816,347	$1,230,031	$3,650,207
	7	$5,909,693	$0	$5,909,693	$0	$5,909,693
	8	Removed				

[a] Operation and maintenance costs are the totals over 1,000 years.
[b] Present worth cost is the amount needed to be set aside prior to initiating the alternative to cover all associated future costs including nondiscounted design and capital costs and discounted operation, maintenance, and contingency costs.

Although some changes were made to the remedial alternatives presented in the 2012 FS, the alternatives analysis remains the same. Major factors affecting the comparison of alternatives did not change. The summary of detailed analysis of remedial alternatives for OU-1 and OU-2 is presented in Tables ES-4 and ES-5, respectively.

Table ES-4. Summary of Comparative Analysis of Remedial Alternatives for OU-1

CERCLA Criteria	Alternative 1: No Action	Alternative 2: Limited Action and Land Use Controls	Alternative 3: Complete Removal with Off-site Disposal
Overall protection of human health and the environment	Not Protective	Protective	Protective
Compliance with ARARs	Not Compliant	Compliant	Compliant
Long-term effectiveness and permanence	Low	Moderate	High
Reduction of contaminant toxicity, mobility, or volume through treatment	None	None	None[a]
Short-term effectiveness	High	High	Moderate
Implementability[b]	Not Applicable	Low	High
Cost Present Worth	$0	$6,186,258	$32,784,001

[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 (see 2012 FS).

Table ES-5. Summary of Comparative Analysis of Remedial Alternatives for OU-2

CERCLA Criteria	Alternative 5: No Action	Alternative 6: Limited Action and Land Use Controls	Alternative 7: Complete Removal with Off-Site Disposal
Overall protection of human health and the environment	Not Protective	Protective	Protective
Compliance with ARARs	Not Compliant	Compliant	Compliant
Long-term effectiveness and permanence	Low	Moderate	High
Reduction of contaminant toxicity, mobility, or volume through treatment	None	None	None[a]
Short-term effectiveness	High	High	Moderate
Implementability[b]	Not Applicable	Low	High
Cost Present Worth	$0	$3,650,207	$5,909,693

[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 ratings for technical and administrative implementability (see 2012 FS).

The next step in the CERCLA process for the Harshaw Site is for USACE to prepare a proposed plan (PP). The PP will evaluate the remedial alternatives discussed in the 2012 FS and this FSA, and recommend the USACE's preferred remedial alternative.

1. INTRODUCTION

The Former Harshaw Chemical Company Site, referred to hereafter as the Harshaw Site, is located at 1000 Harvard Avenue, Cleveland, Ohio, 4.8 kilometers (km) (3 miles) south of downtown Cleveland (see Figure 1 in Appendix A). Pursuant to a memorandum of understanding (MOU) between the United States Department of Energy (DOE) and the United States Army Corps of Engineers (USACE) signed in March 1999, the DOE sent a letter to USACE indicating the Harshaw Site was eligible for the Formerly Utilized Sites Remedial Action Program (FUSRAP). Subsequent to that letter, USACE determined that contamination needing to be addressed was present at the site and added the site to FUSRAP. Congress required in Public Laws 105-245 and 106-60 that eligible FUSRAP cleanup would be completed 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., as amended, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] §300). The USACE is the lead federal agency in the administration and execution of FUSRAP response actions.

The Harshaw Site was evaluated within the CERCLA framework with the completion of a feasibility study (FS). The FS process requires the development, screening, and detailed analysis of remedial alternatives. An FS report was completed in 2012, *Former Harshaw Chemical Company Site Feasibility Study Report* (USACE 2012), detailing part of the ongoing evaluation at the Harshaw Site. This addendum was prepared to assess three data gaps identified in the completion of the FS relevant to 1) contaminated soil volume, 2) surface water discharges to the Cuyahoga River, and 3) groundwater impacts and quality. This FS addendum (FSA) should be used in conjunction with the original FS report and does not replace it.

1.1 PURPOSE, SCOPE, AND ORGANIZATION

1.1.1 Purpose

The FS evaluated and compared remedial alternatives identified for the site using the following nine criteria specified in the NCP [40 CFR §300.430(e)(9)(iii)]:

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

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

- Modifying Criteria:
    - State acceptance
    - Community acceptance

The description of these criteria and the detailed analysis of alternatives against these criteria may be found in the 2012 FS report. This FSA provides updated information to further refine the remedial alternatives and their appropriateness based on new site data and conditions.

1.1.2 Scope

The intent of the USACE activity at the Harshaw Site is to address residual contamination by radioactive and other hazardous substances resulting from past activities of the Manhattan Engineer District (MED)/Atomic Energy Commission (AEC) connected with the Nation's early atomic energy and weapons program. The scope of the FS was confined to the evaluation of remedial alternatives addressing those FUSRAP-related radioactive and hazardous substances. The Harshaw Site was used in the production of commercial chemicals (e.g., nickel and/or hydrofluoric acid production) prior to, during, and after MED/AEC activities took place. Any contamination from non-MED/AEC-related activities was not included in the scope of the FS. The scope of this addendum remains consistent with the scope of the 2012 FS, and includes new site characterization data and updated information on the conceptual site model (CSM), remedial requirements, remedial alternatives, and costs. This document should be used in conjunction with the 2012 FS report and does not replace it.

1.1.3 Organization

This FSA has been organized to retain the outline of the 2012 FS with summaries of work performed since the FS. Associated impacts to the remedial alternatives are discussed in Sections 3 and 4.

- **Section 1 – Introduction**: Presents abbreviated details of the addendum purpose, scope, and organization; Harshaw Site background information; site history; and updates to the feasibility study.

- **Section 2 – Identification and Screening of Technologies**: A place holder was retained in this addendum for this section but only to reference the information provided in the 2012 FS. No changes have been made to this section.

- **Section 3 – Development and Screening of Alternatives**: Presents a summary of the alternatives identified in the 2012 FS. The FS should be referenced for the detailed development and screening of alternatives.

- **Section 4 – Detailed Analysis of Alternatives**: Provides updates to the analysis of alternatives based on the site work completed since the 2012 FS.

- **Section 5 – References**: Lists the applicable references cited in this addendum.

1.2 BACKGROUND INFORMATION

The background information section of the FS provides a summary of the *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1* (USACE 2009*)* (RI), including site description, site history, nature and extent of contamination, contaminant fate and transport, and the baseline risk assessment (BRA). This information has been repeated below in an abbreviated form for ease of reference. Updates to the CSM since the 2012 FS are presented in Section 1.3.

1.2.1 Site Description

The Harshaw Site is located at 1000 Harvard Avenue in Cleveland, Ohio, 4.8 kilometers (3 miles) south of downtown Cleveland (see Figure 1 in Appendix A). Most of the site is owned by the BASF Corporation. The former Building G-1 area and the undeveloped parcel located east of the Cuyahoga River (IA-06) are currently owned by the Chevron Corporation. The site is adjacent to the Cuyahoga River and Big Creek within an industrialized area in Cuyahoga County. The site consists of 22.3 hectares (55 acres) and includes several developed and undeveloped land parcels near the intersection of Harvard Avenue and Jennings Road (see Figure 2 in Appendix A). Developed site parcels include former production areas with foundations; parking areas associated with previously demolished buildings; and redeveloped, privately owned commercial properties. Industry and commercial businesses surround the site to the north, south, east, and west. Neighboring industries include Arcelor Mittal Steel; Aluminum Company of America; Chemical Solvents, Inc.; and CSP Fabricating. There are a few private residences adjacent to the site.

1.2.1.1 Environmental Setting

The Harshaw Site and surrounding residential, commercial, and industrial properties are serviced by municipal water supplies. Groundwater is not used for drinking or industrial processes since no potable drinking water wells are within a 3.2-kilometer (2-mile) radius of the site. In addition, the groundwater quality and yield are not suitable for use by industries or residents. 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 (see Figure 3 in Appendix A), 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 residential dwellings and commercial/industrial structures located within city boundaries must be connected to the city municipal water supply system. These conditions together indicate that groundwater will not be used as a drinking water resource at the Harshaw Site.

1.2.1.2 Geology

On average, subsurface geology at the Harshaw Site consists of 6.7 meters [m], (22 feet [ft]) of unconsolidated material that overlies shale bedrock. Bedrock is relatively shallow beneath the central and northern part of the property (near the former boiler plant and former Building G-1) and becomes deeper in a radial pattern toward the north, east, west, and south, where the thickness of the unconsolidated overburden increases accordingly. This overburden consists of both anthropogenic (manmade) fill and native alluvial sediments. The native alluvium is indicative of the site's geographic setting within the Cuyahoga River valley, where boring logs note the presence of both fluvial (coarse-grained) and floodplain (fine-grained) sediment across the site (USACE 2009). The extent of the fill and alluvium was further refined during the Building G-1 deconstruction activities and associated soil and groundwater investigations.

1.2.1.3 Hydrogeology

Potentiometric maps show groundwater flow in the saturated portions of the unconsolidated fill and alluvium is generally from west to east across the Harshaw Site. Groundwater flow directions across the site appear to be influenced by the bedrock elevations and changes in surface water levels in the Cuyahoga River and Big Creek.

Primary groundwater flow occurs within the saturated zone of the alluvium, which thickens and coarsens where the bedrock deepens. The underlying shale bedrock exhibits a thin fractured zone (< 5 feet thick) that has been observed to be dry in the vicinity of former Building G-1 and the boiler house (i.e., where bedrock is shallow) and saturated where bedrock deepens distal from this site area. Appendix B figures B-10 and B-11 show where the shallow bedrock (thin overburden) occurs. However, USACE assumes this bedrock zone transmits groundwater and modeled it as a 5-foot thick extension of the overburden, but with lower permeability (USACE 2012). This characterization is supported by a shallow bedrock well near former Building G-1 that produced very low sampling yields and hydraulic conductivity values.

Regionally, the shale bedrock is not a significant groundwater-bearing zone, historically producing 11 to 38 liters per minute (3 to 10 gallons per minute). The similarities observed between groundwater levels within the alluvium and the fractured bedrock zone suggest these zones are hydraulically connected.

The fill and alluvium represents the primary water-bearing zone in the vicinity of the site. 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 from Lake Erie. Potentiometric maps developed during the RI (see RI Figures 6-36 and 6-37) and subsequent groundwater modeling (USACE 2012, Appendix D) indicate groundwater in the alluvium discharges to the Cuyahoga River and Big Creek.

1.2.1.4 Surface Water

The Harshaw 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 Flood Hazard Area (see RI Figure 2-10). 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 7.6 to 9.1 m (25 to 30 ft) is present along the west bank of the river. The land surface in the middle portion of the site is approximately 3 to 4.6 m (10 to 15 ft) 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.

In 2014 and 2015, the property owner (BASF Corporation) removed multiple segments of the site stormwater system; Appendix B discusses these removals as part of the groundwater study. Surface water ponding occurs in various areas of the site due to building demolition and sewer line changes. 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

Historical government-contracted operations at the Harshaw Site began in 1944 with the conversion of uranium concentrate feed materials to uranium tetrafluoride, uranium hexafluoride, and uranium trioxide. These operations ceased by May 1953, although in 1953 and 1954, the refinery purified uranium trioxide produced from recycled uranium. After 1954, no MED/AEC-related operations occurred. Major processing operations took place in the former Buildings G-1, shown on Figure 2 in Appendix A.

The USACE conducted an RI (USACE 2009) and separated the site into two operable units (OUs), OU-1 and OU-2, and an investigative area (IA), IA-06. These areas are shown on Figure 2 in Appendix A. During the investigation of IA-06, an undeveloped parcel east of the Cuyahoga River, USACE concluded there is no unacceptable risk to current or reasonably anticipated future land users from FUSRAP-related constituents on IA-06. As a result, USACE prepared a separate no action record of decision for IA-06 (USACE 2011).

The remainder of the site was divided into two OUs to account for differing foreseeable land uses for each OU. The reasonably foreseeable land use for OU-1 is industrial, and the critical exposure group is the construction worker. This area is the portion of the site north of Big Creek and west of the Cuyahoga River where USACE confirmed contamination in soil, groundwater, and buildings. The extent of contamination within OU-1 is in the area surrounding the site of the former Building G-1 and a limited area near the Cuyahoga riverbank where FUSRAP-related materials may have been placed. The site buildings were deconstructed in 2015, so remedial actions are no longer required for this media.

The OU-2 portion of the site is south of Big Creek and west of the Cuyahoga River. The reasonably foreseeable future land use for OU-2 is residential; the adult resident is the critical exposure group.

Based on the RI and FS (USACE 2009 and USACE 2012), FUSRAP-related constituents of concern (COCs) in OU-1 and OU-2 are radium-226, thorium-230, thorium-232, and total uranium. The only media where USACE found FUSRAP-related contamination in OU-2 was soil. The extent of contamination in this OU is isolated to a few areas towards the middle portion of the operable unit. The extent of contaminant impacts is discussed in more detail in the 2012 FS.

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
- Sewers and drains

A summary of the results of the nature and extent of sampling conducted during the RI may be found in the RI and FS reports (USACE 2009 and 2012). Abbreviated forms of the relevant sections have been repeated below for ease of reference.

Investigations were also conducted in 2015, 2016, and 2017 to collect additional site characterization data following concerns that contaminated groundwater may be discharging into the Cuyahoga River. Results of the 2015 and 2016 groundwater investigations are also summarized in the following sections. A detailed description of the 2015, 2016, and 2017 investigations is found in Appendix B.

1.2.3.1 Groundwater

Groundwater flow directions across the site were identified through the collection of water level measurements during RI groundwater sampling events, along with subsequent sampling through 2015. The generalized groundwater surface elevations (also known as the potentiometric surface) developed from these measurements indicate groundwater flows easterly across the site toward the Cuyahoga River.

Groundwater characterization during and after the RI identified FUSRAP-related impacts in the former process area, specifically in the unconsolidated material beneath and in the vicinity of former Building G-1 (see Figures B-1 and B-2 in Appendix B). Uranium contamination in groundwater does not currently extend beyond the site boundary.

Groundwater modeling conducted during the RI and FS evaluated the fate and transport of radiological groundwater contamination at the site. The contaminant transport analyses indicated the contamination plume near the former location of 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 predicted the uranium plume near former Building G-1 would not reach the river at concentrations above background within the 1,000-year performance period.

The updated modeling approach presented in Appendix B supplements the RI and FS models. The model includes the expanded groundwater monitoring wells inventory and recent sampling data. This update also indicates that uranium in groundwater will not pose an unacceptable risk or radiological dose to ecological receptors or human receptors associated with current and future potential land uses (e.g., recreational, commercial, or industrial properties). Future remedial actions to address FUSRAP-related soil contamination throughout the site should have a beneficial impact on the level of radiological groundwater contaminants by reducing the mass available to reach and transport in groundwater.

1.2.4 Contaminant Fate and Transport

Figures B-1 and B-2 in Appendix B identify FUSRAP-related contamination requiring remedial action and the associated groundwater impacts (primarily the contiguous uranium plume).

The mechanisms of physical contaminant transport on-site include the following:

- 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
- Contaminant leaching from unsaturated soil to groundwater

The relocation of contaminated soil 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. This is also the case with surface water runoff or wind erosion, since the current site conditions do not promote off-site discharges (e.g., the stormwater system has been partially dismantled by the site owner, and the balance of the site is anthropogenically covered). In addition, groundwater monitoring has demonstrated that groundwater contamination is not reaching the site boundaries.

Contaminant leaching from saturated soil or fill material is thought to represent the primary source for groundwater contamination in the vicinity of former Building G-1. Significantly elevated FUSRAP-related radionuclide concentrations identified within saturated subfloor material beneath the former building strongly suggest direct contaminant transport to groundwater in this location (see Appendix B). The leaching of radiological contamination via recharge through the unsaturated material (i.e., shallow or surface soil) to groundwater is considered a secondary transport pathway at the site.

The fate and transport of FUSRAP-related radiological groundwater contamination at the site was evaluated using a numerical groundwater flow, particle tracking, and solute transport computer model during the RI and FS (USACE 2009 and 2012). These models estimated the near-term and future risks from groundwater. Appendix B details the updated modeling approach, CSM, numerical model updates, and predictive results.

The recent contaminant transport analyses, which agree with the RI and FS analyses, indicate the uranium plume near former Building G-1 is migrating radially to the north, east, and south, then dispersing in the thicker water-bearing sediments that dominate the subsurface near the Cuyahoga River. The plume is not predicted to impact the Cuyahoga River within the 1,000-year performance period for FUSRAP (per 10 Code of Federal Regulations [CFR] 20.1401[d]).

The updated groundwater model documented in Appendix B also predicts conditions similar to the original evaluations of remedial alternatives in the FS (USACE 2012), which indicates the alternative analyses are still valid for subsequent CERCLA decision making.

Additional modeling, conducted as part of this FSA, is discussed in detail in Section 1.3.6. The Cuyahoga River Watershed hydraulic modeling and riverbank erosion assessment are included in Appendix C. The hydraulic modeling assessed riverbank stability along Cuyahoga River and Big Creek and recommended erosion-prevention measures to reduce the risk of impacts to the waterways due to soil erosion. Appendix D contains a Cuyahoga riverbank assessment completed in 2014. The assessment's objectives were to 1) identify bank erosion or sloughing that may compromise the stability of the banks supporting the Harshaw Site and 2) identify surface runoff points or seepage that may lead to bank erosion in the future. The assessment identified no areas of immediate concern relative to erosion.

1.2.5 Baseline Risk Assessment

The USACE conducted a baseline risk assessment (BRA) to provide an analysis of the potential unacceptable risk or radiological dose to human health and environmental receptors associated with past MED/AEC-related activities at the site, as if no FUSRAP remediation were to occur (USACE 2009).

The Harshaw Site 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 FUSRAP-related 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.
- **Screening Level Ecological Risk Assessment**: An evaluation of the potential hazard to ecological receptors from FUSRAP-related chemical and radioactive constituents remaining in environmental media.

The following sections summarize the findings of each of the BRA components. However, the Building HHRA is no longer applicable because all impacted buildings have since been removed from the Harshaw Site.

1.2.5.1 Human Health Risks

The HHRA identified FUSRAP-related constituents by media and exposure unit (EU) based on an evaluation of data collected during the site characterization process. (The EUs were later combined into OUs for the FS; the reevaluation of exposure point concentrations for characterizing risk on an OU-specific basis is described in Section 1.3.3 of the FS.) The evaluation of potential exposure to FUSRAP-related constituents included several human-receptor populations.

- Maintenance worker (current)
- Trespasser/recreational user (current/future) adult and adolescent

- Industrial worker (future)
- Construction worker (future)
- Resident (future) adult and child
- Subsistence farmer (future) adult and child

Potentially impacted media evaluated in the risk assessment included soil, surface water and sediment (both in underground site utilities and the Cuyahoga River), and groundwater. Exposure pathways include inhalation, dermal contact, incidental ingestion (of soil for all receptors, and soil, sediment, surface water, and groundwater for other receptors according to the conceptual site model), external gamma exposure, and consumption of potentially impacted game fish (for hypothetical residents and farmers only). The risk posed to human-receptor populations was quantified for each impacted medium and exposure pathway. Through this evaluation, specific FUSRAP-related contaminants were identified posing the greatest potential risk to human health: radium-226, thorium-230, thorium-232, and uranium isotopes (including uranium-234, uranium-235, and uranium-238).

Soil was identified as a media of concern based on potential health risks to critical groups selected for the site. Unacceptable incremental lifetime cancer risks were identified for the industrial worker, maintenance worker, resident, and subsistence farmer receptors for soil. Unacceptable radiological doses (i.e., above 25 mrem/yr) in soil were noted for the maintenance worker, construction worker, resident, and subsistence farmer receptors.

There were no unacceptable cancer, noncancer, or radiological dose risks associated with FUSRAP-related contaminants for any receptor for surface water, sediment, or sewers and drains.

The only noncancer chemical risk found to have a hazard quotient (the exposure divided by the appropriate chronic or acute value) exceeding the acceptable limit of 1 for exposure to uranium was for the hypothetical scenario of a subsistence farmer exposed to uranium by drinking groundwater from the site. Unacceptable radiological doses were noted for the subsistence farmer receptor for hypothetical exposures to groundwater. Based on an analysis of likely future land use, farming is not expected to occur at this property in the future; therefore, risks associated with drinking groundwater at this site are not considered to be applicable. The groundwater at the site is not a source of drinking water due to 1) relatively poor quality and slow production rate, 2) proximity to replaceable surface water sources (e.g., Cuyahoga River and Lake Erie), 3) the urban location that also lies within the buffer zones of two Ohio VAP USDs, and 4) the requirement for occupied dwellings to be connected to the City of Cleveland municipal water supply system. The USACE has concluded no action is needed to address groundwater, as articulated in Appendix B.

The risk characterization results, presenting cancer risks, radiological doses, and noncancer hazards on an OU-specific basis (as described in Section 1.3.3) are summarized in Tables 6, 7, and 8 in Appendix E.

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, City of Cleveland planning indicates a portion of OU-2 may be zoned residential. Therefore, in the FS, USACE evaluated the impacts in OU-2 with regard to future residential development. Based on these results, the critical receptors, or populations with the greatest future hypothetical risk, were identified as the construction worker for OU-1 and the resident for OU-2.

Although other media (i.e., building surfaces, surface water, sediment, and groundwater) were also investigated and evaluated, only soil remains a medium of concern based on potential health risks to critical exposure groups.

Further details for the HHRA can be found in the FS (USACE 2012) and in the RI Addendum (USACE 2009).

The USACE updated its risk evaluations for this FSA. It evaluated excavation alternatives to determine whether residual soil contamination would pose an adverse hazard to human health from the chemical (toxic, nonradioactive) effects of uranium (e.g., kidney damage). This was done as an additional check to ensure that the soil cleanup goals, which were established to be protective against radiological (absorbed dose) effects would also be protective against chemical effects of uranium (soil cleanup goals are discussed in Section 3.1).

Residual uranium concentrations remaining after the volume of contaminated soil was removed, including additional volumes of soil needed to be removed when the excavation is deeper than 5 feet (setbacks for safety), were examined. The data was imported into the United States Environmental Protection Agency's (USEPA's) software, ProUCL version 5 (USEPA 2013), and upper confidence limits on the mean concentrations were determined. In OU-1, the 95th percentile upper confidence limit (UCL95) of mean concentration is approximately 9.2 pCi/g U-238 (or approximately 27.6 mg/kg total U). In OU-2, the UCL95 of mean concentration is approximately 3.3 pCi/g U-238 (or approximately 10 mg/kg total U). A copy of the ProUCL output table is included as Table 9 in Appendix E. Although the soil cleanup goals are based on radiation protection standards, the average uranium residual concentration in each OU will not exceed risk-based levels that would be protective against noncancer chemical health effects of uranium for the receptors of concern in each OU (indicated in Table 8-27 of the 2009 RI).

1.2.5.2 Ecological Risks

There are no sensitive habitats or threatened and endangered species on the Harshaw 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 likely be for human benefit. In addition, no ecosystem or habitat restoration is planned for the site. The Screening Level Ecological Risk Assessment indicates no further action is warranted with respect to ecological receptors.

1.3 UPDATES IN SUPPORT OF THE FEASIBILITY STUDY

1.3.1 Deconstruction of Building G-1

In December 2014, USACE deconstructed Building G-1, where uranium processing had taken place. All utility connections were terminated and floor drains grouted before the start of deconstruction (see discussion in Section 1.3.4, below). Deconstruction proceeded in a top-down fashion, first by cutting steel connections from the roof and allowing the roof to collapse inward. Then each story was demolished by cutting with a demolition grapple and removing steel beams at strategic points, and pushing the walls of the structure inwards. This approach kept the debris within the confines of the building slab. Deconstruction began on the southwestern corner of the structure and proceeded along a path towards the northeast part of the building, with Environmental Chemical Corporation (ECC) demolishing sections of the building as work proceeded. The three-story “high bay” section was the last portion of the building deconstructed. The building slab remained and was used to sort and stage the building debris.

The USACE shipped all building debris via truck and rail to US Ecology in Grandview, Idaho, for disposal. Debris shipments began in January 2015 and ended in May 2015. Approximately 5,500 tons of building debris were shipped to US Ecology for disposal.

Upon completion of building debris shipment, USACE cleaned and decontaminated the building slab. The USACE collected radiological wipe samples on a systematic grid and completed a gamma walkover survey to verify decontamination of the building slab. Decontamination and radiological survey efforts were completed by the end of May 2015.

Detailed information on deconstructing the former Building G-1 and decommissioning the site’s storm sewer can be found in *Project Construction Report for the Building G-1 Deconstruction and Groundwater Investigation Former Harshaw Chemical Company Site* (USACE October 2016).

1.3.2 BASF Building Removals

From 2014 to 2015, the BASF Corporation removed the five remaining former process buildings in two stages. The deconstructed buildings included the warehouse, the former foundry, the former boiler plant, a garage, and the former hydrogen fluoride plant wastewater treatment system building. The remaining buildings at the time of this report include the groundwater treatment plant, a field office trailer, and a Quonset hut. The treatment plant removes groundwater exhibiting high nickel concentrations derived from the dewatering of a sanitary sewer-line trench in the western portion of the property; this interim measure is designed to preclude nickel-impacted infiltration into the sewer line and is operated by BASF.

Consistent with regulations, contaminated building materials were sent to off-site landfills, while uncontaminated brick and concrete were crushed and left on-site to be used as fill around the site. Building foundations and slabs will remain in place until the property undergoes remediation via USEPA Resource Conservation and Recovery Act action (USEPA ID# OHD000804682).

1.3.3 Supplemental Soil Investigation

The USACE identified a data gap in soil characterization beneath former Building G-1 and along the former railroad spur that ran along the northern fence line of the site. With the deconstruction of Building G-1, USACE expanded soil sampling to the former building footprint and the railroad spur. The USACE collected additional soil data to reduce the uncertainty in contaminated soil volume estimations. Additional soil samples were collected at 57 locations, including soil samples generated from groundwater well installations. Soil sample locations are shown in Figure 4 in Attachment A. The USACE focused on areas and depths that had the most uncertainty to close data gaps pertinent to potential remedy designs.

The USACE used 2-inch by 2-inch sodium iodide gamma radiation detectors in 1-foot depth increments to scan soil borings for radioactive contamination. Generally, three depths were selected for analysis (sampled) for each soil boring: surface interval, highest scan interval, and the interval with water or native soil interface. Approximately half of the samples were drilled to bedrock, at an average depth of 9 meters or 30 feet (ft). The other half of the samples were drilled to an average depth of 2.5 meters or 8 ft. The USACE analyzed samples for concentrations of radium-226, radium-228, thorium-228, thorium-230, thorium-232, uranium-234, uranium-235 and uranium-238. The soil sampling results are shown in Table 1 in Appendix E, and laboratory reports can be found in Appendix F. The updated estimated contaminated soil volume summary is included on Table ES-1 (Summary of Estimated Contaminated Soil and Debris Volumes to Go Off-Site) and in Table 2 in Appendix E. Individual soil sample results are provided in Table 3.

1.3.4 Utilities Investigation and Decommissioning

In the fall of 2014, BASF removed a portion of the storm-sewer system in response to concerns raised by the U.S. EPA and the City of Cleveland over uncontrolled effluent discharges from two storm-sewer outfalls to the Cuyahoga River along the eastern site boundary. The BASF activities resulted in the removal of the storm-sewer lines that partially emanated from former Building G-1. Storm-sewer outfalls and laterals that fed the main lines were plugged with concrete during the sewer line removal activities. The remaining storm-sewer trenches were backfilled with 3-inch angular limestone cobble to allow for surface water infiltration. As a result, there are no longer any storm-sewer lines that allow discharge from the former Building G-1 areas to the Cuyahoga River.

In December 2014, USACE performed exploratory test pits to locate and terminate utilities associated with Building G-1 just prior to deconstruction. Utilities formerly servicing Building G-1 included water, fire suppression, roof drains, and stormwater system lines, all of which were terminated at their junctions with the building.

The USACE identified a leaking municipal water supply line north of the Harshaw Site along Old Denison Road. The leak apparently followed some legacy water lines and infiltrated into the fill below former Building G-1, basically saturating the uranium contamination below and around the building. The City of Cleveland repaired the leak in the late summer of 2014, which stopped an uncontrolled stormwater discharge to the Cuyahoga River. The groundwater investigation in Appendix B discusses the hydrogeological impacts of removing this water source from infiltrating the site (see Section 1.3.5).

1.3.5 Groundwater Investigation

The USACE identified a data gap in groundwater characterization beneath and to the north of the former Building G-1 location where an unexplained groundwater mound was identified in the subsurface. The USACE performed a groundwater investigation in conjunction with the supplemental soil investigation in 2015 and 2016. Thirteen new temporary well points (TWPs) were installed north of the Harshaw Site on January 22 and 23, 2015. The TWPs were installed to provide water level and quality measurements between the former location of Building G-1 and the municipal water supply lines under Old Denison Road. A total of 22 new groundwater monitoring wells were also installed under and around the former Building G-1 location during two campaigns in 2015. Eighteen wells were installed to address data gaps in the existing monitoring well network. The USACE also upgraded four previously installed well points to permanent monitoring wells.

To account for seasonality and changes to site conditions, USACE performed groundwater level gauging and sample collection throughout 2015 and 2016; see Appendix B for a detailed analysis of the data.

In general, water level measurements from 104 wells dating back to 2003 were evaluated to determine whether site groundwater is reacting to: 1) the demolition of site buildings (mid-2015),

2) repair of the municipal water lines (late summer 2014), and 3) the termination of site water (May 2015). Groundwater elevation data collected in January and June 2016 and March 2017 depict lower groundwater levels when compared to historical levels. This decrease in groundwater elevations is largely attributed to the repair of a water line leak under Old Denison Road that stopped saturating the shallow fill under and near former Building G-1. Groundwater fluctuations were otherwise generally consistent with historically documented seasonal fluctuations.

Total uranium concentrations (total U) in groundwater samples collected at the Harshaw Site are summarized on Tables 4 and 5 in Appendix E. The data was assessed for temporal trends at each monitoring well. In general, the trend analyses indicate a stable plume that is not undergoing significant mass transport from the soil-source areas (i.e., 73 percent of site wells are stable or decreasing in uranium concentration). Fourteen wells appear to be reequilibrating to the water line repair and site changes by declining in concentrations, which should continue to lessen with time (i.e., the surcharge of the contaminated surficial fill has ceased and natural conditions are emerging). Of the ten wells exhibiting increasing or probably increasing trends, eight are below the drinking-water standard of 30 micrograms per liter (µg/L) for total uranium. The remaining two wells, IA10-MW001 and RMW39, averaged 32 µg/L and 71.6 µg/L for total uranium concentrations, respectively. See Appendix B for a detailed discussion of water quality and trends.

As indicated in Appendix B, the new CSM and associated numerical groundwater rendering did not change the conclusion of the RI and FS: the plume will remain on-site and at concentrations similar to those currently observed due to residual leachate additions. The plume expands slightly with time, but disperses and attenuates into the thicker alluvium that flanks the bedrock high. The plume would not impact the Cuyahoga River with concentrations that could put the surface water resource at risk (e.g., the maximum discharge concentration to the river is 9 µg/L of total uranium, which is instantly diluted).

1.3.6 Riverbank Stability Assessments

To support previous FS analyses and provide planning support for potential remedial actions, USACE performed hydraulic modeling of the Cuyahoga River and Big Creek waterways to assess riverbank stability. The detailed summary of the watershed modeling is included in Appendix C. The analysis indicates that a potential exists for long-term erosive forces (shear stresses) to scallop the current bank along OU-1. This could possibly increase the risk to future remedies. By assessing the subsurface geology (via soil borings) and other nearby riverbanks (i.e., historical banks and floodplains), USACE determined that uncontrolled erosion of the fill by the river may allow the river to encroach upon the groundwater plume. Under the erosion scenario assessed in Appendix C, the equilibrium channel would reflect known “pre-site conditions” and would not affect groundwater and soil near the former Building G-1 location. A modified groundwater model that simulated a partially eroded site estimated that the uranium plume would discharge more mass to the river, but the release could not affect river quality. Based on this information, no modification to the remedial alternatives is required to address riverbank stability.

The resulting groundwater flow and uranium-transport simulations did not show significant changes in plume fate (i.e., it did not grossly change the long-term configuration), although the Cuyahoga River would receive higher uranium concentrations from baseflow over the 1,000-year period (Figure B-38). A maximum concentration of 37 µg/L (at year 1,000) occurs along a 25-foot long stretch of bank represented by one model cell, whereas the balance of the baseflow concentrations are significantly less. This maximum concentration is greater than the baseline value of 9 µg/L since the river is closer to the higher concentration plume area. Figure B-39 shows an overall greater flux to the river due to the simulated erosion, even though the baseflow rate is reduced from 1,154 cubic feet per day to 444 cubic feet per day due to less recharge area (i.e., some of the site is eroded). The concentration curve shows the baseflow concentrations initially attenuating (i.e., decline as the plume is flushed from soils near the new bank) and then increasing as higher plume concentrations nearer to Building G-1 slowly migrate towards the river.

This condition does not appear to place the riverine environment at risk from uranium (i.e., discharge concentrations are still low and would be attenuated by dilution in the river), but the potential for this erosion scenario to accurately depict a likely future bank morphology is uncertain.

2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section presented the remedial action objectives (RAOs), ARARs, and general response actions (GRAs), and presents the initial identification and screening of technology types and process options considered for possible use in site remediation.

Due to lack of remaining building materials to address in OU-1, the RAOs for both OU-1 and OU-2 were revised to prevent exposure to impacted soil containing concentrations of COCs to ensure the critical group (construction worker and adult resident, respectively) does not receive a dose equivalent exceeding 25 mrem/yr total effective dose equivalent (TEDE) above background.

No updates to the ARARs, GRAs, and the identification and screening of technologies are required since the 2012 FS, with the exception of the removal of treatment options previously evaluated in Section 2.3.1.4. Treatment options have been incorporated into other alternatives and are therefore redundant as stand-alone options (see discussion in Section 3.1.4 and 3.1.8, below).

3. DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 DEVELOPMENT OF ALTERNATIVES

Based on the RI-based risk assessment and FS-based ARAR evaluation (USACE 2009 and USACE 2012), a remedial action is required to address FUSRAP-related contaminants in soil within OU-1 and OU-2. The alternatives are summarized on Table ES-2 (Summary of Remedial Alternatives). The FS detailed OU-specific alternatives, which are abbreviated below to account for any modifications derived from site actions since the original FS. The remedial action objectives (RAOs) developed for the 2012 FS are not changed for this FSA, except the RAOs developed for buildings have been eliminated.

As indicated in the 2012 FS, the RAOs developed for soil in OU-1 and OU-2 are to prevent exposure to impacted soil containing concentrations of COCs to ensure the critical group (construction worker or adult resident, respectively) does not receive a total dose equivalent exceeding 25 mrem/yr.

The RAOs above will be achieved using cleanup goals based on COC-specific preliminary remediation goals (PRGs) developed for the critical group for OU-1 and OU-2. For soil 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 residential future land use, is defined as the adult resident.

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

Table 3-1. PRGs for OU-1 and OU-2 Soil

COC	Construction Worker PRG (OU-1)[a]	Adult Resident PRG (OU-2)[a]	Average Background Concentration
	(pCi/g)	(pCi/g)	(pCi/g)
Ra-226[b]	9.1E+00	3.6E+00	9.4E-01
Th-230	3.5E+01	1.6E+01	8.8E-01
Th-232[c]	6.0E+00	3.6E+00	9.8E-01
Total U[d]	4.0E+02	3.6E+02	3.8E+00
U-238[e]	1.9E+02	1.5E+02	1.3E+00

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]PRG for total U includes contribution to dose from U-234, U-235, and U-238, assuming natural abundance of uranium isotopes (in ratio of U-234:U-235:U-238 1:0.046:1).
[e]U-238 can be used as surrogate for total U PRG by multiplying total U PRG by U-238's activity fraction (0.489).
CAS = Chemical Abstract Service

COC = Constituent of Concern
N/A = not applicable
OU = Operable Unit
pCi/g = PicoCuries Per Gram
PRG = Preliminary Remediation Goal
RESRAD = Residual Radioactivity Computer Code

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. 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 landowners would be responsible for this compliance.

The CSM was updated based on newly collected soil and groundwater data since the FS (see Appendix B). The new CSM was assessed for impacts to Alternative 1. No significant changes in the ratings of Alternative 1 were identified.

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

Alternative 2 is a limited action alternative previously consisting of the dismantlement of Building G-1 and the off-site disposal of the building debris, bank stabilization, land use controls, and site monitoring. Since USACE deconstructed Building G-1 in 2015, the site now meets the standards in 10 CFR 20, Subpart E, Section 20.1403, Radiological Criteria for License Termination Under Restricted Conditions. Specifically, the critical group receptor may not be exposed to dose limits of 100 mrem/yr TEDE, or 500 mrem/yr TEDE should institutional controls fail (see baseline worker radiological doses in Table 1-5 of the 2012 FS). Contamination in soil is at levels that meet ARAR dose limits required for the application of institutional controls (i.e., they are greater than 100 mrem/yr TEDE but less than 500 mrem/year). Under this alternative, the remaining impacted media at OU-1 would remain in place, with no implementation of other active remedial measures involving removal.

Components of this alternative include:

- Remedial design plan.
- Bank stabilization.

- Land use controls.

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 in the OU-1 portion of 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 potential for human exposure for the critical group (construction worker) to contaminated soil located in OU-1. Access controls, such as fencing, would be implemented under this alternative. Although the land use controls may preclude exposures to the critical group, under this alternative the land could be employed as passive recreation (e.g., concrete bike or walking paths); this scenario assumes no full-time maintenance or commercial workers would maintain the land. Informational tools would include posting signs and placing placards to indicate the presence of hazardous substances and warn against intruding onto the impacted portion of OU-1.

All appropriate substantive requirements relating to the implementation of this alternative will be considered and addressed in the remedial design. 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.

The CSM was updated based on newly collected soil and groundwater data since the FS (see Appendix B). The new CSM was assessed for impacts to Alternative 2. The alternative is still viable. The cost of Alternative 2 was refined in this addendum to account for USACE and BASF building demolitions (see Section 4) and 2016 pricing.

3.1.3 Alternative 3—Complete Removal and Off-Site Disposal (OU-1)

Alternative 3 consists of excavation of impacted soil exceeding the PRGs in OU-1 and subsequent off-site disposal. The soil sampling and well installation program provided new laboratory data that was used to refine the contaminated soil volumes to be shipped off-site for this alternative; the volume (and associated uncertainty) was reduced from 25,300 cubic yards to about 5,178 cubic yards.

Building G-1 was dismantled so USACE could access impacted soil beneath the building slab/foundation. Contaminated building material above PRGs at the remaining buildings was removed, and the buildings were returned to a safe condition (e.g., removal or replacement or decontamination of contaminated concrete window sills). This alternative would require landowner/tenant coordination to minimize health and safety risks to on-site individuals and the disruption to activities consistent with a safe and effective remediation. Since this action will address only soil impacted by AEC/MED activities, stakeholder coordination would also be required to address non-MED/AEC-impacted soil left on-site.

Components of this alternative include:

- Remedial design plan.
- Excavation.
- Transportation.
- Off-site disposal.
- Confirmatory sampling.
- Site restoration.

All appropriate substantive requirements relating to the implementation of this alternative will be considered and addressed in the remedial design. 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.

The following changes have been made to Alternative 3 since the 2012 FS:

- The estimates of contaminated soil have been refined using the data collected during the supplemental soil investigation.
- This alternative previously included building removal remedy components; however, this work was completed prior to remedy selection. As such, these components have been removed from the alternative.
- The method of excavation stabilization adjacent to the Cuyahoga River has been updated from sheet piling to a cofferdam. The cofferdam would offer additional structural integrity over the sheet piling with resilience to flow fluctuations not thoroughly considered in the 2012 FS.
- The cost estimate has been updated with 2016 pricing.

- Alternative 3 has also been revised to clarify the disposal method(s) proposed. The soil excavated from OU-1 may be characterized as low activity radioactive waste or as mixed waste. Low activity radioactive waste may be disposed of at a disposal facility without treatment. Mixed waste is impacted with both low activity radiological and inorganic contaminants, and requires treatment prior to land disposal to comply with the Resource Conservation and Recovery Act Land Disposal Restrictions (LDRs). The cost estimate for Alternative 3 includes a conservative assumption that the mixed waste will be shipped off-site for treatment by a mixed waste disposal facility prior to land disposal. As a cost saving measure, the future remediation contractor may choose on-site treatment of mixed waste for the RCRA component and satisfy LDRs for placement into an off-site land based unit. The on-site treatment could eliminate the requirement for the disposal facility to treat the waste and may allow the waste to be accepted directly into a disposal facility.
- The CSM was updated based on newly collected soil and groundwater data since the FS (see Appendix B).

The new CSM and updates to the alternative components led to lower remedial costs (based on the completed deconstruction of Building G-1, decreased soil volumes for excavation, etc.) and increased the viability of Alternative 3, which is reflected in the rating of the alternative.

3.1.4 Alternative 4 – Complete Removal With *Ex Situ* Treatment and Off-Site Disposal (OU-1)

Alternative 4 consisted of excavation of impacted soil exceeding the PRGs in OU-1 (as updated in 2015-2016), *ex situ* treatment by solidification and/or stabilization, and subsequent off-site disposal. Based on the clarification of the disposal requirements for Alternative 3, Alternative 4 has become redundant. Alternative 4 was removed from further consideration.

3.1.5 Alternative 5—No Action (OU-2)

Alternative 5 leaves the OU-2 portion of 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 landowners 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 in the OU-2 portion of 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 potential for human exposure for the critical group (resident) to contaminated soil located in OU-2. Access controls, such as fencing, would be implemented under this alternative. Although the land use controls may preclude exposures to the critical group, under this alternative the land could be employed as passive recreation (e.g., concrete bike or walking paths); this scenario assumes no full-time maintenance or commercial workers would maintain the land. Informational tools would include posting signs and placing placards to indicate the presence of hazardous substances and warn against intruding onto the impacted portion of OU-2.

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 evaluations would be required to document the effectiveness of this alternative.

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 unrestricted use/unlimited exposure. Alternative 6 is considered to be protective.

The cost of Alternative 6 was refined to account for inflation since the completion of the 2012 FS (see Section 4).

3.1.7 Alternative 7—Complete Removal and 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 individuals. Stakeholder coordination would also be required to address soil to be left on-site.

Components of this alternative include:

- Remedial design plan.
- Excavation.
- Transportation.
- Off-site disposal.
- Confirmatory sampling.
- Site restoration.

Alternative 7 has also been revised to clarify the disposal method(s) proposed. The soil excavated from OU-2 may be characterized as low activity radioactive waste or as mixed waste. Low activity radioactive waste may be disposed of at a disposal facility without treatment. Mixed waste is impacted with both low activity radiological and inorganic contaminants, and requires treatment prior to land disposal to comply with the Resource Conservation and Recovery Act Land Disposal Restrictions. The cost estimate for Alternative 7 includes a conservative assumption that the mixed waste will be shipped off-site for treatment by a mixed waste disposal facility prior to land disposal. As a cost saving measure, the future remediation contractor may choose on-site treatment of mixed waste for the RCRA component and satisfy LDRs for placement into an off-site land based unit. The on-site treatment could eliminate the requirement for the disposal facility to treat the waste and may allow the waste to be accepted directly into a disposal facility.

Alternative 7 would achieve levels acceptable for unrestricted use/unlimited exposure. Five year reviews are not required.

All appropriate substantive requirements relating to the implementation of this alternative will be considered and addressed in the remedial design.

The cost of Alternative 7 was refined since the completion of the FS (see Section 4).

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

Alternative 8 consisted of excavation of impacted soil exceeding the PRGs in OU-2, *ex situ* treatment by stabilization and solidification, and subsequent off-site disposal. Based on the clarification of the disposal requirements for Alternative 7, Alternative 8 has become redundant. Alterative 8 was removed from further consideration.

4. DETAILED ANALYSIS OF ALTERNATIVES

Summaries of comparative analysis of remedial alternatives for OU-1 and OU-2 are presented in Tables ES-4 and ES-5, respectively, including updated cost estimates. Cost estimates are intended to form a basis for comparing alternatives and support remedy selection. The original FS cost estimates were presented in Section 4.3.7 and Appendix C of the feasibility study (USACE 2012). Those estimates were updated to reflect the changes detailed in this FSA.

The USACE applied updates to the CSM and made the following changes to the remedial alternatives:

- Removed all costs related to the removal of the former Building G-1
- Updated estimated soil volumes for excavation, backfill, and disposal
- Added USACE oversight costs to estimates
- Removed costs related to the decontamination of the boiler plant, warehouse, foundry, and garage
- Used the installation of a cofferdam during excavation adjacent to the Cuyahoga River instead of the sheet piling used in the original estimate
- Updated the abbreviated cost and schedule risk assessment
- Updated all unit costs from August 2012 (4Q12) to February 2016 (2Q16)
- Adjusted the discount factor to 3.26 percent

The costs for the following alternatives were updated to reflect the new conceptual site model:

- Alternative 2—Limited Action and Land Use Controls (OU-1)
- Alternative 3—Complete Removal With Off-Site Disposal (OU-1)
- Alternative 6—Limited Action and Land Use Controls (OU-2)
- Alternative 7—Complete Removal With Off-Site Disposal (OU-2)

The balance of the alternatives did not require updates since they either have no costs associated with the alternative (No Action) or have been removed from future consideration, including:

- Alternative 1—No Action (OU-1).
- Alternative 5—No Action (OU-2).
- Alternative 4—Complete Removal With *Ex Situ* Treatment and Off-Site Disposal (OU-1).
- Alternative 8—Complete Removal With *Ex Situ* Treatment and Off-Site Disposal (OU-2).

The USACE updated the unit prices using Engineer Manual EM1110-2-1304, the Corps of Engineers Civil Works Construction Cost Index System Amendment #9 tables, revised as of September 30, 2016. The Civil Works Breakdown Structure Feature Code 19 Buildings, Grounds & Utilities was used since there is no hazardous, toxic or radioactive waste feature code. The duration for each alternative was updated using productivity factors and engineering judgment.

The present value analysis is a method to evaluate expenditures, either capital or operations and maintenance (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. The remedial alternatives were evaluated using a 0–1,000-year period of performance and a 3.26 percent discount factor. The capital and design costs were not discounted due to their relatively short implementation duration (e.g., less than 5 to 10 years).

Tables 10 and 11 in Appendix E present a summary of the projected remedial costs and contingencies. Alternative 2, Limited Action and Land Use Controls (OU-1), has a lower total capital cost ($4,545,926) over Alternative 3, Complete Removal with Off-Site Disposal (OU-1), ($32,551,854). The average annual O&M costs for Alternative 2 ($58,650) are higher than those for Alternative 3 ($8,078) resulting in a higher non-discounted total cost for Alternative 2 ($63,195,848) when compared to Alternative 3 ($40,629,675). The discounted O&M and total costs for Alternative 2 ($1,640,332 and $6,186,258, respectively) are less than the discounted O&M and total cost for Alternative 3 ($232,148 and $32,784,001, respectively). The results of a comparison of costs associated with Alternative 6, Limited Action and Land Use Controls (OU-2), and Alternative 7, Complete Removal with Off-Site Disposal (OU-2), are similar. Alternative 6 has a lower total capital cost ($2,420,176) over Alternative 7 ($5,909,693). The average annual O&M costs for Alternative 6 are $40,396 while there are no annual O&M costs associated with Alternative 7. The discounted O&M and total costs for Alternative 6 are $1,230,031 and $3,650,207, respectively while the total discounted cost for Alternative 7 is $5,909,693.

Appendix G contains the detailed cost sheets, including all key parameters and quantities used in the estimates.

5. REFERENCES

USACE 2009. *Former Harshaw Chemical Site Remedial Investigation Report, Revision 1*. October.

USACE 2011. *Former Harshaw Chemical Company FUSRAP Site Cleveland, OH Record of Decision Investigative Area – 06*. March.

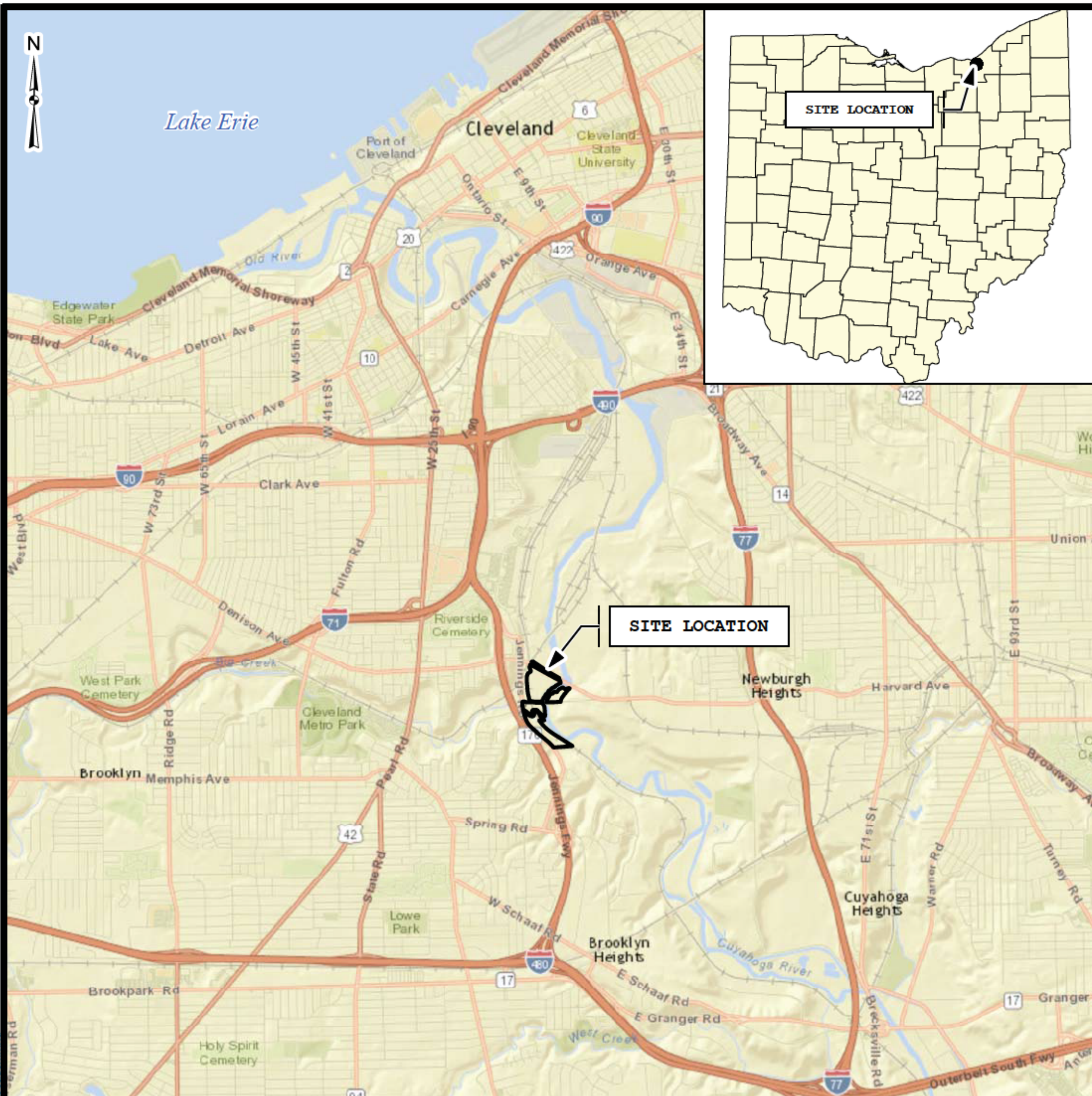
USACE 2012. *Former Harshaw Chemical Company Site Feasibility Study Report*. September.

USACE 2017. *Project Construction Report for the Building G-1 Deconstruction and Groundwater Investigation Former Harshaw Chemical Company Site*. May 2017.

USEPA 2013. Statistical Software ProUCL 5.0.00 for Environmental Applications for Data Sets with and without Nondetect Observations, USEPA/600/R-07/041. September 2013. https://www.epa.gov/land-research/proucl-software

APPENDIX A

FIGURES



Legend

Site Boundary

0 0.5 1 2 Miles

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
BUFFALO, NY

US Army Corps of Engineers
Buffalo District

SITE LOCATION

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FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE 1

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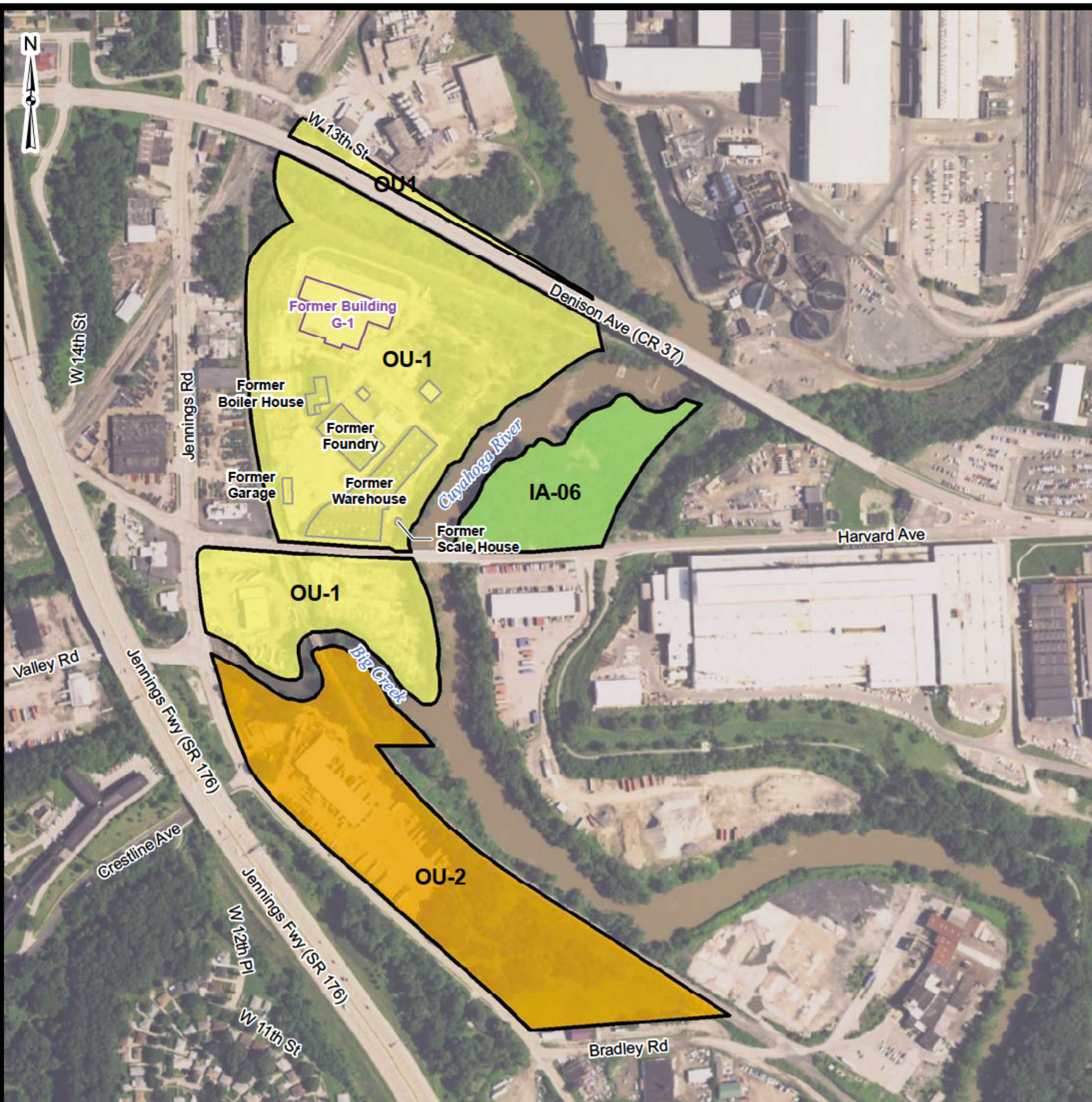

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Site Boundary

0 250 500 1,000 Feet

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SITE LAYOUT

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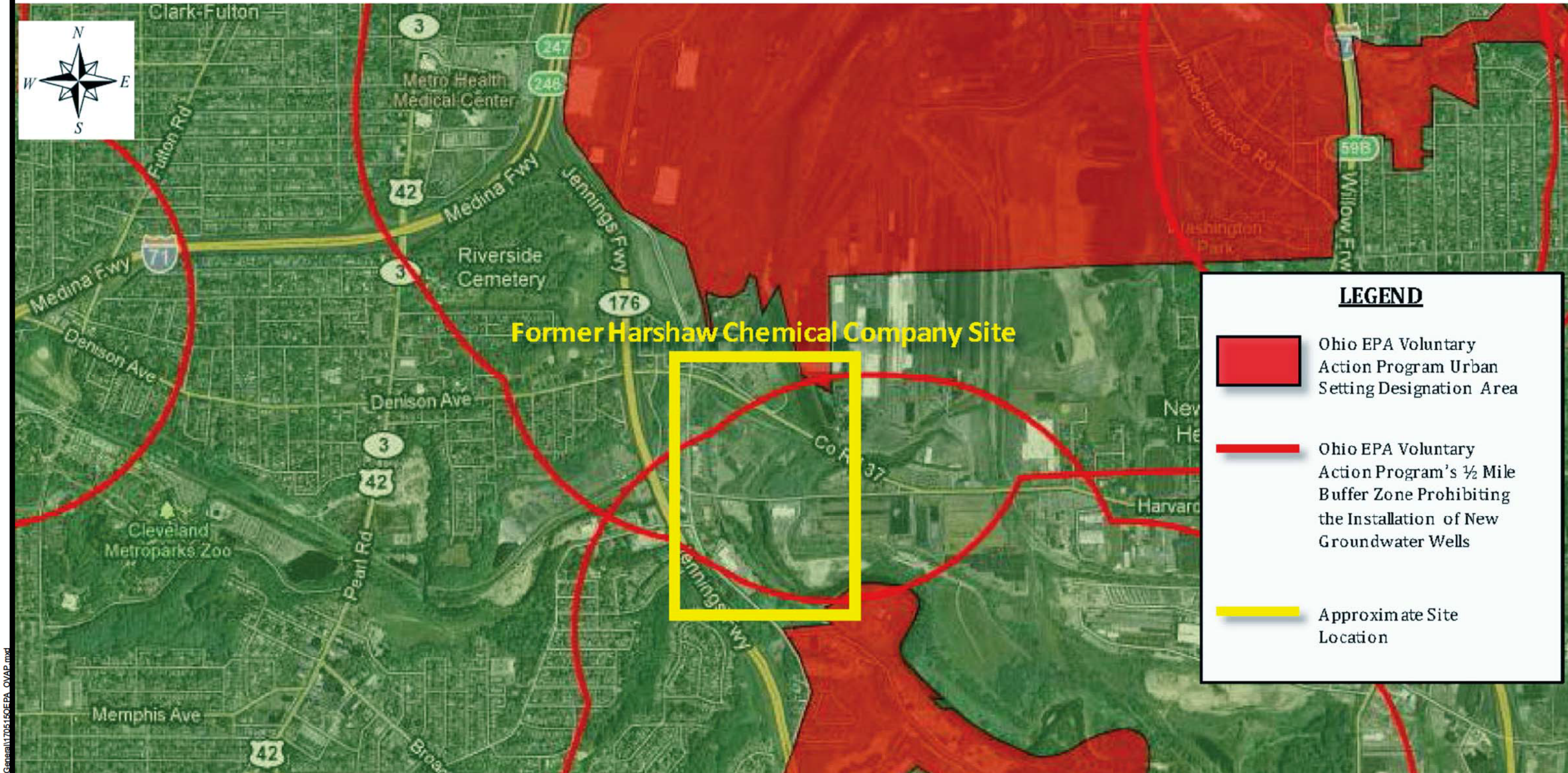
FIGURE 2



Note: Image provided by Ohio EPA.

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OHIO VOLUNTARY ACTION PROGRAM
URBAN SETTING DESIGNATION AREA BOUNDARIES

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FIGURE 3

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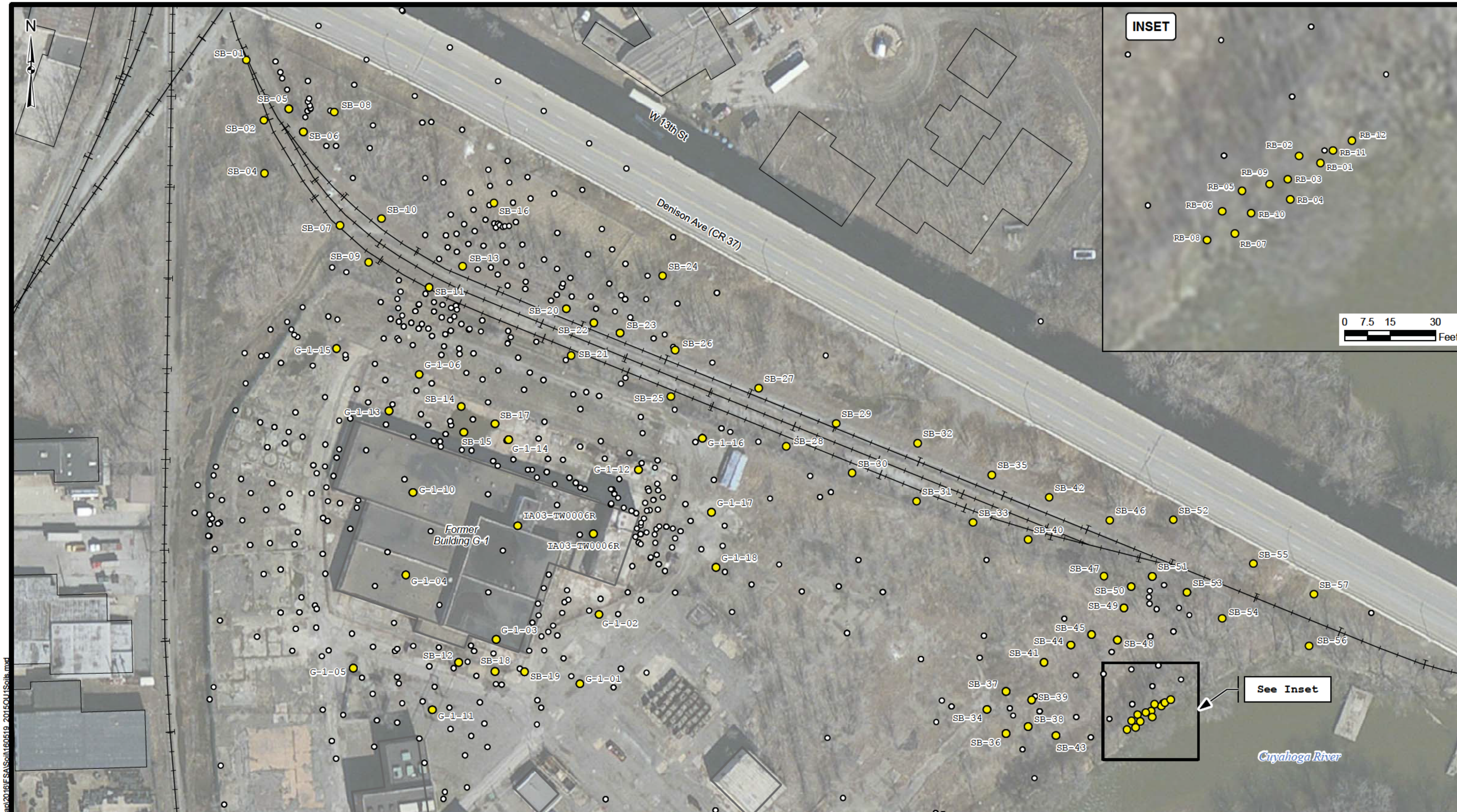

Legend

- 2015 Soil Sample Location
- Previous Soil Sample Location
- Railroads
- Site Buildings

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

0 50 100 200 Feet

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2015 SOIL SAMPLE LOCATIONS

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FIGURE 4

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Legend

- Spatial Extent of Contamination (BAASS 80% Probability)
- Site Buildings
- OU1 Boundary
- OU2 Boundary

Depth of Contamination (ft bgs)

< 2	6 - 8	12 - 14
2 - 4	8 - 10	14 - 16
4 - 6	10 - 12	> 16

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

0 125 250 500 Feet

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PLANNED AREAS OF EXCAVATION

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FIGURE 5

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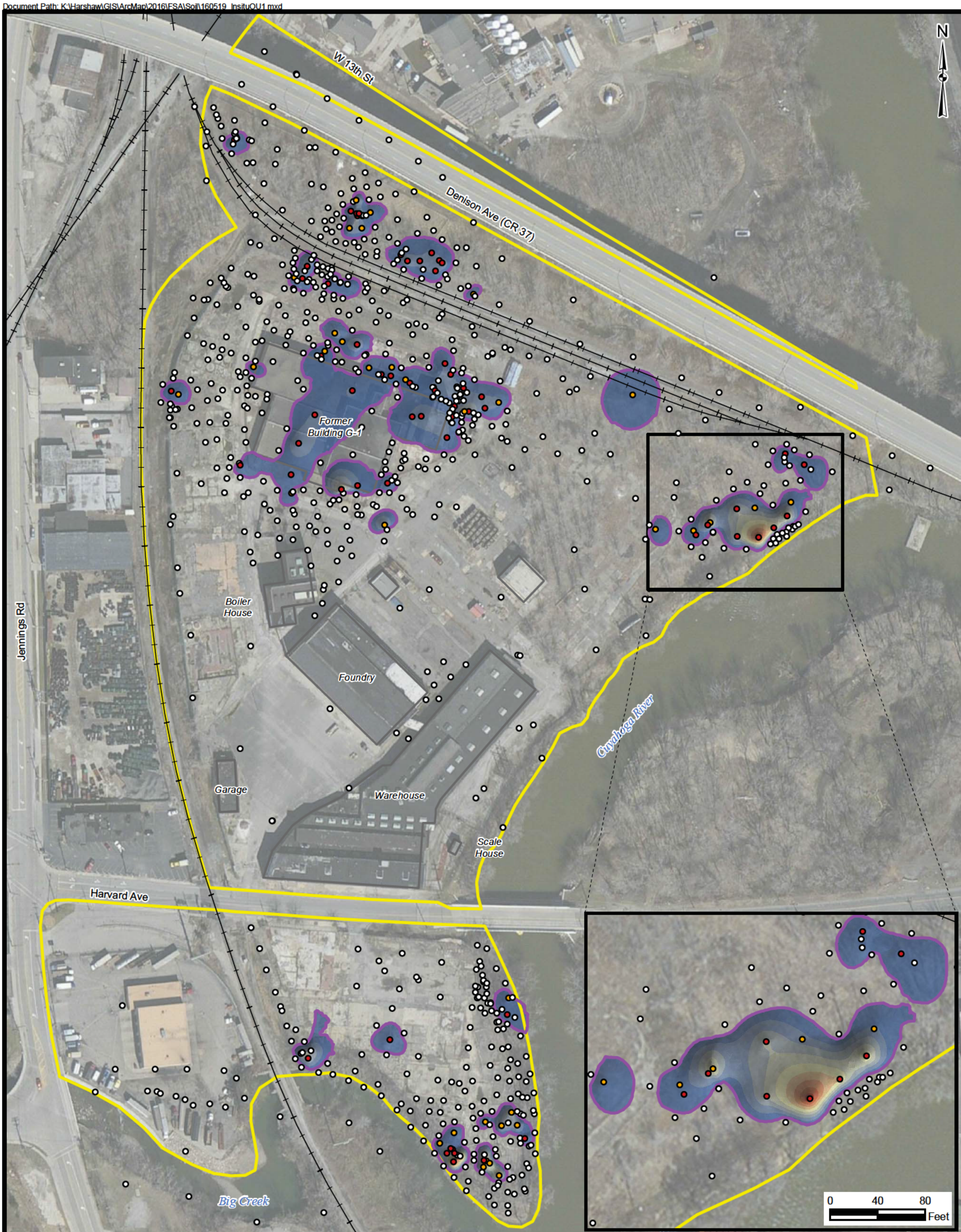

Legend

- SOR < 0.5
- SOR 0.5 - 1
- SOR > 1
- Spatial Extent of Contamination (BAASS 80% Probability)
- OU1 Boundary
- Site Buildings

Depth of Contamination (ft bgs)

< 2	6 - 8	12 - 14
2 - 4	8 - 10	14 - 16
4 - 6	10 - 12	> 16

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

0 80 160 320 Feet

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BAASS MODEL OUTPUTS FOR OU1

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CLEVELAND, OHIO

FIGURE 6

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Legend

- SOR < 0.5
- SOR 0.5 - 1
- SOR > 1
- Spatial Extent of Contamination (BAASS 80% Probability)
- OU2 Boundary
- Site Buildings

Depth of Contamination (ft bgs)

- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- > 16

0 50 100 200 Feet

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SPATIAL AND VERTICAL INSITU EXTENT OF FUSRAP CONTAMINATED SOIL FOR OU2

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FIGURE 7

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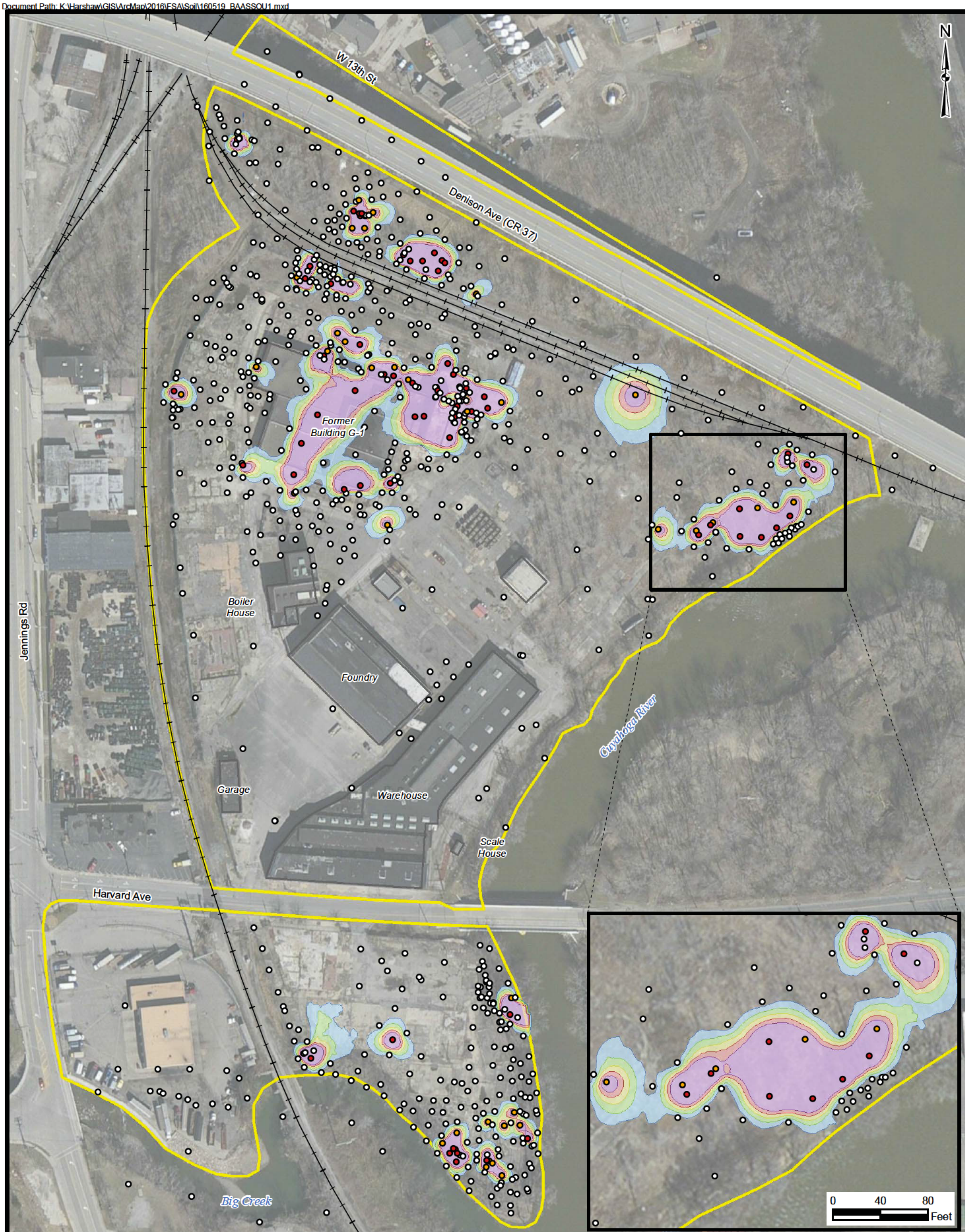

Legend

- SOR < 0.5
- SOR 0.5 - 1
- SOR > 1
- OU1 Boundary
- Site Buildings

BAASS Model Model Output

- 50% Probability
- 60% Probability
- 70% Probability
- 80% Probability
- 90% Probability

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

0 80 160 320 Feet

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BAASS MODEL OUTPUTS FOR OU1

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CLEVELAND, OHIO

FIGURE 8

Legend

- SOR < 0.5
- SOR 0.5 - 1
- SOR > 1
- OU2 Boundary
- Site Buildings

BAASS Model Model Output

- 50% Probability
- 60% Probability
- 70% Probability
- 80% Probability
- 90% Probability

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

0 50 100 200
Feet

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BAASS MODEL OUTPUTS FOR OU2

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FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE 9

APPENDIX B

GROUNDWATER INVESTIGATION

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1. GROUNDWATER INVESTIGATION

1.1 INTRODUCTION

Groundwater conditions at the Former Harshaw Chemical Company Site were investigated by site owners throughout the 1990s and later by USACE. These investigations are summarized in the remedial investigation (RI) and feasibility study (FS) reports (USACE 2009, USACE 2012). The dismantling of the G-1 Building by USACE, along with site-owner demolition of other buildings, allowed USACE to optimize the delineation of soil and groundwater contamination and ensure remedial alternatives reflect accurate site conditions, including externalities that affect site hydrogeology and uranium migration.

The majority of MED/AEC-related soil and groundwater contamination underlies Operational Unit 1 (OU-1), so the USACE groundwater analyses focused on OU-1 (Figure B-1 and Figure B-2). Groundwater in the OU-1 subsurface flows generally from west to east across the site, with the Big Creek and Cuyahoga River being the receiving waters (Figure B-3). The primary groundwater flow zone is a silty shale-rich gravel fill layer near Building G-1, which grades into a native coarse-grained alluvium under the balance of the site. Both the water-bearing zones are capped by two anthropogenic fill layers and underlain by the Cuyahoga Shale bedrock. Figure B-4 depicts the fill layers, the approximate shale-rich fill zone, and the thicker alluvium where the bedrock deepens on the site (Section 1.3 expands the geologic discussion).

Groundwater level measurements indicate the dominant east to west groundwater flow near the site is interrupted by a groundwater mound under Building G-1 and the boiler plant, which also coincides with shallow bedrock and thus thinner soil layers. This high-water condition provides a physical mechanism to saturate soil-based contamination under and around Building G-1, which produced the uranium impacts observed in site groundwater (Figure B-2). Thorium also was observed in groundwater and is collocated with the highest uranium impacts directly under Building G-1. However, the thorium impacts do not exhibit migration.

The source of the groundwater mound also promoted the leaching and transport of uranium through groundwater that partially infiltrated the site storm-sewer system, which discharged to the Cuyahoga River (see sampling location IA09-SW0008 or BASF Outfall 007 on Figure B-3). Uranium concentrations in the discharge varied over a four-year period, yet pipe flow rates were consistent even during prolonged dry-weather periods. The geochemical profile of the discharge (e.g., potential of hydrogen [pH], oxygen reduction potential [ORP], specific conductance, natural metals, and common anions) indicated a diluted groundwater source; i.e., groundwater constituents were present at concentrations at or less than characteristic site ranges. A storm-sewer sampling program verified remedial investigation results and indicated that the sewer system and other utility features (e.g., valve pits) near Building G-1 were receiving uranium-impacted groundwater (Figure B-5) (USACE 2013).

During the planning phase of the Building G-1 deconstruction, USACE also evaluated the municipal water-supply lines that exist north of the Harshaw Site, along Old Denison Road (directly north of and parallel to the Harvard Denison Road Bridge). The utility consists of a singular 42-inch high-pressure, water-supply line that traverses the Cuyahoga River and splits into two 24-inch diameter, high-pressure (~160 pounds per square inch [PSI]), municipal water supply lines (Figure B-5). This system exhibited long-term leakage that created a wetland feature surrounding the vault that housed the utility split. The Cleveland Water Department repaired the line leakage in 2015, which caused:

1) The surrounding land surface to dry out.
2) The site storm-water outfall (IA09-SW0008) to cease continuous discharge.
3) The reduction in groundwater levels in several site wells.

The dismantlement of Building G-1 throughout 2014 and 2015 allowed the execution of the groundwater and soil investigation that refined the delineation of FUSRAP-related contamination on the site, which led to an update of the alternative cost analyses.

1.2 INVESTIGATION ACTIONS

1.2.1 Temporary Well Point Array

Thirteen new temporary well points (TWPs) were installed north of the Harshaw Site from January 22, 2015, through January 23, 2015, using a direct-push technology (Figure B-6). The TWPs were installed to provide groundwater levels and water-quality measurements between Building G-1 and the municipal water-supply lines under Old Dennison Road.

The well installation, construction, and sampling data are reported in Appendix B of the construction report (USACE 2016). The geologic data from boring logs were input to the site geographic information system (GIS) that was used to update geologic information related to the soil volume estimates, along with the numerical groundwater flow and contaminant-transport model (see Section 3). The TWPs penetrate the upper two fill layers that averaged about 12 feet in thickness; the well screens are between 20- and 30-feet deep in the native alluvial sediments. The shale-based gravel layer is not evident in the borings since the conditions north of G-1 are similar those east of G-1, where bedrock topography declines and alluvium dominates the groundwater flow regime.

Water sampling was conducted using a peristaltic pump, and water-quality measurements were collected at several five-minute intervals during sampling events on January 26, and 29, 2015; a calibrated Horiba U-52 water quality instrument (sonde) was used to determine water quality parameters. One round of uranium samples was collected to support contaminant delineations. Groundwater sampling results are discussed in the well installation report found in the construction report (USACE 2016).

1.2.2 Groundwater Monitoring Well Installation

A total of 23 monitoring wells were installed or modified under and around Building G-1 during two campaigns in 2015 (Figure B-6). Eighteen wells were installed to address data gaps in the existing monitoring well network, whereas five previously installed wellpoints were reinstalled or upgraded to permanent monitoring wells. These wells augment the previous well array that monitor the fill layers and/or native sediments under and around Building G-1. Consequently, the wells varied in screened length, sand-pack thickness, and boring depth to account for the thickness of the groundwater zones below the site (i.e., depth to shale bedrock). The well installation and construction data are reported in Appendix B of the construction report (USACE 2016).

The OU-1 site area now includes 94 wells and wellpoints that are screened in the fill layers and/or native sediments, or bedrock (one well); OU-2 contains 12 monitoring wells screened in native sediments (mainly historic Cuyahoga River sands and gravels).

The new wells were developed to optimize clarity and representativeness of samples. Lithologic logs of the soil borings containing the new wells also were input to the site GIS, which was used to update the site conceptual and numerical models.

Sampling results for total uranium (and water levels) from these wells were incorporated into the project database and used in the analyses discussed in this Attachment A. Appendix B of the Building G-1 construction report (USACE 2016) contains the laboratory reports.

1.2.3 Test Pit Observations

On January 28, 2015, USACE excavated five test pits to explore subsurface conditions near underground utilities at the Harshaw Site. Three other pits and trenches excavated before the Building G-1 dismantlement unearthed several utilities (e.g., water and electric). The locations of the test pits shown on Figure B-6 are identified with "TP" in the name (Figure B-12 also exemplifies the locations). These pits varied in depth between 1 meter and 3 meters, or 3 feet and 10 feet, depending on utilities or lithology (fill or soil layers) encountered.

The utilities entering and leaving Building G-1 included exterior water transmission lines, fire suppression lines, roof drains, and stormwater drains connected to the site-wide storm-sewer system. All visible exterior utilities were terminated and/or plugged at their junctions, preferably within nearby utility vaults or where tied into the main water-transmission and sewer network serving the Harshaw Site.

Field filtered groundwater samples from the five test pits obtained with a peristaltic pump and characterized with a Horiba water-quality sonde were collected for total uranium analyses. Physical trench observations are in Appendix B of the construction report (USACE 2016).

Section 3 discusses how the analytical results from the water samples tie into the overall groundwater characterization effort.

1.3 CONCEPTUAL HYDROGEOLOGIC MODEL UPDATE

The conceptual site model of the hydrogeology is based on three simplified soil sequences that underlie the site. On-site and site area soils generally consist of one to two surficial fill layers that overlie a silty and clayey shale-rich gravel that grades into natural floodplain and alluvial deposits derived from historical (post-glacial) Cuyahoga River flows. The gravel layer consist of mixed soils and shale fragments that were derived from the leveling of a bedrock remnant (topographic high) during early site development (USACE 2012). The bedrock mound below former Building G-1 and the boiler plant is the remaining portion of the original outcrop. The shale-rich gravel and alluvium layers transmit the majority of groundwater under the site. The extent and thickness of the site layers are depicted in the following figures:

- Total thickness of the overburden soil (both fills and native): Figure B-7
- Thickness of new or coarse-grained fill: Figure B-8
- Thickness of older clayey fill: Figure B-9
- Thickness of water-bearing sediments (shale-rich gravel and alluvium): Figure B-10
- Topography of the bedrock contact with soils: Figure B-11

Groundwater observed as perched saturation in select areas of the site is contained in a surficial coarse-grained (new) fill layer. This perched water partially recharges the underlying clayey (old) fill and the shale-rich gravel below; some perched saturation appears to disperse laterally from the Building G-1 area in the fill. This condition was observed via the sampling of shallow test pits (~1 meter or 3 feet deep) north of Building G-1, where uranium impacts were evident in the pit water (Figures B-2 and B-4). The underlying shale-rich gravel layer grades into the native alluvium as the bedrock high radially declines away from the former Building G-1 and the boiler plant area. In general, once the bedrock is deeper than 3 to 4.5 meters, or 10 to 15 feet, the shale-rich gravel pinches out and the alluvium dominates the overburden thickness and associated groundwater flow zone. Soil boring logs note where the darker shale gravel is different from the lighter-colored coarse-grained alluvium.

In subsurface areas that are dominated by the alluvium (and associated floodplain deposits that are occasionally seen in soil borings), the overlying fill units can also thicken to account for one-third of the total overburden. This is most notable in the eastern portion of OU-1, where the fill elevated the industrial plateau above the historic Cuyahoga River floodplain. Below the shale-rich gravel and alluvium, the shale bedrock is not a significant flow zone due to low permeability (USACE 2009, USACE 2012).

The new hydrogeologic data are described in greater detail below, with respect to contaminant transport.

1.3.1 Perched Water Zone

The combined overburden on the Former Harshaw Site varies from less than 0.6 meter to nearly 12 meters (or 2 feet to nearly 40 feet) in thickness (Figure B-7). The uppermost surficial fill is a well- to moderately drained, coarse-grained layer containing, or in contact with, radiologic contamination (Figures B-1 and B-8). Results of the groundwater investigation indicate this upper fill contains perched water in areas near Building G-1, which allows some dissolved uranium to disperse laterally away from G-1. This dispersion was exemplified by the uranium concentrations observed in several utility trenches and test pits surrounding Building G-1 (Figure B-2). The perched uranium plume can migrate vertically into and through the underlying finer-grained fill, especially where thin or absent (Figure B-9). The clayey fill is a leaky aquitard between the perched zone and underlying shale-rich gravel, where perched contamination can migrate into the lower gravel and transport radially to other areas of the site (Figure B-3).

The movement of water from the previously leaky water main north of the site was influenced apparently by subsurface site utilities that serviced the Harshaw Site (Figure B-12). High groundwater elevations noted in several monitoring wells that are also near the site-service lines, namely wells IA03-TW0001, IA04-TW0003, IA10-MW0004, IA10-MW005, and possibly ERM47 (Figure B-3 and Figure B-12). Although the depth of this water line is unknown, other water lines on site vary between 1.2 and 2.5 meters (4 to 8 feet) in depth, which would place the service line in the clayey fill as it entered the site and then in the shale-rich gravel as it approached Building G-1. The USACE believes the buried service line is in a trench bedded with coarse-grained fill that provided a preferential pathway for main-line leakage to enter the site.

The fresh water inflow then dispersed within the fill under G-1 and into other nearby utility trenches with coarse-grained bedding, as observed in several test pits. This preferential flow path (i.e., utility bedding in a trench surrounded by fine-grained soils) was not overly apparent on groundwater elevation maps since the service trench was partially independent of (separated from) site water-bearing zones (Figure B-3). This separation allowed the main-line leakage to flow southerly, or opposite of the observed northerly hydraulic gradients seen in the water-bearing zone. This hydraulic separation is evident in water levels from temporary wellpoints TWP01 through TWP13, which do not show mounding in the native alluvium (i.e., wells screened between 6.0 and 9.0 meters [20 to 30 feet] below grade).

The leakage onto the site appeared to infiltrate other utility trenches or fill zones under and near Building G-1, along with the site storm-sewer lines connected to Cuyahoga River outfall BASF-007. Figure B-12 exhibits the waterlines, sewer lines, groundwater levels, and Outfall 007. The repair of the water-main leakage in the north substantially reduced discharge and uranium concentrations at Outfall 007. The hydraulic connection between the leaking water source and sewer line appeared to occur between former manholes BASF-7-06 and BASF-7-01 (Figure B-5), as evidence by increased flow and decreased uranium concentration toward outfall BASF-007 (USACE 2012). The redistribution of this leakage under and near Building G-1 promoted a “bathtub” condition in the contaminated surficial fill. This created uranium-impacted groundwater that 1) infiltrated the G-1 area sewer lines, 2) dispersed into coarse-grained fill layers near G-1, and 3) migrated to the shale-rich gravel below and near Building G-1. This subsurface connection was exemplified during the grouting of manhole #10 (MH10) near the southern corner of former Building G-1. The sump yielded about 1,500 gallons of “clear water” with a uranium concentration of 2,700 µg/L over 24 hours before grouting; USACE believes this yield originated from leaky subfloor drains capturing contaminated water in the fill under Building G-1 (see Figures B-2, B-5, B-12).

The loss of this fresh water input to the groundwater system (i.e., water-main repair) will eventually be reflected in site water-level data reductions and changes in uranium concentrations as the source-area desaturates (i.e., attenuation processes should be become evident). Some of this reaction is beginning to occur, as discussed in Section 2.

1.3.2 Basal Water-Bearing Zone

The primary groundwater flow and contaminant-transport zone under OU-1 includes the basal shale-rich gravel under and near former Building G-1 (as fill) and the native alluvium that blankets bedrock (Figures B-4 and B-10). The shale-rich gravel varies in thickness and extent since it originated as a mechanically leveled bedrock mound that needed removal for site development (see the 1905 USGS topographic map in USACE 2012). The gravel appears mixed with clayey silts that may have originated as glacial till and/or lacustrine sediments that are more evident in boring logs from soil samples and background wells installed west and south of the of the site. Consequently, the shale-rich gravel is limited to the bedrock high area near Building G-1 and the boiler plant.

The hydraulic conductivity (or permeability) of the silty gravel averages 1.1E-3 cm/s (3.0 ft/d). It reflects the wide sediment gradation (e.g., a loose mixture of clayey to silty gravels). The color of this mixed material varies from dark olive brown to dark gray. It is a clayey gravel (GC) with silty clay to silty sand (SC to SM) mixture. The layer becomes lenticular and grades into a natural alluvial deposit in a radial manner that mimics the decline in bedrock topography; as bedrock deepens, floodplain and coarse-grained alluvial sediments thicken to dominate the groundwater flow zone. The hydraulic conductivity of the alluvial layer averages 8.7 E-03 cm/s (25 ft/d). The alluvium eventually discharges groundwater as baseflow to the Cuyahoga River or adjacent Big Creek.

There was no direct evidence that the alluvium continues to off-site areas (such as north of the Harshaw Site towards the Chemical Solvents, Inc., property). Yet soil borings to the north, east, and south of the site show the alluvium thickens to over 9 meters (30 feet), as shown in Figure B-10. However, the native soils generally thin to the west (towards Jennings Road) due to shallower bedrock and become more clayey in texture (possibly reflecting native till and lacustrine sediments) (Figure B-9).

Uranium migration from the perched zone in the fill into the lower shale-rich gravel does not significantly promote transport from the Building G-1 area (Figure B-2). The presence of silts and clays in the fill, along with organic carbon in the crushed shale, may augment the attenuation of uranium entering the layer (Kumar 2011). Dissolved uranium that migrates into the alluvial layer flanking the bedrock mound appears to attenuate to lower concentrations. This is caused by the alluvium thickening to over 6 meters (20 feet) to the east, north, and south of G-1; there, the increasing saturated thickness and permeability provide a highly dispersive environment that dilutes and attenuates (via sorption) the uranium to lower concentrations observed over the rest of the site (Figure B-2).

The uranium plume dispersion to the west and southwest is augmented by the intermittent operation of a six-well nickel treatment system designed to dewater a sanitary sewer-line trench just west of Building G-1 (see wells RW01 through RW08 on Figure B-2). This system was designed to reduce 1) the infiltration of nickel-impacted groundwater into the sewer and 2) nickel transport to other portions of the site. The system operated historically in a noncontinuous manner using water-level-triggered sump pumps that removed groundwater from the utility trace. Uranium-impacted groundwater drawn westerly into several remediation wells is exemplified on

Figure B-2 by two plume lobes to the northwest and southwest of Building G-1. Uranium contamination is not prevalent west of the pumping wells, so they unintentionally act as a hydraulic control on the western dispersion of the plume. The average uranium concentration for these wells is 65 µg/L, with the greatest concentrations found in RW01 and RW04, which average 135 µg/L and 83 µg/L, respectively. The balance of the RW wells exhibit an average uranium value of 7.2 µg/L.

The transport conditions are also detailed in Section 3.

1.3.3 Bedrock

The RI and FS conceptual and numerical modeling analyses treated bedrock similarly to this analysis. The bedrock is considered a 5-foot thick groundwater zone exhibiting an average hydraulic conductivity of 1.0E-4 cm/s (0.14 ft/d); this is derived from RMW 38 that is screened in the upper bedrock and averages 37.5 µg/L in total uranium due to proximity to Building G-1. However, the drilling of soil and groundwater sampling locations also cored into the bedrock, which usually appeared dry. Consequently, the bedrock was represented in the RI and FS as a five-foot thick flow zone of low to moderate permeability (USACE 2012), although observations do not indicate the layer is an actual transport pathway.

2. GROUNDWATER ANALYSIS

The expansion of the groundwater monitoring well inventory discussed in Section 1.2 provided additional water level data to optimize the interpretation of site conditions. The repair of the water main north of the site stopped the routine discharge of water from the site outfall into the Cuyahoga River (RI location IA09-SW0008 or BASF-007). The loss of this influx should eventually manifest changes in groundwater levels and contaminant distributions derived from the previous infusion of water into the subsurface fill layers. The following sections discuss the observations apparent in the water-level and uranium data.

2.1 WATER-LEVEL ANALYSIS

Water-level measurements from 104 wells taken between 2003 and 2016 were converted to elevations and evaluated to see if site groundwater is reacting to 1) the demolition of site buildings (mid-2015), 2) repair of the municipal water lines (Fall 2014), and 3) the termination of site water (May 2015). The hydrographs and datasets suggest that water levels at most wells fluctuate seasonally (Figure B-19). Water levels after the water main repair (Fall 2014) and site-water termination (May 2015) exhibited several low measurements, some of which are typical of the variability in these wells. However, several levels from wells near these utilities (and associated trenches) are indicators of emerging changes in site groundwater.

The groundwater-level analysis indicted some responses (lowering levels) to the site changes, including:

- IA04-TP0002: Exhibits lowest consecutive levels since installed.
- IA04-TP0004: Exhibits two lowest levels during the last year since installed.

- IA04-TW0003: Exhibits lowest level since October 2004.
- IA04-TW0005: Exhibits lowest level since May 2012.
- IA04-TW0006: Exhibits two lowest levels since Nov 2014.
- IA10-MW0002: Exhibits lowest level since 2004.
- IA10-MW0003: Exhibits two lowest consecutive levels since installed.
- IA10-MW0004: Exhibits lowest consecutive levels since 2009.
- IA10-MW0005: Exhibits three lowest levels since installed.
- IA10-MW0007: Exhibits two lowest consecutive levels since installed.

The groundwater levels collected synchronously during annual and ad-hoc field actions were evaluated for the following periods:

- May 2002 - Figure B-13
- May 2005 - Figure B-14
- May 2010 - Figure B-15
- October 2014 - Figure B-16
- January 2016 - Figure B-17

These figures reveal several trends that indicate subtle changes in site conditions from external influences, along with better interpretation from the new spatial data, as noted below:

- A groundwater mound (or high groundwater elevation) was observed under and near the former Building G-1 and the boiler plant from May 2004 through January 2016.
- This mounding varies in extent and is persistent irrespective of season.
- Site-wide pH values average 6.5, whereas a zone of more neutral pH is evident near Building G-1 (Figure B-18); this appears as an artifact of the water line leakage that entered the site and dispersed radially from under former Building G-1.
- The mound is coincident with the bedrock high that exists in the subsurface, especially overlapping an area where bedrock is shallow (<10 ft below grade) (Figure B-11).
- Boring and trench logs indicate the saturation of the surficial fill under and around the former Building G-1 due to the underlying fine-grained fill that partly blankets bedrock.
- An 8-inch service line (and associated utility trench) that entered the Harshaw Site from the water main under Old Denison Road appeared to provide a preferential pathway for leakage to enter the site.
- The mounding resembles a “bathtub” effect where natural recharge combined with other inputs reached an equilibrium with the two-level groundwater system and interconnections with site utility lines.
- The radial flow from the mound dispersed uranium from the eastern end of Building G-1 to areas north, west and south of the building. The westerly plume dispersion is augmented by the six-well nickel treatment system operated by BASF.
- The Old Denison Road water main was repaired in the fall of 2014 (Figures B-3 and B-12).
- Upon repair, the stormwater outfall BASF-007 ceased flowing at 57 to 114 liters per minute, or 15 to 30 gallons per minute.

- Afterwards, this outfall sewer and select tributary lines were removed in the fall of 2014 and backfilled with cobble- and gravel-sized fill (small riprap), as discussed in Section 3.1.3.

A comparison between wells near the test pits and water lines (solid colored lines on Figure B-19) and wells in other areas of the site (dashed colored lines) show very similar behavior before and after the site water line terminations. The USACE assumes an overall reduction in groundwater elevations will occur as the site reaches a new equilibrium without the water line leakage. The observed low groundwater levels from January 2016 (Figure B-17) and June 2016 (Figure B-3) may indicate the onset of re-equilibration. However, the graph on Figure B-19 does not specifically indicate a downward trend in water levels. Consequently, USACE expects residual influences from over 10 years of water leakage to persist for several years while the groundwater system drains. Groundwater levels may be monitored by USACE during the project lifecycle to track the groundwater reductions and aid potential remedial designs.

2.2 URANIUM ANALYSIS

In addition to the previous water-level analysis, total uranium concentrations (total U) in groundwater samples collected at the Harshaw Site were assessed for temporal trends at each monitoring well. The uranium dataset spans 2003 to 2017 and includes isotopic uranium (U-238) values that were converted to mass-based concentrations (µg/L) using natural uranium isotope ratios; these were coupled with laboratory-based total uranium values in the following manner:

- The U-238 values in pCi/L were multiplied by 3.003 µg/pCi to produce equivalent total U values in µg/L, which was cross-verified using samples analyzed by both spectroscopy and mass-based methods (e.g., samples analyzed under alpha spectroscopy and Kinetic Phosphorescence Analyzer or KPA).
- Any total uranium values that were reported in mg/L were converted to µg/L for consistency.
- U-238 samples that were analyzed by inductively coupled plasma mass spectrometry (ICP-MS), and thus reported as mg/L, were assumed to be 99.28% natural uranium and thus considered equivalent to total U and converted to µg/L.
- Total uranium values already in µg/L were used directly in the data analysis.

Total uranium values include 905 results from 59 locations, which were sorted by well and date by using only results that were assigned no validation flag or an estimated (J) flag; values defined as below-detection limits (U flag) were omitted. The amount of data from each well ranged from multiple sample results to a single measurement at a particular point in time. Wells with the least data exhibited nondetectable uranium results during the RI (2003-2004) or were distant from the MED/AEC-related processes.

The dataset also contains field duplicates and filtered/unfiltered sample pairs. Total fraction (unfiltered) results generally match filtered results (i.e., the ratio of filtered to unfiltered is nearly unity or 1.0), thus uranium is dissolved in groundwater and not present in colloidal form (USACE 2009). The July 2007 and September 2008 values for U-238 and total U exhibit disparities between the activity-based values converted to mass-based values and the actual total uranium (mass-based) values reported by the laboratory. This difference may be a laboratory issue since some U-238 results show relatively large laboratory uncertainties. The omission of the 2007-2008 data from the trends for seven wells (BKGD-MW0001, BKA48, RMW35, IA10-MW0001, IA10-MW0004, IA04-TW0004, and IA03-TW0005R) do not significantly change the Mann-Kendal results. For example, IA10-MW0004 shows a decreasing trend with all uranium data and a probably decreasing trend without the 2007-2008 data; similarly, IA03-TW0005R has a probably increasing trend with all the data and an increasing trend without the 2007-2008 data. Consequently, the 2007-2008 data were included in the trend analyses for completeness.

Attachment A shows the Mann-Kendall Statistic Tests for project wells with more than four sample results; wells with less than four results are not statistically appropriate for the Mann-Kendall analysis (i.e., a trend cannot be confidently established). The trend analyses produced the following results:

- 10 wells show probably increasing to increasing trends (17% of site wells), which indicates the plume is not grossly transporting from the soil-source areas.
- 35 wells show stable or no trends (60 percent of site wells) that are indicative of dispersive and geochemical conditions minimizing plume expansion from the uranium-impacted soil sources.
- 14 wells (24 percent of site wells) show decreasing trends due to plume dispersion and attenuation that may continue to be affected by site changes.

An additional analysis of the boring logs and well construction diagrams from the remedial investigation and recent work (see Appendix B of USACE 2016) indicate that 15 wells have filter packs (sanded intervals) that reach into or contact the surficial (new) fill (Figure B-21). These wells also reflect the groundwater mounding and exemplify how the saturation of the shallow fill can influence the interpretation of hydrologic and chemical site conditions. A representation of site potentiometry without these 15 wells is shown on Figure B-22. Figures B-8 and B-9 present zones where the surficial fill promotes uranium migration through the old fill, specifically where the old fill is either 1) absent and allows the impacted shallow fill to contact the shale-rich gravel, or 2) less than two feet thick, where vertical migration would be greater to the underlying gravel and native alluvial sediments. Several wells with shallow seals or apparent damage exhibit uranium impacts. A uranium distribution without data from those wells is shown on Figure B-23 and may more closely depict impacts to the basal shale-rich gravel and alluvium. To be conservative, the larger uranium distribution in Figure B-2 was input to the contaminant-transport model.

In general, the trend analyses indicate a stable plume (i.e., ~83 percent of wells are stable or decreasing in uranium concentration) that is not undergoing significant mass transport from the soil-source areas. Of the 16 wells probably in contact with the surficial fill, 11 have enough data to develop uranium trends, which show the following:

- None show increasing trends.
- Seven have stable or no trends.
- Four show declining trends.

This analysis indicates that groundwater conditions are still responding to site changes, which should lessen concentrations with time (i.e., the surcharge of the surficial fill has ceased and more natural conditions will emerge).

2.3 GEOCHEMICAL ANALYSIS OF SITE CONDITIONS

The hydrogeochemical conditions at the Harshaw Site do not appear to promote significant uranium transport (nor radium or thorium isotopes), since uranium impacts in groundwater are still near soil-impacted areas. These site conditions (uranium-transport limiting and attenuation) are discussed presently.

2.3.1 Geochemical Screening of Well-Specific Conditions

Historic groundwater sampling dataset include several constituents commonly used as geochemical indicators for the potential mobility of uranium in groundwater. These markers include (U.S. Environmental Protection Agency [USEPA] 1999, Kumar et al 2011):

- Ferrous iron (Fe^{+2}).
- Manganese (Mn^{+2}).
- Arsenic (As^{+3}).
- Nitrate (NO_3-^{1}).
- Nitrite (NO_2^{-1}).
- Sulfate (SO_4^{-2}).
- Dissolved oxygen (D.O.).
- Oxidation reduction potential (ORP).

Concentrations of manganese, arsenic, and iron found in total-fraction (unfiltered) and dissolved-fraction (field-filtered) results were compared to indicate geochemical conditions prevalent in site groundwater. The dissolution of these metals normally progress through manganese, arsenic, and then iron. A greater ratio of dissolved to total cations (exceeding 0.9 for this assessment) indicates more reductive groundwater conditions exist; normally this is accompanied by lower dissolved oxygen and ORP. This reduced state inhibits the solubilization of uranium and associated transport from source areas (i.e., an inverse relationship of these dissolved metals with uranium) (Kumar et al., 2011).

Site wells were analyzed for reductive conditions using *An Excel Workbook for Identifying Redox Processes in Ground Water* by Bryant C. Jurgens, Peter B. McMahon, Francis H. Chapelle, and Sandra M. Eberts (U.S. Geological Survey Open-File Report 2009–1004). The site-specific results of the aforementioned analytes were averaged for each well and input to the spreadsheet tool (Table B-3). The calculated reductive capacity at each well indicates a mixed oxic-anoxic condition exists throughout the site. A secondary analysis of well-specific averages of ORP presented on Figure B-24 shows low-ORP zones (values below zero millivolts [0 mV]) both upgradient (west and north) and downgradient (east) of the former Building G-1. A comparison of Figures B-2 and B-24 indicates the uranium plume occupies areas where ORP is above zero millivolts; the plume is then surrounded by a geochemical condition that may inhibit uranium transport. A tertiary assessment of total-fraction and dissolved manganese, arsenic, and iron indicates areas of geochemical conditions that affect uranium transport (near one-to-one ratio of dissolved to total fraction results), as illustrated on Figure B-25.

The hydrogeochemical conditions vary between more oxic groundwater under and near Building G-1 and more reductive (anoxic) groundwater to the north, east, west, and partly south of G-1. The oxygenated water under and near the east end of G-1 appears to be derived from past migration of the water line leakage onto the site.

The more reductive conditions downgradient (east) of the G-1 area appears derived from a buried floodplain that contains organic material and sediments, which produces a zone that can attenuate uranium transport before reaching the river (Figure B-24). However, this low-ORP area shows a gap under the legacy storm-sewer likely due to previous exfiltration that influenced local geochemistry. Groundwater in several wells along the line show uranium impacts collocated with more oxygenated conditions. This legacy condition is expected to change to ambient geochemical conditions (reductive) due to line-source removal (i.e., cessation of sewer exfiltration). Consequently, the potential transport zone shown on Figure B-25 should geochemically diminish as a potential migration pathway for uranium.

An additional transport marker at the site is lithium, which is highly soluble and transportable (low K_d). Figure B-26 presents the average lithium values for each well and a contour line encompassing values of 100 µg/L or greater. The distribution appears as two plumes separated by the line of nickel pump-and- treat wells. The eastern portion provides insight to a potential flow pathway for uranium, although reductive groundwater conditions exist along this flow path, as previously discussed.

This complicated groundwater flow condition is well suited for remedial action through soil-source removal, where the loss of contaminant mass in the surficial fill and the attenuation of uranium in the native alluvium will mitigate additional transport and ensure plume growth does not impact the Cuyahoga River, as exemplified by the numerical modeling results presented in Section 3.

2.3.2 Geochemical Trend Analysis

The geochemical analytes (cations and anions) that normally have interrelationships in different geochemical environments were used to identify potential trends in the site data. Some of the relationships indicated chemical thresholds (i.e., concentrations where conditions change) that may promote the attenuation of uranium in groundwater.

The geochemical trends of metals against uranium provided best-fit equations that approximated the concentration of each analyte where the lines crossed the uranium MCL of 30 µg/L. The trends were performed using site-wide and Building G-1 centric datasets; the Building G-1 area includes data within 200 feet of the building. The site-wide and Building G-1 relationships shown in Figures B-27 and B-28, respectively, indicate the following:

- The site-wide data show weak or widely scattered, inverse correlations exist between elemental uranium and dissolved manganese (Mn), arsenic (As), and Iron (Fe).

- The G-1 area dataset also shows variance about the trend lines and inverse correlations between elemental uranium and dissolved Mn, As, and Fe.

The best-fit trend lines on the graphs exhibit variability about the lines, although provide a general relationship between the data. The trend-line (or correlation) equations on the graphs were solved for a uranium value of 30 µg/L, which may indicate constituent concentrations that could promote uranium-attenuating conditions. The resulting values for the indicator constituents listed below are minimum values for Mn, As, and Fe (i.e., greater values may indicate more uranium attenuation), and maximum values for ORP and D.O. (i.e., lower values would promote uranium attenuation).

Dissolved Analyte Value	Site-Wide Value	Building G-1 Area
Manganese (mg/L)	0.61	0.63
Arsenic (mg/L)	0.006	0.0006
Iron (mg/L)	4.1	4.2
Oxygen Reduction Potential (mV)	15.8	38.0
Dissolved Oxygen (D.O. mg/L)	2.3	2.8

To supplement this analysis, additional soil and water partitioning (K_d) data were collected during the monitoring well installation program. Eighteen soil samples collected from each new well boring at a depth interval coincident with the screened interval were compared to the groundwater results from the well. The resulting K_d values were generated by dividing the soil results by the groundwater results for uranium from these wells. These 18 results were added to three RI results for a total of 21 soil-water pairs (K_d values) that reflect overburden properties. Figure B-29 exemplifies these data and indicates the following:

- The additional K_d values ranged between 10 and 28,685 L/kg, with an average of 2,988 L/kg.
- The combination of new and RI-based K_d results produced an average of 2,563 L/kg and geometric mean of 221 L/kg.
- Lower redox values (ORP) enhance the adsorption-based K_d via reducing conditions that lowers uranium solubility and enhances the overall K_d of the system.

The geometric mean of the K_d values (221 L/kg) was used in the numerical transport model to better reflect the observed conditions that do not show significant migration of uranium on the site. The previous RI and FS models used a conservative K_d of 14 L/kg (USACE 2009, USACE 2012), which promotes more transport, although lies below the 99 percent confidence interval of the log-transformed Kd dataset, so is not considered statically appropriate for the site (Davis 1986).

2.4 GROUNDWATER USE

An evaluation of the groundwater quality and potential for groundwater resource development on the site indicates that groundwater use at the Harshaw Site would require treatment for potable or operational use due to wide-ranging impacts from over 100 years of industrial use.

2.4.1 Water Quality

The Harshaw Site RI and FS reports discussed the ambient water quality at the Harshaw Site. Subsequent groundwater sampling results, included in the summary listed in Table B-1; for informational purposes, site conditions were compared against federal and Ohio primary or secondary drinking water standards, action levels, or international screening levels. This analysis exemplifies site groundwater degradation due to the wide-ranging history of industrial land use on the Harshaw Site (USACE 2009).

The following groundwater constituents affect the viability of site groundwater as a drinking or industrial-use resource due to exceeding their respective screening values:

- Cations: aluminum, antimony, arsenic, beryllium, cadmium, lead, lithium, manganese, nickel, selenium, sodium, uranium
- Anions: fluoride, sulfate
- Water Quality Criteria: total dissolved solids, below-neutral pH
- Radionuclides: gross alpha, Th-230, U-234, and U-238

These degraded conditions indicate the site groundwater is not a viable resource for operational or drinking water without significant treatment for inorganic compounds. The available municipal and surface-water resources (Cleveland Water or Cuyahoga River) provide a replaceable resource that would require less treatment.

The exclusion of site groundwater as a viable drinking water resource due to wide-area anthropogenic impacts also precludes the application of the USEPA groundwater maximum contaminant level of 30 µg/L for total uranium. However, the proximity of groundwater contamination to soil sources does not preclude the ancillary removal of impacted groundwater during potential soil remediation as a method to reduce site risk and control water inflow into excavations.

2.4.2 Groundwater Use Classification and Well Yield Analysis

Groundwater conditions at the Harshaw Site were also compared against the following groundwater classification and groundwater response requirements:

- OAC Rule 3745-300-10 (Ohio EPA March 2009)
- Technical Guidance Compendium VA30010.09.001
- *Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy* (USEPA, 1986).

The Ohio EPA Rule provides four classifications for groundwater in Ohio, as summarized below.

- <u>Critical-resource groundwater</u> is groundwater in a saturated zone that meets any of the following criteria:

  - The groundwater zone is being using by a public water system and is in a "drinking water source protection area for a public water system using groundwater."
  - The groundwater is in an unconsolidated saturated zone that is capable of yielding water at a time-weighted average rate greater than 100 gallons per minute over a 24-hour period.
  - The groundwater is in a consolidated saturated zone that is part of a sole source aquifer.

- <u>Class A groundwater</u> is groundwater in any saturated zone that does not meet any of the criteria for critical resource groundwater (discussed above) and meets any of the following criteria:
  - The groundwater is in a saturated zone that is used as a source of potable water on the property or within one-half mile of the boundary of the property; or zone is being using by a public water system and is in a "drinking water source protection area for a public water system using ground water."
  - The groundwater is in the unsaturated zone that has a natural level of total dissolved solids (TDS) of less than 3,000 mg/L.

- <u>Class B groundwater</u> has the following characteristics:
  - Groundwater is in a saturated zone that yields less than three gallons per minute for a 24-hour period.
  - Another groundwater zone underlies the property that is a potential source of potable water within one mile of the property (The groundwater zone used for comparison must be present beneath the property and the surrounding area off-property, and yield three or more gallons per minute and at least twice as much groundwater as the zone being classified.), or
  - The groundwater is in an unconsolidated saturated zone that yields less than three gallons per minute over a 24-hour period and all parts of the zone are wholly contained within 5 meters or15 ft below ground surface (bgs).

- <u>Urban groundwater designation</u> essentially eliminates the potable use pathway for areas surrounding the property and is governed by the following characteristics or threshold criteria:
  - The property or properties are entirely within the boundaries of the corporation boundaries of a city (e.g., Cleveland);
  - The city has a community water system where one of the following conditions apply:
    - 90 percent of the parcels within the city are connected or capable of being connected to the community water system. Parcels in unincorporated areas that are wholly surrounded by the city limits must also be considered in the calculation of parcels connected (e.g., Cleveland, Cuyahoga Heights, and Newburgh Heights all connect to Cleveland Water, the regional municipal water system).
    - 90 percent of the parcels within a minimum of one-mile from the proposed boundary of the urban setting designation are connected or capable of

being connected to the community water system. Parcels in unincorporated areas that are wholly surrounded by the city limits must also be considered in the calculation of parcels connected (e.g., Cleveland, Cuyahoga Heights and Newburgh Heights all connect to Cleveland Water, the municipal water system).

  - If less than 90 percent of the parcels are connected or are capable of being connected to a community water system, then one of the following applies:
    - The parcels that are not connected or capable of being connected to a community water system would be unaffected by hazardous substances or petroleum on or emanating from the properties within the urban setting designation.
    - Installation of well(s) used for potable water supply at the parcels that are not connected or capable of being connected to a community water system would be impractical for reasons other than groundwater quality or the presence of the community water system (e.g., Cleveland, Cuyahoga Heights and Newburgh Heights all connect to Cleveland Water, the municipal water system).
  - The city or township has a community water system that the city or township considers capable of meeting its future water supply needs.
  - The affected property or properties are not located within a "drinking water source protection area for a public water system using ground water."

The U.S Environmental Protection Agency guidelines define "nonpotable," or Class III, groundwater as having the following criteria:

- Contains TDS concentrations of 10,000 mg/L or greater.
- Yields less than 150 gallons per day (or 0.1 gpm).
- Is so contaminated by naturally occurring conditions (e.g., salinity) or broad-scale human activity not related to a specific contaminant source that cleanup is not practicable using treatment methods reasonably employed in public water supply systems.

Potential groundwater yields from site wells were assessed by assuming each monitoring well was built like a water-supply or industrial-operation well. Table B-2 presents the results of the pumping yield calculations for several monitoring wells by using hydraulic conductivity values estimated during the RI (USACE 2009). The hydraulic conductivity and saturated thicknesses at each well determined an average transmissivity value that was input to the drawdown calculation.

To determine if each tested well would sustain certain pumping rates associated with the classifications (i.e., not dry out), the calculated drawdown was compared to the saturated thickness of the water-bearing zone at each well. Where drawdown was less than the saturated thickness, the well location exhibited sustainable yields that were compared to the associated classification characteristics.

The following equation estimates drawdown (Driscoll 1986):

$$s = \frac{264Q}{T} Log(0.3\,Tt/r^2S)$$

where:
s = drawdown in the well (ft)
Q = yield of the well (gpm)
T = transmissivity of the well (gpd/ft)
t= time of pumping (days)
r = radius of the well (ft)
S = storage coefficient of the aquifer

The following parameters were constants in the equation to solve for drawdown:

Q = 5 gpm, 10 gpm, 0.1 gpm, and 3 gpm
T = K * b, where K = hydraulic conductivity (gpd/ft^2) from each well slug test and b = saturated thickness (ft) of the water-bearing zone
t = 365 days
r = 0.5 ft (typical radius of a water supply well)
S = 0.18 (typical value) (USACE 2012)

The well-specific drawdown to saturated thickness comparison produced the following breakdown:

- Two wells are sustainable as a critical groundwater resource or Class A resource in Ohio (20 are unsustainable).
- Eight wells are sustainable as an Ohio EPA Class B resource (14 wells are unsustainable).
- Eighteen wells are sustainable as a U.S. EPA Class III resource (four well are unsustainable).

In general, the wells with sustainable yields are those with the greatest hydraulic conductivity values and saturated thickness; these are normally near the Cuyahoga River and/or Big Creek, where the alluvium dominates the subsurface (Figure B-20 and Table B-2). In contrast, the least sustainable areas are near the former Building G-1, where the saturated thickness is normally less than 15 feet and overall overburden thickness is less than 20 feet. Consequently, the uranium plume occupies a non-productive zone on the site.

2.4.3 Groundwater Disposition

The groundwater at the Harshaw Site is not characteristic of a potable source due to the following conditions:

- Site groundwater is not used currently as a potable or operational resource.
- Only three wells along the Cuyahoga River could produce critical-resource rates of 100 gpm and would likely draw river-water contributions to a production well.
- Fourteen of 22 wells (64 percent) cannot sustainably produce 3 gpm to meet the Ohio Class B criteria; only wells near the river can produce sustainable yields.

- Four wells (19 percent of those tested) cannot meet the U.S. EPA Class III production standards of 0.1 gpm.
- Groundwater lies from just below grade (~2-ft depth) near the former Building G-1 to about 25 ft deep near the Cuyahoga River and averages 14.8 ft deep at the site.
- The site partly falls within two urban groundwater designation zones, and no drinking water wells exist within a 2-mile radius of the site boundary (USACE 2009).
- Harshaw is within the City of Cleveland limits, and all local municipalities are served by Cleveland Water (Cleveland, Cuyahoga Heights, and Newburgh Heights).
- Site groundwater exhibits TDS concentrations that range from 320 to 9,790 mg/L (n=119) and average 1,570 mg/L, which it does not fully exceed the Ohio or USEPA criteria, yet reflects the industrial history of the site (manufacture and storage of inorganic compounds). Total dissolved solids in wells upgradient of the site average 555 mg/L.
- Site groundwater reflects broad-scale human activity from a significant industrial history not related to a specific contaminant source, as exemplified in Table B-1.
- Use of site groundwater as a potable resource for multiple connections would require water treatment for an array of inorganic compounds that will pose a cost burden.
- Municipal and multiple surface water resources (Cuyahoga River and Lake Erie) are available to replace groundwater for site use.

Consequently, site-wide groundwater reflects many of the characteristics of USEPA Class III, Ohio Class B, and Urban Groundwater designations. Operable Unit 1 includes the primary chemical plant site and exhibits poor quality (and quantity) groundwater conditions that indicate the groundwater below OU-1 is not a potable or operational resource. Operable Unit 2 is located south of OU-1 (across the Big Creek) and exhibits groundwater conditions that reflect a more potable quality and quantity, although inorganic (metals) impacts are evident and would require treatment for domestic consumption.

Consequently, USACE does not consider the Harshaw Site groundwater to be a viable consumption resource without significant treatment (especially under OU-1). The groundwater also is slightly acidic and thus is not a viable operational water source without treatment (i.e., the site average pH of 6.5 would have to be elevated to neutral conditions to preclude pipe-system corrosion).

3. NUMERICAL MODEL UPDATE

The numerical groundwater flow and contaminant-transport model developed for the 2012 FS was updated to reflect the new conceptual site model and hydrogeologic understanding of site conditions. The original model is fully reported in Appendix D of the FS (USACE 2012) and includes the following updates for this FS Addendum assessment.

3.1 GROUNDWATER FLOW MODEL INPUTS

The groundwater flow and uranium transport model carried over all the inputs from the original model, including the following systemic inputs and updates:

- Length = feet/foot (ft)

- Time = day
- Mass = milligram (mg)
- Force = pound
- Water concentration = micrograms per liter (µg/L) (MT3DMS input and output)
- Hydraulic conductivity distribution = same as feasibility study model with an increase along the excavated storm-sewer segments to conservatively represent backfill in excavations, even though not all segments are perennially saturated with groundwater.
- Effective porosity = soil at 0.18 and bedrock at 0.08
- Bulk soil density = soil at 1.6 g/cc and bedrock at 2.40 g/cc
- Soil-water partitioning coefficient (K_d) = 1,000 mL/g (linear isotherm) for soil leaching and 221 mL/g for saturated-zone transport
- Geologic boundaries = bedrock topography was updated based on new boring data
- Starting concentration = updated to reflect new distribution in Figure B-8
- Recharge distribution = updated to reflect interpretation of well levels discussed in Section 3.1.3.
- Recharge-based leachate concentration = same as feasibility study model and spatially modified to reflect new soil impact areas (Figure B-1)
- Nickel system pump-and-treat wells = 2.5 gpm cumulative (or 0.31 gpm each well)
- The new baseline plume has an estimated 10,423 grams (23 pounds) of uranium both dissolved in groundwater and adsorbed to saturated soils; the previous model simulated the fate of 30,037 grams of uranium. The difference reflects the detailed soil and groundwater assessment that used high-density sampling data to lessen site uncertainty.

3.1.1 Hydrogeologic Boundaries

Hydrogeologic data from the recent soil borings, test pits, temporary wells, and permanent wells allowed a refinement of the subsurface conditions near the former Building G-1 and reduced contaminated soil volume uncertainty. New contour maps of potentiometry (water levels), overburden thickness, fill and native sediment contacts, and top of bedrock augmented the groundwater flow and contaminant-transport model.

The most significant update to the conceptual site model is the recognition that the surficial fill (new fill) provides a laterally dispersive medium for dissolved uranium in the former Building G-1 area (Figures B-1 and B-8). The remedial investigation noted the extent and partial saturation of this layer that was not considered a significant transport pathway due to observed ephemeral conditions (i.e., perched water was not always observed in the fill). The municipal water line leakage north of the site flowed onto the site via utility trenches and/or fill layers, which elevated groundwater levels under and around Building G-1. The repair of that source appears to be manifesting some water-level and uranium-concentration reductions in several wells near the former Building G-1.

The removal and backfill of select stormwater sewers by BASF may affect groundwater conditions where the sewers were in contact with the underlying shale-rick gravel or alluvium. In sewer segments where the trenches are contained within the upper two fill layers, groundwater wells installed by BASF (see GEO-01 through GEO-18 on Figure B-32) show evidence of perched conditions in the trenches, especially in the sewers near the Foundry and Warehouse

Buildings. This perched water provides additional recharge to the overall groundwater system, as discussed in Section 3.1.2. However, the storm-sewer segment near monitoring wells IA10-MW0008 and IA04-TP0002 appears to contact the saturated zone, which has manifested lower well levels near this segment. This may be due to the trench acting as a partial drain in the groundwater system from about MH09 to IA04-TP0002, and possibly farther southeast towards the Cuyahoga River. This groundwater lowering effect is also augmented by the operation of the BASF pump and treat well #6 (USACE 2015, USACE 2016).

Consequently, the groundwater flow model was updated with new recharge distributions (discussed presently), potentiometry, and higher hydraulic conductivity zones to reflect removed storm-sewer segments specifically along the trench extending southeast of MH09 to the river.

3.1.2 Plume Delineation

Figure B-2 exemplifies the largest extent of uranium impacts in groundwater by mapping the maximum uranium value sampled at each location (data spans from 2003 through 2016), which are generally collocated with soil impacts. This new plume was input to the contaminant-transport model as the starting contaminant condition for predictive modeling. The soil contamination that now occurs on site was modeled in the FS to continually leach to the groundwater and transport with the new plume (USACE 2012). This condition was used also in the updated model to reassess FS alternatives. The residual influxes spatially vary in each remedial area due to residual concentrations and soil properties; these differences are discussed below.

- Areas under and near Building G-1 that are candidates for remediation were assigned a uranium leachate value for recharge that varied between 0 µg/L and 620 µg/L, and averaged 128 µg/L.
- Residual impacts north and east of Building G-1 are expected to include leachate that will vary between 0 µg/L and 600 µg/L, with an average of 83 µg/L.
- The MED/AEC-impacted area along the Cuyahoga River, in the northeast corner of the OU-1, was assigned a leachate range between 0 µg/L and 550 µg/L, with an average of 86 µg/L.
- Uranium impacts in the southern OU-1 area (or Investigative Area 05 of the RI) has leachate inputs ranging between 0 µg/L and 650 µg/L, with an average of 57 µg/L.

The new plume and recalcitrant residual sources ensures conservatism in the model, so the remedial alternatives and associated residual risk can be properly assessed.

3.1.3 Recharge Characteristics and Distribution

Groundwater recharge by precipitation and runoff from building slabs partially infiltrates into nearby utility trenches that contain gravel and sand backfill, as seen in TP-4 and on geophysical surveys (Figure B-30). Prior to Building G-1 demolition, runoff from precipitation was uncontrolled by most storm-\water conveyances, so building runoff was allowed to infiltrate wherever surface-discharge and ponding occurred. Post-demolition runoff commonly ponds north and southwest of Building G-1, with smaller accumulations occurring east of the G-1 slab. Site groundwater-level data do not show gross influences from stormwater changes, although the surficial fill present in these areas will have a greater tendency to be saturated and possibly disperse Building G-1 area impacts in the fill, as noted in Figure B-2.

Groundwater recharge from precipitation has lowered water levels in several wells and may reflect the continued equilibration of site conditions. The potentiometry on Figure B-22 was input to the model as the starting head and calibration surface. Surface-cover conditions that control recharge were updated to reflect drilling and test-pit observations; these data, in conjunction with geophysical surveys, indicate that utility line clusters can be represented as coarse-grained fill features that promote greater recharge.

The following updates to the simulated recharge distribution led to a new calibration of the model that was used in the uranium plume prediction:

- The thin overburden area outlined on Figures B-7, B-8, and B-9 was assigned a recharge zone to best assess the potential impacts from uranium transport from the surficial fill.
- Several zones around the former Building G-1, outlined on figure B-30, were created to simulate the dense distribution of utilities that are in sand-backfilled trenches (e.g., Test Pit 4).
- Greater recharge was assigned along the excavated stormwater utility lines to reflect precipitation falling on the cobble-sized fill in the trenches, which was shown to gather and perch shallow groundwater.

The recalibrated hydraulic heads and recharge distributions are presented in Figures B-33 and B-34, respectively. Table B-4 presents the residual head analysis (i.e., differences between observed and calculated heads), which indicates no model biases.

Actual recharge may be partly dispersed in the shallow fill around former Building G-1 prior to vertical movement, but this condition is not included in the model. The long-term transport analysis applies residual leachate directly into the shale-rich gravel and alluvium during the predictive simulations.

3.2 REMEDIAL ACTION ALTERNATIVE EVALUATIONS

The updated model was used to reevaluate remedial alternatives for OU-1 and determine if the new baseline condition would result in changes to the alternative components and rankings. OU-2 components were not revisited since conditions in that unit did not change (i.e., the 2012 FS alternatives still apply).

The following eight alternatives for OU-1 and OU-2 were evaluated in the original FS (USACE 2012):

1. Alternative 1: No Action (OU-1)
2. Alternative 2: Limited Action and Land Use Controls (OU-1)
3. Alternative 3: Complete Removal with Off Site Disposal (OU-1)

4. Alternative 4: Complete Removal with *Ex Situ* Treatment and Off Site Disposal (OU-1)
5. Alternative 5: No Action (OU-2)
6. Alternative 6: Limited Action and Land Use Controls (OU-2)
7. Alternative 7: Complete Removal with Off Site Disposal (OU-2)
8. Alternative 8: Complete Removal with Ex Situ Treatment and Off Site Disposal (OU-2).

The groundwater model was constructed to evaluate several OU-1 alternatives with only two modeling scenarios. For example, Alternatives 1 and 2 would be modeled the same since no soil actions would occur, whereas Alternatives 3 and 4 include soil excavation options that were modeled similarly. Consequently, the four alternatives were evaluated with two model configurations. The most specific update that may affect alternative rankings would be the smaller extent of both the uranium plume and areas of residual uranium leachate.

The objective of this modeling is to determine whether the updated plume and conceptual site model promote greater uranium discharge to the Cuyahoga River with and without soil remediation.

3.3 OU-1 ALTERNATIVES 1 AND 2 ASSESSMENT

For these two alternatives, the updated model calculated results that were similar to the original FS model. The reduction in impacted soil areas did not have a noticeable effect on the predicted plume since the high-concentration soil areas (groundwater sources) did not grossly change. Consequently, the collocated high-concentration impacts remained unaffected by the re-analysis, although the extent of the plume and internal concentration gradients were modified from the previous RI and FS. The modeling results presented in Figure B-35 indicate the following:

- The uranium plume under and around the former Building G-1 transports downgradient at a very slow rate similar to the original RI and FS predictions (USACE 2009, USACE 2012).
  The highest concentration expected to reach the Cuyahoga River within 1,000 years is 9 µg/L and emanates from the northeast contamination area.
- The uranium mass that discharges into the Cuyahoga River over the 1,000-year performance period is 416 grams (0.9 pounds), most of which is derived from low-concentration release (<9 µg/L total uranium) over the 1,000-year simulation (i.e., most uranium is adsorbed to site soils and dispersed to lower concentrations in groundwater).

Consequently, the new conceptual site model and associated numerical rendering did not change the conclusion of the RI and FS, which was that the plume will remain on site and at concentrations similar to those currently observed due to residual leachate additions. The plume expands slightly with time, but disperses and attenuates into the thicker alluvium that flanks the bedrock high. The plume would not impact the Cuyahoga River with concentrations that could put the surface water resource at risk (e.g., the maximum discharge concentration to the river is 9 µg/L of total uranium, which is instantly diluted).

3.4 OU-1 ALTERNATIVES 3 AND 4 ASSESSMENT

The construction worker receptor is the critical group for OU-1 and remedial goals for soil would limit receptor dose to 25 millirem/year (mrem/yr) under the 10 CFR 20 Subpart E; this includes minimal groundwater consumption (0.2 liters per day of incidental ingestion). To protect the future construction worker under 10CFR20, MED/AEC-impacted soils would be excavated to a set of remedial goals under Alternatives 3 and 4. However, residual soil concentrations will remain on site and range between background and the remedial goal; these residuals will continue to affect groundwater via leaching, as discussed previously and included in the model.

The updated Alternative 3 and 4 simulation reflects the new soil and groundwater distribution, along with the modified residual leachate inputs to reflect the updated soil extents and post-remedy conditions. The uranium distribution in groundwater was modified to exclude a small area under Building G-1 that would be excavated deeply enough to remove soils collocated with groundwater that exceeds 130,000 µg/L of uranium, which is an incidental exposure concentration that could pose risk to a future construction worker. This post-remedy condition would remove about 200 grams (0.44 pounds) from the saturated soil and groundwater (i.e., the mass of uranium partitioned to soil and dissolved in groundwater for Alternatives 1 and 2 is 9,786 grams and 9,584 grams for Alternatives 3 and 4). The modeling results on Figure B-36 are interpreted below:

- The uranium plume under and around the former Building G-1 minimally transports downgradient and reflects rates similar to the original RI and FS model predictions.
- The highest concentration expected to reach the Cuyahoga River within 1,000 years is also 9 µg/L, which is below the drinking water standard, as a comparative screening value. This concentration is similar to Alternatives 1 and 2 because it emanates from soil leachate inputs that are in the northeast area of the site near the riverbank.
- The removal of a small area within the uranium plume still promoted recalcitrance in the model, so the limited plume reduction did not affect the alternative rankings.

The soil excavation Alternatives 3 and 4 indicate that land-use or institutional controls may be required after implementing the construction worker protections via soil removal. Figure B-36 demonstrates the recalcitrance of the plume due to residual soil leachate and remaining groundwater concentrations; as in the case of Alternatives 1 and 2, only minor plume expansion occurs since dispersion and attenuation occur in the thicker alluvium. Long-term, five-year reviews will assess site condition against the protectiveness of the final remedy and the performance of potential land-use controls (i.e., five-year inspections will determine whether OU-1 is used for residential development or groundwater resources).

3.5 URANIUM PLUME TRANSPORT WITH SITE EROSION

The potential residual contamination that would be left on site under a limited action alternative (FS Alternative 2) or soil removal remedy (Alternatives 3 or 4), along with the recalcitrance of the uranium plume throughout the 1,000-year performance period, indicate the need for land-use controls to ensure protectiveness of these alternatives (and eventual final remedy). The five-year reviews that may be required after remedy completion would also document any changes in site conditions, including site erosion along the Cuyahoga River and Big Creek. Erosion prevention under Alternative 2 would be a federal responsibility (protect contaminants from release), while under Alternatives 3 or 4, the near-river impacts are removed and the site owner logically protects the land investment.

To assess the risk of site erosion along the Cuyahoga River banks, a river-channel model using the Hydrologic Engineering Center – River Assessment System (HEC-RAS) was developed to estimate potential sheer stresses on the riverbanks along the site. FS Addendum Appendix C presents the HEC-RAS analyses for a series of storm-related flows that together indicate a range of protective stone (riprap) sizes that may mitigate long-term erosion along the Cuyahoga River and Big Creek. The shear-stress calculations generally indicate that stone sizes averaging 5 inches (12 centimeter [cm]) on the banks to 1 inch (2.5 cm) on the horizontal site surfaces (i.e., gravel cover over exposed and contaminated soils) would stem erosive forces associated with the modeled storm events.

The calculated shear stresses indicate that the industrial fills and underlying alluvium, which are composed of silty clays to gravelly sands to sandy gravels, would be susceptible to erosion or riverbank sculpting. The 1,000-year performance period required under the applicable and relevant or appropriate requirements (ARARs) listed in the FS (USACE 2012) will include a series of low-frequency storm events (e.g., the 50-year and 100-year storms) that could affect the remedial alternatives for contamination near the Cuyahoga River.

The five simulated low-frequency storm events estimated the following inundation elevations (rounded) along the Harshaw Site:

- Ten percent annual exceedance probability (10-year) = 176.8 meters or 580 ft (flow is retained in the channel)
- Two percent annual exceedance probability (50-year) = 178.9 meters or 587 ft (most flow stays in the channel)
- One percent annual exceedance probability (100-year) = 179.2 meters or 588 ft (adjacent lowlands flooded)
- 0.2 percent annual exceedance probability (500-year) = 182.0 meters or 597 ft (OU-1 flooded)
- 0.1 percent annual exceedance probability (1,000-year) = 182.9 meters or 600 ft (OU-1 flooded)

The industrial plateau under OU-1 has an average riverbank elevation (top of bank) of 181.4 meters or 595 feet, so only the 500-year and 1,000-year events will inundate the site. The normal river stage of the Cuyahoga River and Big Creek along the site is 175.3 meters or 575 feet (see Appendix D of USACE 2012). The one-percent annual exceedance probability (100-year) storm has the potential to erode the riverbanks, as depicted on Figure B-37. This is a concern for Alternative 2 (Limited Action) since contamination would remain near the riverbank in the northeastern portion of OU-1. However, for soil-removal Alternatives 3 and 4, the concern is the potential erosion of fill and native sediments between the river and groundwater plume near former Building G-1; these interim soils attenuate uranium in groundwater prior to river discharge via baseflow. As detailed in Appendix C, storm-related river flows (and associated erosional forces) have a potential to re-establish pre-industrial riverbanks that are evident in subsurface boring logs (e.g., site fill layers cover a mature [vegetated] floodplain and deeper alluvium that blankets bedrock). This sculpting could occur if the site owner allowed the uncontrolled loss of land to the river.

To assess the effects of a re-established historical riverbank, the groundwater model was reconfigured with a river edge (toe of bank) along the 575-ft elevation contour (normal river flow elevation) where it intersects with the native alluvium. The upper bank topography was assumed a one-to-two vertical-to-horizontal (1V:2H) slope (Figure B-38), which reflects current riverbank slopes. The simulated bank configuration may not appear gently meandering as nature normally achieves, but provides a shortened transport path for the uranium plume near former Building G-1 to reach the river.

The resulting groundwater flow and uranium-transport simulations did not show significant changes in plume fate (i.e., it did not grossly change the long-term configuration), although the Cuyahoga River would receive higher uranium concentrations from baseflow over the 1,000-year period (Figure B-38). A maximum concentration of 37 µg/L (at year 1,000) occurs along a 25-foot long segment of bank represented by one model cell, whereas the balance of the baseflow concentrations are significantly less. This maximum concentration is greater than the baseline value of 9 µg/L, since the river is closer to the higher concentration plume area. Figure B-39 shows an overall greater flux to the river due to the simulated erosion. The baseflow rate reduced from 1,154 cubic feet per day (cfd) to 444 cfd due to less recharge area on the plateau. Figure B-39 shows the baseflow concentrations initially attenuating (i.e., decline as the plume is flushed from soils near the new bank) and then increasing due to transport of higher plume concentrations towards the river.

This modified condition does not appear to place the riverine environment at greater risk from uranium impacts, since site-wide discharge concentrations are still low and would dilute in the river. This is exemplified by assessing Cuyahoga River discharge data from the Independence, Ohio, gage, where the median flow is 2.5×10^7 cfd, mean flow is 4.8×10^7, and the 25^{th} and 75^{th} quartiles are 1.6×10^7 cfd and 4.5×10^7 cfd. By comparing these flows and the estimated baseflow discharge, site groundwater would dilute minimally about 36,000 times in the river throughout one day (e.g., 1.6×10^7 cfd divided by 444 cfd).

Consequently, this screening level evaluation indicates that potential Five-Year Review inspections derived from Alternatives 3 or 4 should document site erosion that would be addressed by the site owner.

4. GROUNDWATER INVESTIGATION CONCLUSION

The soil and groundwater investigations and modeling for the Harshaw FSA indicate the ranking of FS Alternatives 2, 3, and 4 has not changed with different site conditions. The removal of Building G-1 by USACE and the balance of site buildings by BASF (site owner) uniformly affects each alternative. In addition, the soil and groundwater investigations that occurred coincidentally with building deconstruction 1) refined (lessened) the contaminated soil volume estimate, 2) optimally delineated groundwater impacts from FUSRAP-related material, and 3) exemplified contaminant trends related to potential migration pathways.

The updated soil and groundwater data for OU-1 indicate that uranium is dissolved in 1) an intermittently perched water zone in the uranium-impacted surficial fill under and near Building G-1, 2) utility trenches under and near the building, and 3) underlying shale-rich gravel and alluvium that provide a migration pathway to the Cuyahoga River. The perched water partly originated as leakage from a ruptured drinking water main observed north of the site; water escaping the main likely followed a service-line trench that entered the site and fed Building G-1 (among others). The leakage also entered the backfill and bedding supporting the site storm-sewer system and propagated uranium-impacted discharge into the Cuyahoga River. This leak was terminated in 2014 and reduced the sewer discharge to the river to a trickle; subsequent removal of several stormwater sewer segments leading to the river ceased all discharge.

The dissolved uranium in the perched zone also dispersed laterally from Building G-1 due to the water-main inflows and associated mounding. Some wells exhibit an influence from the surficial fill (e.g., high water levels and uranium concentrations) due to filter-packs contacting the fill. The perched water also migrates vertically into the underlying silty gravel and coarse-grained alluvium below the Building G-1 area, especially where the fine-grain fill is absent or thin (i.e., less than two feet in thickness). Once in the silty shale-rich gravel, the dissolved uranium migrates into the surrounding alluvium, where uranium concentrations lessen due to greater dispersion and attenuation derived from a thicker saturated zone, increased soil adsorption, and geochemical conditions that decrease uranium solubility (and thus mobility). These conditions together indicate the high-concentration groundwater near former Building G-1 will not negatively affect the Cuyahoga River.

The updated FS groundwater flow and contaminant-transport model accounted for site changes and new sampling data. The model updates include:

- New recharge and hydraulic conductivity (or permeability) distributions to reflect subsurface utility clusters bedded in coarse-grained fill and sewer-line removals.
- Modified water-table contour distribution to account for the separation of perched water levels from lower zone water levels, but still reflect the influences of high recharge from the perched zone.
- Updated leachate generation zones to reflect refined soil contamination areas.
- New plume concentrations and extents derived from the sampling of wells and pits.
- Plume modifications for remedial action alternatives that will remove groundwater collocated with impacted soils.

The updated model predicted minor transport of the uranium plumes under and near former Building G-1 during the 1,000-year performance period. The uranium discharge to the Cuyahoga River for this analysis is similar to the original FS, which also predicted only low-concentration discharges (baseflow) to the river along the site (e.g., up to 9 µg/L as an average concentration). This level of discharge is below the USEPA drinking water standard of 30 µg/L for uranium and thus will not affect potential future river use as a consumptive source, even if portions of the site eroded along OU-1.

The FS alternatives for site remediation do not include a groundwater remedy since site groundwater (OU-1 specifically) is not considered a potable resource due to wide-ranging impacts by anthropogenic contamination that is both FUSRAP-related and commercial in origin.

Groundwater use at the site is impractical due to the limited areas that could provide notable well yields and hydrogeologic conditions that meet many of the characteristics of substandard groundwater classifications (i.e., urban groundwater). In addition, the groundwater at the site is replaceable by municipal and surface-water supplies that meet health standards.

Consequently, the new conceptual site model and associated numerical rendering did not change the conclusion of the previous RI and FS. The Cuyahoga River will not be impacted by concentrations that could put the surface water resource at risk, and on-site (OU-1) groundwater is not a potable resource without significant treatment. In addition, the exposure point concentration for total uranium was recalculated and presented in Table B-1. The maximum uranium values seen in groundwater under former Building G-1 (e.g., 240,000 µg/L of uranium in well IA03-TW006R) can pose a risk to the remediation worker since it exceeds an exposure concentration of 130,000 µg/L for uranium (USACE 2009, USACE 2012). However, the high-concentration groundwater is collocated with soil above preliminary remedial action goals, so the implementation of an excavation alternative for soil in OU1 would logically remove this water and protect the future (post-remedy) construction worker at the Harshaw Site.

5. REFERENCES

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TABLES

Table B-1. Groundwater Quality Summary

Cation	Constituent Symbol	Sampling Count	Minimum Result	Maimum Result	Average of Results	Water-quality Screening Limits (1)	Units
Aluminum	AL	410	0.00099	390	6.56	0.05 - 0.2	mg/L
Antimony	SB	206	0.00022	0.46	0.012	0.006	mg/L
Arsenic	AS	432	0.0003	0.64	0.020	0.01	mg/L
Barium	BA	485	0.0018	0.944	0.06	2 0	mg/L
Beryllium	BE	114	0.00006	0 21	0.013	0.004	mg/L
Cadmium	CD	259	0 000092	1.1	0.057	0.005	mg/L
Calcium	CA	484	9.6	830	213.52	ND	mg/L
Chromium	CR	317	0.00013	0.535	0.03	0.10	mg/L
Cobalt	CO	456	0.0001	8.4	0.33	ND	mg/L
Copper	CU	306	0.00021	1.1	0.05	1 3	mg/L
Iron	FE	411	0.016	1100	46.61	300 000	mg/L
Lead	PB	225	0 000054	1.3	0.03	0.015	mg/L
Lithium	LI	341	0.0043	1 22	0.10	0.06	mg/L
Magnesium	MG	486	0 24	330	65 06	ND	mg/L
Manganese	MN	481	0.00073	26	2.53	0.05	mg/L
Mercury	HG	62	0 000027	0 00207	0 0005	0.002	mg/L
Molybdenum	MO	512	0.00011	0 28	0.02	ND	mg/L
Nickel	NI	514	0.0018	360	15.46	0.7 - 1.3	mg/L
Potassium	K	486	2.1	145	17.74	ND	mg/L
Selenium	SE	266	0.00041	0.75	0.06	0.05	mg/L
Silver	AG	85	0.00005	0.43	0.02	ND	mg/L
Sodium	NA	484	3	1600	176.78	20.0	mg/L
Thallium	TL	183	0 000036	0 21	0.006	0.002	mg/L
Uranium	UTOTAL	662	0 000588	250	2.49	0.03	mg/L
Vanadium	V	239	0.00017	0 22	0.02	ND	mg/L
Zinc	ZN	389	0.00169	2.14	0.12	4.7	mg/L
Anion							
Total Alkalinity	ALK	195	7500	2230000	296,079	ND	ug/L
Bicarbonate Alkalinity	ALKB	144	31000	1300000	297,201	ND	ug/L
Bromine	BR	86	22	23000	901	ND	ug/L
Chloride	CL	269	82	2800000	238,632	250,000	ug/L
Cyanide	CN	6	5.1	102	69	200	ug/L
Flourine	F	194	37	84	4,576	2,000	ug/L
Nitrite-N	NO2N	46	0	5400	564	1,000	ug/L
Nitrate	NO3N	169	0	24000	1,462	10,000	ug/L
Phosphorus	P	16	17	410	191	ND	ug/L
ortho-Phosphate	PORTHO	8	96	2400	451	ND	ug/L
Sulfate	SO4	270	40000	7100000	746,219	500,000	ug/L
Miscellaneous							
Total Dissolved Solids	TDS	118	320	9790	1614	500	mg/L
Total Suspended Solids	TSS	10	0.8	136	39	--	mg/L
Dry Residue	DRES	84	340	8200	2219	--	mg/L
Deisel Range Organics	TPH-DRO	26	32	1200	205	ND	ug/L
pH	pH	303	3.2	8.74	6 5	6.5 - 8.5	pH units
Radionuclide							
Ac-227	AC-227	99	-42.1	35	-4.13	0.31	pCi/L
Ac-228	AC-228	31	0.18	14.2	5.52	ND	pCi/L
Am-241	AM-241	100	-20	21.1	-0.07	1.30	pCi/L
Ba-133	BA-133	1	0.883	0.883	0.88	ND	pCi/L
Ba-140	BA-140	1	3.78	3.78	3.78	ND	pCi/L
Be-7	BE-7	1	-0.0201	-0.0201	-0.02	6000.00	pCi/L
Bi-212	BI-212	31	-7.47	31.9	5.93	ND	pCi/L
Bi-214	BI-214	36	0	125	29 98	ND	pCi/L
Ce-139	CE-139	1	0 28	0 28	0.28	ND	pCi/L
Ce-141	CE-141	1	2 96	2 96	2.96	300.00	pCi/L
Ce-144	CE-144	1	-6.62	-6.62	-6.62	30 00	pCi/L
Co-56	CO-56	1	0.382	0.382	0.38	ND	pCi/L
Co-57	CO-57	1	-0.13	-0.13	-0.13	1000.00	pCi/L
Co-58	CO-58	1	0.134	0.134	0.13	300.00	pCi/L
Co-60	CO-60	1	0.842	0.842	0.84	100.00	pCi/L
Cr-51	CR-51	1	16	16	16 00	6000.00	pCi/L
Cs-134	CS-134	1	0.883	0.883	0.88	80 00	pCi/L
Cs-136	CS-136	1	-0.557	-0.557	-0.56	800.00	pCi/L
Cs-137	CS-137	99	-8	4.2	0.15	9.20	pCi/L
Eu-152	EU-152	69	-8	11	0.44	71 00	pCi/L
Eu-154	EU-154	69	-35	26	-2.13	480.00	pCi/L
Eu-155	EU-155	1	-4.49	-4.49	-4.49	600.00	pCi/L
Fe-59	FE-59	1	-0.43	-0.43	-0.43	ND	pCi/L
Gross Alpha	GALPHA	89	-1.8	18000	525.14	15 00	pCi/L
Gross Beta	GBETA	89	-7.2	12400	327.20	ND	pCi/L
Hg-203	HG-203	1	1 27	1 27	1.27	60 00	pCi/L
Ir-192	IR-192	1	-0.168	-0.168	-0.17	100.00	pCi/L
K-40	K-40	69	-140	110	10.43	250.00	pCi/L
Mn-54	MN-54	1	0.488	0.488	0.49	300.00	pCi/L
Na-22	NA-22	1	0.331	0.331	0.33	400.00	pCi/L
Nb-94	NB-94	1	-0.471	-0.471	-0.47	ND	pCi/L
Nb-95	NB-95	1	0.725	0.725	0.73	300.00	pCi/L
Nd-147	ND-147	1	0.993	0.993	0.99	200.00	pCi/L
Np-237	NP-237	69	-0.288	0.189	0.02	1.00	pCi/L
Np-239	NP-239	1	-1.44	-1.44	-1.44	300.00	pCi/L
Pa-231	PA-231	99	-107	107	8.39	0.43	pCi/L
Pb-210	PB-210	84	0.061	3.17	0.83	0.63	pCi/L
Pb-212	PB-212	32	0	14.3	2.88	ND	pCi/L
Pb-214	PB-214	37	0	172	32 80	ND	pCi/L
Pm-144	PM-144	1	-0.412	-0.412	-0.41	ND	pCi/L
Pm-146	PM-146	1	0.0203	0.0203	0.02	ND	pCi/L
Pu-235	PU-235	1	1 01	1 01	1.01	ND	pCi/L
Pu-238	PU-238	69	-0.0949	0 25	0.00	1.40	pCi/L
Pu-239	PU-239	39	-0.057	0.052	0.01	1.30	pCi/L
Pu-239/240	PU-239/240	30	-0.0687	0.192	0.05	1.30	pCi/L
Pu-244	PU-244	9	-0.137	0.885	0.14	ND	pCi/L
Ra-226	RA-226	295	-0.181	3.17	0.60	3 50	pCi/L
Ra-228	RA-228	326	-2.48	14.2	1.62	3.20	pCi/L
Ru-106	RU-106	1	-0.62	-0.62	-0.62	30 00	pCi/L
Sb-124	SB-124	1	1.8	1.8	1.80	60 00	pCi/L
Sb-125	SB-125	1	1 32	1 32	1.32	300.00	pCi/L
Sn-113	SN-113	1	0.243	0.243	0.24	300.00	pCi/L
Tc-99	TC-99	73	-16.5	23.6	0.51	32000 00	pCi/L
Th-228	TH-228	375	-0.506	55.7	0.39	5.70	pCi/L
Th-230	TH-230	406	-0.136	17400	45.46	8.40	pCi/L
Th-232	TH-232	375	-0.783	67	0.25	15 00	pCi/L
Th-234	TH-234	31	-48.7	167	45.15	ND	pCi/L
Tl-208	TL-208	31	0	3 96	1.88	ND	pCi/L
U-233/234	U-233/234	72	-0.0681	139	7.52	16 00	pCi/L
U-234	U-234	338	-0.194	74100	227.84	16 00	pCi/L
U-235	U-235	436	-29	4000	9.96	17 00	pCi/L
U-235/236	U-235/236	72	-0.0809	10.1	0.43	17 00	pCi/L
U-238	U-238	540	-200	78100	171.00	18 00	pCi/L
Yb-88	YB-88	1	-0.101	-0.101	-0.10	ND	pCi/L
Zn-65	ZN-65	1	-10.2	-10.2	-10 20	300.00	pCi/L
Zr-95	ZR-95	1	1 37	1 37	1.37	200.00	pCi/L

NOTES:

Analytes Exceeding Screening Criteria:

(1) Standards Assessed: 2011 Edition of the Drinking Water Standards and Health Advisories, EPA 820-R-11-002.
40 CFR Part 192, Groundwater Standards of Remedial Actions at Inactive Uranium Processing Sites (UMTRCA Rule).
OAC 3745-300-08, Ohio EPA VAP Standards (Rule 8), Appendix A
Nickel in Drinking Water, WHO Guidelines for Drinking-water Quality, WHO/SDE/WSH/05.08/55.
ND = Not Determined

Table B-2. Well Yield Sustainability Calculations

Well Identification	Hydraulic Conductivity (K) (ft/d)	(gpd/ft2)	Saturated Thickness (b) (ft)	Transmissivity (T Kb) (gpd/ft)	Well Avg	Ohio EPA Critical Resource Production Criteria (ft)	Ohio EPA Class B Production Criteria (ft)	USEPA Class III Criteria for Production (ft)
BKA-48 (Falling)	9	67.32	10	673.20	420.19	216.59	6.50	0.38
BKA-48 (Rising)	10	74.80	10	748.00				
BKA-48 (Falling)	1.87	13.99	10	139.88				
BKA-48 (Rising)	1.6	11.97	10	119.68				
BKA-52 (Falling)	3	22.44	22	493.68	493.68	188.09	5.64	0.33
BKA-52 (Rising)	3	22.44	22	493.68				
DM-1 (Falling)	1	7.48	6	44.88	32.09	1,917.13	57.51	4.03
DM-1 (Rising)	0.43	3.22	6	19.30				
DM-4 (Falling)	0.29	2.17	7	15.18	11.00	4,478.10	134.34	10.63
DM-4 (Rising)	0.13	0.97	7	6.81				
DM-9 (Falling)	3	22.44	11	246.84	370.26	241.88	7.26	0.42
DM-9 (Rising)	6	44.88	11	493.68				
DM-14 (Falling)	2	14.96	12	179.52	179.52	452.65	13.58	0.83
DM-14 (Rising)	2	14.96	12	179.52				
DM-22R (Falling)	24	179.52	21	3,769.92	4,162.62	28.18	0.85	0.04
DM-22R (Rising)	29	216.92	21	4,555.32				
DM-23R (Falling)	41	306.68	21	6,440.28	6,047.58	20.10	0.60	0.03
DM-23R (Rising)	36	269.28	21	5,654.88				
DM-25R (Falling)	11	82.28	22	1,810.16	2,962.08	38.28	1.15	0.06
DM-25R (Rising)	25	187.00	22	4,114.00				
DM-27R (Falling)	16	119.68	22	2,632.96	2,879.80	39.27	1.18	0.06
DM-27R (Rising)	19	142.12	22	3,126.64				
DM-29R (Falling)	54	403.92	22	8,886.24	10,531.84	12.15	0.36	0.02
DM-29R (Rising)	74	553.52	22	12,177.44				
RMW-38 (Falling)	0.14	1.05	2	2.09	2.09	14,432.37	432.97	46.73
RMW-38 (Falling)	0.14	1.05	2	2.09				
BKG MW0001 (Falling)	20.87	156.11	14	2,185.51	2,330.02	47.49	1.42	0.08
BKG MW0001 (Rising)	23.63	176.75	14	2,474.53				
BKG MW0005 (Falling)	1.41	10.55	23	242.58	433.54	210.75	6.32	0.37
BKG MW0005 (Rising)	3.63	27.15	23	624.51				
DM-26 (Falling)	4.25	31.79	19	604.01	611.83	155.79	4.67	0.27
DM-26 (Rising)	4.36	32.61	19	619.64				
DM-28 (Falling)	0.6	4.49	21	94.25	71.47	989.21	29.68	1.94
DM-28 (Rising)	0.31	2.32	21	48.69				
DM-30R (Falling)	##	1019.30	19	19,366.69	20,478.78	6.62	0.20	0.01
DM-30R (Rising)	##	1136.36	19	21,590.87				
IA04 TP0002 (Falling)	2.26	16.90	13	219.76	463.35	198.84	5.97	0.34
IA04 TP0002 (Rising)	7.27	54.38	13	706.93				
IA04 TP0004 (Falling)	0.06	0.45	9	4.04	3.03	11,374.86	341.25	33.70
IA04 TP0004 (Rising)	0.03	0.22	9	2.02				
IA04 TP0005 (Falling)	0.82	6.13	15	92.00	106.03	709.45	21.28	1.35
IA04 TP0005 (Rising)	1.07	8.00	15	120.05				
IA010 MW0001 (Falling)	6.1	45.63	23	1,049.44	775.90	126.36	3.79	0.21
IA010 MW0001 (Rising)	2.92	21.84	23	502.36				
IA010 MW0004 (Falling)	0.13	0.97	4	3.89	3.74	9,859.63	295.79	27.95
IA010 MW0004 (Rising)	0.12	0.90	4	3.59				

Sustainable
Unsustainable

Input Variables	Ohio EPA Critical Resource	Ohio EPA Class B Criteria	USEPA Class III Pumping Threshold	Ohio EPA Class B Criteria
Q (gpm)	100	3	0.1	3
Well Radius (r, ft)	0.5	0.5	0.5	0.5
Specific Yield (S)	0.18	0.18	0.18	0.18
Pumping Time (days)	1	1	365	365

Drawdown Estimation Equation: s' (264Q/T)*log(0.3Tt/r^2S)

Table B-3. Cation Reduction Indicator Ratio Analysis

Location	Filtered to Unfiltered Manganese Ratio	Filtered to Unfiltered Arsenic Ratio	Filtered to Unfiltered Iron Ratio
BKA48	0.26	0.93	3.40
BKA53	1.15	1.38	1.11
BKG-MW0001	10.46	1.01	2.99
BKG-MW0003			
BKG-MW0004	0.99	0.92	1.01
BKG-MW0005	0.85	1.00	1.17
DM11	0.88	0.66	0.62
DM14	1.03	1.32	0.97
DM15	0.88	0.63	0.72
DM23R	0.96	0.81	0.90
DM26	0.96	1.07	0.98
DM27R	0.95		0.28
DM29R			
DM30R	1.04	0.60	1.01
DM9	0.82	1.07	0.27
ERM47			
G-1-01	0.78	0.62	0.07
G-1-02	0.86	0.87	
G-1-03	0.97	0.75	0.09
G-1-04	0.97	0.82	0.30
G-1-05	0.99	1.01	0.96
G-1-06	0.96	0.96	0.96
G-1-07	0.94	0.92	1.07
G-1-08	1.01	0.83	
G-1-09	1.25	1.67	0.95
G-1-10	0.98	0.90	0.98
G-1-11	0.72	0.77	
G-1-12	0.91	0.81	
G-1-13	1.00	1.08	1.01
G-1-14	1.03	0.64	0.17
G-1-15	0.97	0.94	0.96
G-1-16	0.97	0.47	0.04
G-1-17	0.71	0.49	
G-1-18	1.27	0.35	0.18
IA03-TP0001	0.96	0.94	0.98
IA03-TW0001	0.41	0.62	0.01
IA03-TW0002			
IA03-TW0002R	0.93	0.49	0.03
IA03-TW0004			
IA03-TW0004R	1.02	0.98	0.98
IA03-TW0005R	0.93	0.77	0.02
IA03-TW0006R	1.03	0.50	
IA04-TP0001	1.09	1.09	1.09
IA04-TP0002	0.94	1.05	0.91
IA04-TP0004	1.15	1.27	1.19
IA04-TP0005			
IA04-TW0004	1.02	0.94	1.07
IA10-MW0001	0.93	0.85	0.63
IA10-MW0002	0.95	0.89	0.89
IA10-MW0003	6.17		2.03
IA10-MW0004	0.66	1.04	0.84
IA10-MW0005	0.92	0.85	6.53
IA10-MW0007	0.85	0.80	0.66
IA10-MW0008	0.92	0.53	0.59
IA10-MW0014	0.90	0.95	0.88
IA10-MW0017	0.90	1.67	2.69
IA10-MW0018	0.99	3.83	0.86
RMW35	1.00	0.89	1.03
RMW38	0.92	2.34	0.79
RMW39	0.79	1.05	0.15
RW01	0.03	0.18	
RW02	0.87	0.26	0.57
RW03	0.09	0.25	
RW04	1.00	0.75	
RW05	0.83	0.59	0.75
RW06	0.96	0.89	0.87
RW07	1.10	1.08	1.11
RW08	0.97	0.26	0.08
TP-01	0.21	0.25	
TP-02	0.08		0.06
TP-04	0.13	1.19	
TP-05	0.70	0.28	0.17
TWP01	0.89	0.88	0.90
TWP02	1.05	1.00	1.05
TWP03	0.86	0.45	0.88
TWP04	0.56	0.78	0.67
TWP05	0.98	0.94	0.95
TWP06	1.07	0.79	1.04
TWP07	1.00	1.03	0.96
TWP08	0.95	0.68	0.87
TWP09	1.00	1.00	0.98
TWP10	0.91	0.85	1.07
TWP11	0.91	1.04	1.27
TWP12	0.64	0.28	1.37
TWP13	0.68	0.70	1.48

NOTES

(yellow) Ratio greater than 0.90 indicates low-level reductive indicators.

(orange) All reductive indicator ratios greater than 0.90 - reductive conditions likely.

Table B-4. Well-Specific Reductive Capacity Analysis

Redox Variables	Dissolved O2	NO3- (as Nitrogen)	Mn2+	Fe2+	SO42-		
Units	mg/L	ug/L	mg/L	mg/L	ug/L		
Location / Threshold values	0.5	500	0.05	0.1	500	General Redox Category	Redox Process
BKA48	2.76	227 29	0.11	0.23	146,875	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
BKA53	0.61	76.02	0.65	9.72	118 000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
BKG-MW0001	0.70	767 50	0.46	4.30	762,500	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
BKG-MW0003	0.93	1032.50	0.08	0.03	102,050	Mixed(oxic-anoxic)	O2-Mn(IV)
BKG-MW0004	0.88	0.03	2.49	34 50	176,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
BKG-MW0005	0.77	390 50	2.40	26 50	124,500	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
DM11	0.68	82.76	0.36	35 00	620,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
DM14	1.11	62.11	11 03	849.00	4,611,667	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
DM15	0.90	198.70	1.20	19 34	120 429	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
DM23R	1.09	189 89	4.88	28 25	433,500	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
DM26	2.18	129 01	11.18	55 84	583 400	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
DM27R	2.76	625 00	0.05	0.14	1,340,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
DM29R	0.63	79.00	8.66	77 80	834,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
DM9	1.01	215 00	2.12	0.48	565,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-01	7.01	456 67	1.11	2.33	863,333	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-02	6.17	2643.33	0.49	1.15	393,333	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-03	9.88	11113.33	0.24	0.95	313,333	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-04	2.75	2950.00	3.80	0.04	360 000	Mixed(oxic-anoxic)	O2-Mn(IV)
G-1-05	4.01	60.00	3.90	1.13	380,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-06	1.42	90.00	1.35	34 50	365,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-07	3.12	60.00	1.85	17 50	305,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-08	5.86	373 33	0.34	0.02	606,667	Mixed(oxic-anoxic)	O2-Mn(IV)
G-1-09	5.53	110 00	1.20	9.80	335,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-10	1.32	60.00	3.95	6.25	300,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-11	14.53	260 00	0.33	4.49	870 000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-12	7.65	3000.00	0.42	0.76	626,667	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-13	3.29	90.00	0.91	40 50	355 000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-14	12.66	206 67	0.52	0.95	970,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-15	3.71	120 00	8.00	99 00	785,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-16	10.29	120 00	1.22	1.60	360,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
G-1-17	N/C	113 33	0.67	5.13	396,667	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
G-1-18	6.64	633 33	0.81	8.27	1,066,667	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA03-TP0001	1.43	60.00	0.91	36 00	230,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA03-TW0001	2.69	844.11	0.31	15.73	109 333	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA03-TW0002R	15.69	390 00	0.51	1.23	110,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA03-TW0004	0.65	0.03	0.20	31 30	468 000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA03-TW0004R	2.68	120 00	0.09	17 67	350,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA03-TW0005R	6.01	673 33	0.41	4.53	490,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA03-TW0006R	3.73	7850.00	0.31	6.90	375,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA04-TP0001	3.40	278 34	2.13	45 20	891,429	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA04-TP0002	4.37	132.75	18 23	56 50	1,130,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA04-TP0004	1.07	0.18	1.56	97 95	291,250	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA04-TP0005	0.63	109 00	3.91	118.00	1 790 000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA04-TW0004	0.96	136 21	8.30	159.60	1,786,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0001	2.02	172.43	0.02	0.76	218,143	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0002	4.79	4.48	1.74	22 26	423,800	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0003	2.00	1100.00	0.00	0.38	430,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0004	1.10	673.17	1.36	0.58	1,303,125	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0005	1.27	185 26	0.32	0.84	402,400	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0007	0.81	167 61	3.47	4.17	621 167	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0008	2.48	640 33	1.02	29 52	1,516,667	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0014	1.21	348 39	8.66	111.22	1 825 000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0017	1.61	5926.67	6.50	0.39	2,135,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
IA10-MW0018	0.56	2101.17	0.45	0.50	1,449,167	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
RMW35	1.22	0.03	2.00	31 90	356,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
RMW38	2.86	112 55	0.16	0.37	557,500	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
RMW39	N/C	8643.33	0.09	0.59	218,667	Mixed(anoxic)Or(oxic-anoxic)	Fe(III)/SO4-O2?OrNO3
RW01	N/C	1900.00	0.05	3.60	46,000	Mixed(anoxic)Or(oxic-anoxic)	Fe(III)/SO4-O2?OrNO3
RW02	N/C	770 00	1.50	28 00	120 000	Mixed(anoxic)Or(oxic-anoxic)	Fe(III)/SO4-O2?OrNO3
RW03	N/C	2200.00	0.03	3.30	58,000	Mixed(anoxic)Or(oxic-anoxic)	Fe(III)/SO4-O2?OrNO3
RW04	N/C	2100.00	0.04	2.10	83 000	Mixed(anoxic)Or(oxic-anoxic)	Fe(III)/SO4-O2?OrNO3
RW05	N/C	240 00	18 00	20 00	780,000	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
RW06	N/C	110 00	2.80	15 00	110,000	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
RW07	N/C	170 00	4.00	74 00	190,000	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
RW08	N/C	170 00	3.80	11 00	170,000	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
TP-01	N/C	340 00	0.18	12 00	910,000	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
TP-02	N/C	91.00	0.17	2.70	950,000	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
TP-04	N/C	25.00	0.01	0.25	990 000	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
TP-05	N/C	62.00	4.70	23 00	1,200,000	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
TWP01	4.47	79.00	1.90	77 00	1,000,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP02	3.15	2000.00	0.56	61 00	460,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP03	4.26	23.00	0.94	24 00	580,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP04	3.04	25.00	0.41	42 00	360,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP05	3.81	24.00	0.89	60 00	380,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP06	3.95	25.00	0.89	57 00	540 000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP07	5.97	25.00	2.70	27 00	910,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP08	4.54	260 00	0.91	54 00	540 000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP09	4.80	170 00	1.20	42 00	430,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP10	6.02	370 00	1.10	8.40	180,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP11	5.42	230 00	6.90	11 00	58,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP12	5.84	25.00	2.20	19 00	640,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
TWP13	6.31	110 00	4.10	8.10	220,000	Mixed(oxic-anoxic)	O2-Fe(III)/SO4

NOTE: N/C = Not Collected

FIGURES

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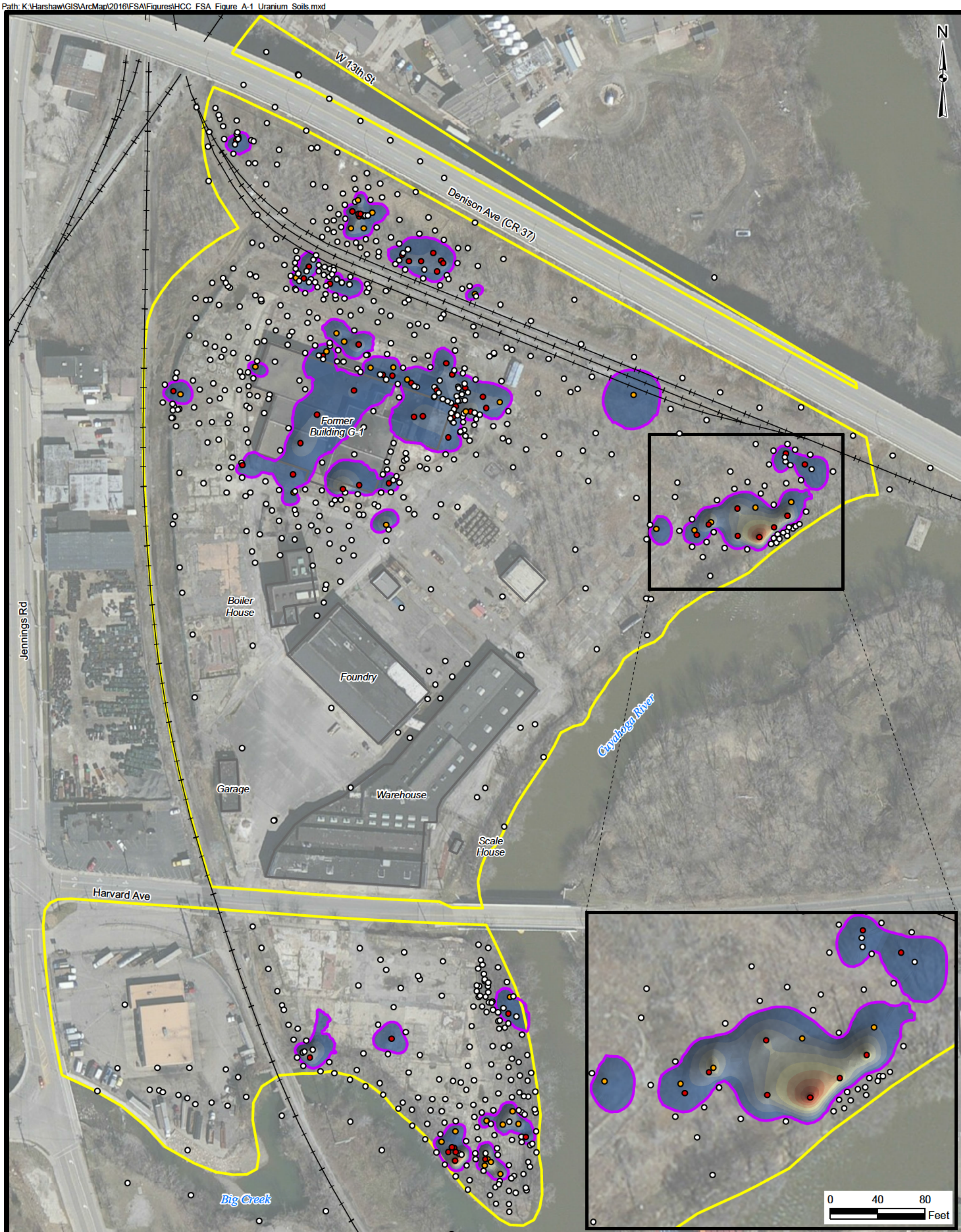

Legend

- SOR < 0.5
- SOR 0.5 - 1
- SOR > 1
- Spatial Extent of Contamination (BAASS 80% Probability)
- OU1 Boundary
- Site Buildings

Depth of Contamination (ft bgs)

< 2, 2 - 4, 4 - 6, 6 - 8, 8 - 10, 10 - 12, 12 - 14, 14 - 16, > 16

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

0 80 160 320 Feet

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U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS BUFFALO, NY

FUSRAP-RELATED SOIL CONTAMINATION IN OU1

FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-1

Document Name: HCC_FSA_Figure_A-1_Uranium_Soils.mxd
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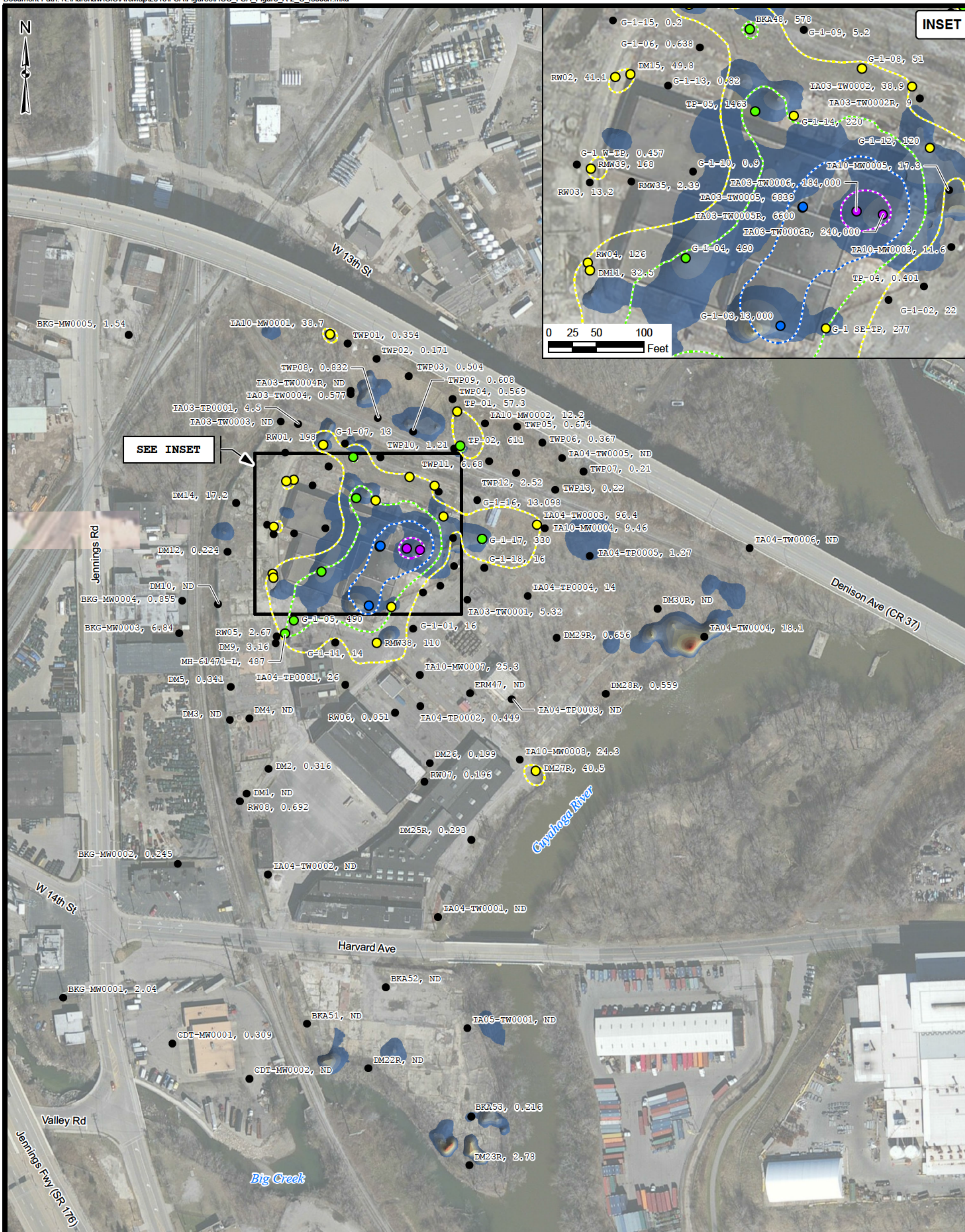

Legend

Total Uranium (ug/l)

- < 30 ug/l
- 30 - 300 ug/l
- 300 - 3,000 ug/l
- 3,000 - 30,000 ug/l
- > 30,000 ug/l

Total Uranium Concentrations

- 30 ug/l
- 300 ug/l
- 3,000 ug/l
- 30,000 ug/l

IA10-MW0008, 24.3
Location ID
Total Uranium (ug/l)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ND - Not Detected
All concentrations reported in ug/l.
ug/l - Micrograms per Liter.

0 100 200 400 Feet

US Army Corps of Engineers
Buffalo District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
BUFFALO, NY

MAXIMUM DETECTED TOTAL URANIUM CONCENTRATION IN GROUNDWATER

Document Name:
HCC_FSA_Figure_A-2_U_Isocon.mxd
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Date Saved: 16 Feb 2017
Time Saved: 9:40:49 AM

FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-2

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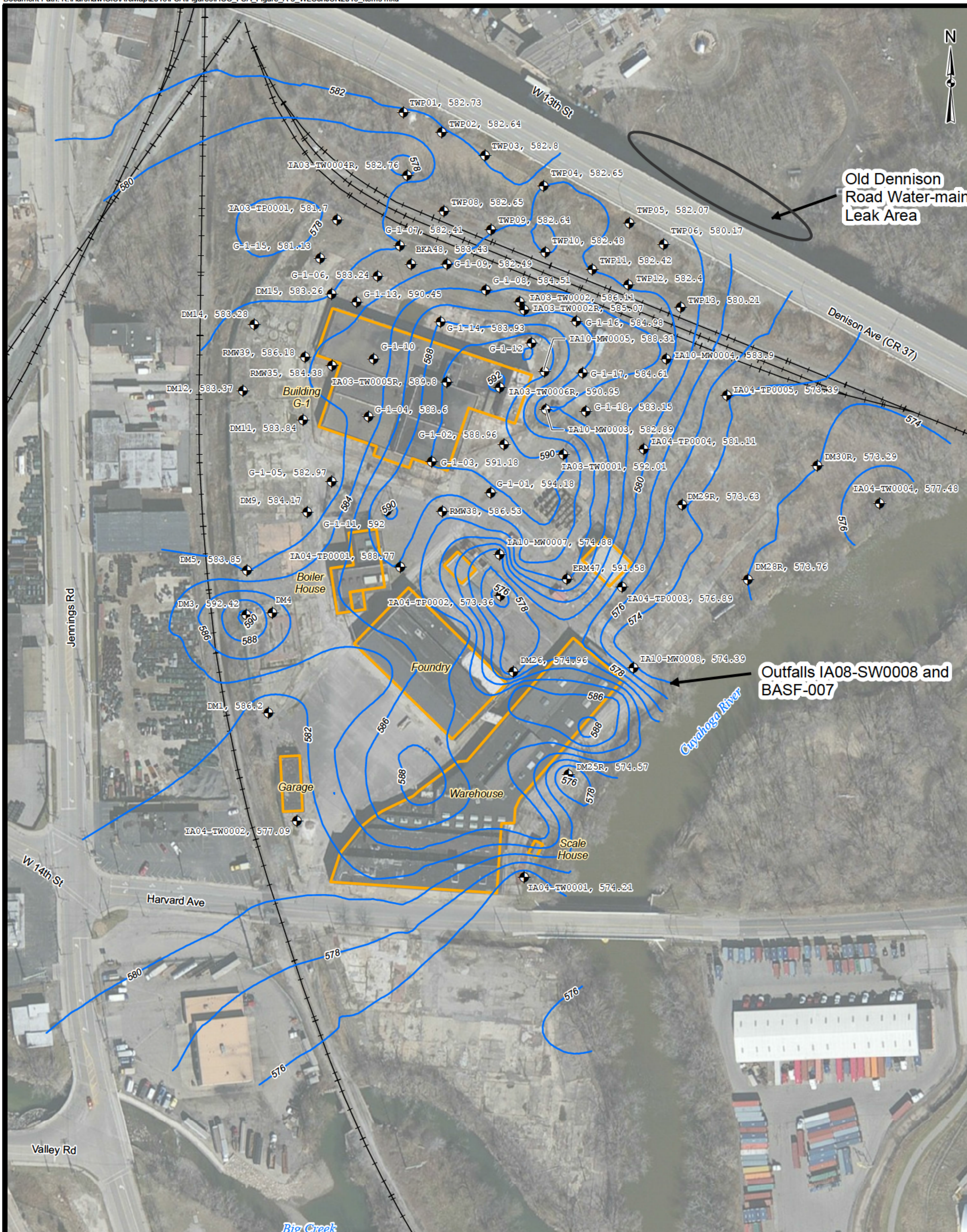

Legend

- Monitoring Well
- Groundwater Elevation Contour (ft amsl)
- Site Buildings

IA10-MW0008, 574.39
Location ID
Groundwater Elevation (ft amsl)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

TWP Classification based on Soil boring data
ERM47 - Compromised in 2009-2010

0 75 150 300 Feet

US Army Corps of Engineers® Buffalo District
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS BUFFALO, NY

GROUNDWATER POTENTIOMETRIC SURFACE MAP (JUNE 2016) and SITE-AREA HYDROLOGIC FEATURES

Document Name: HCC_FSA_Figure_A-3_WLConJUN2016_Items.mxd
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Date Saved: 07 Feb 2017
Time Saved: 2:42:53 PM

FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-3

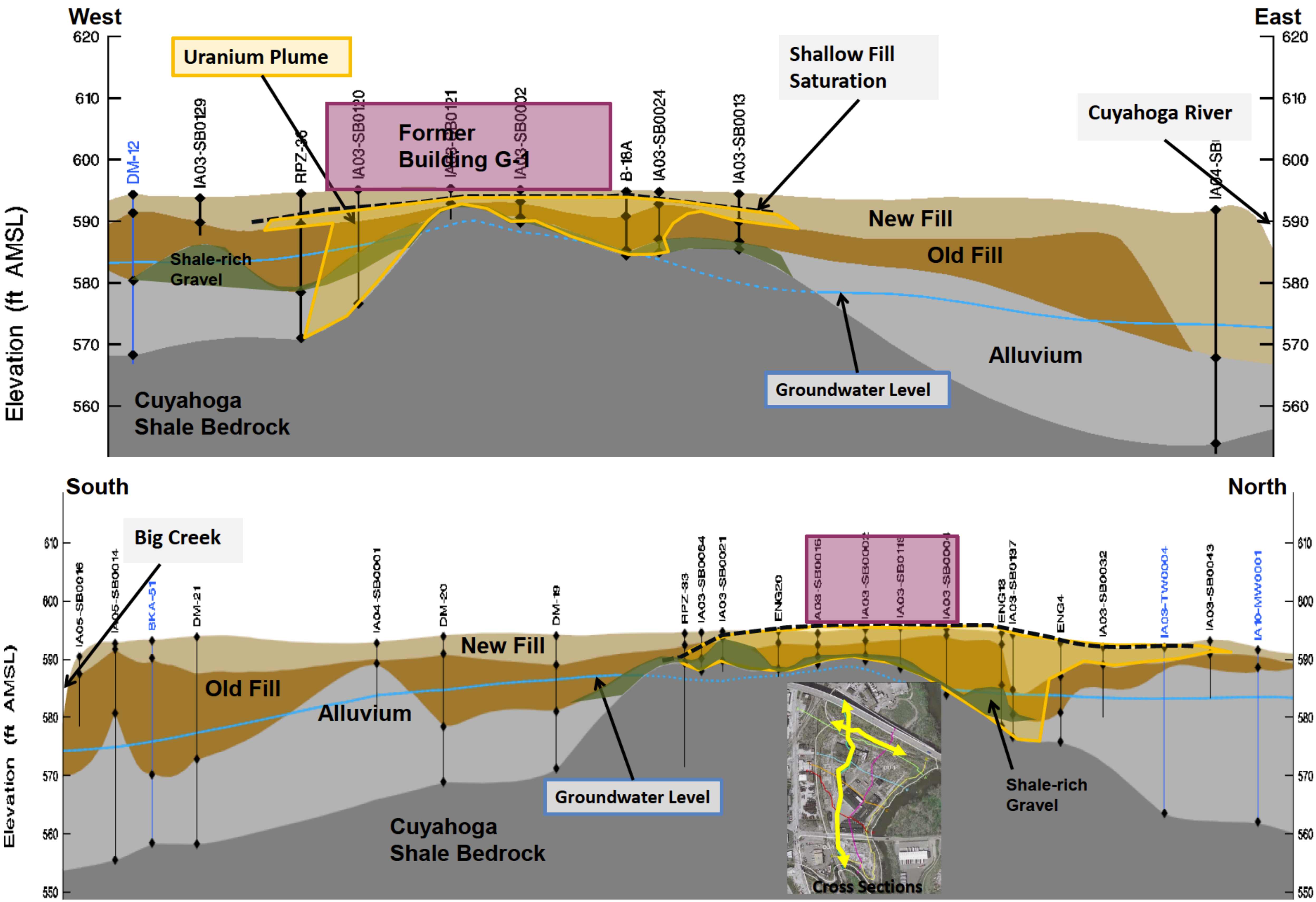
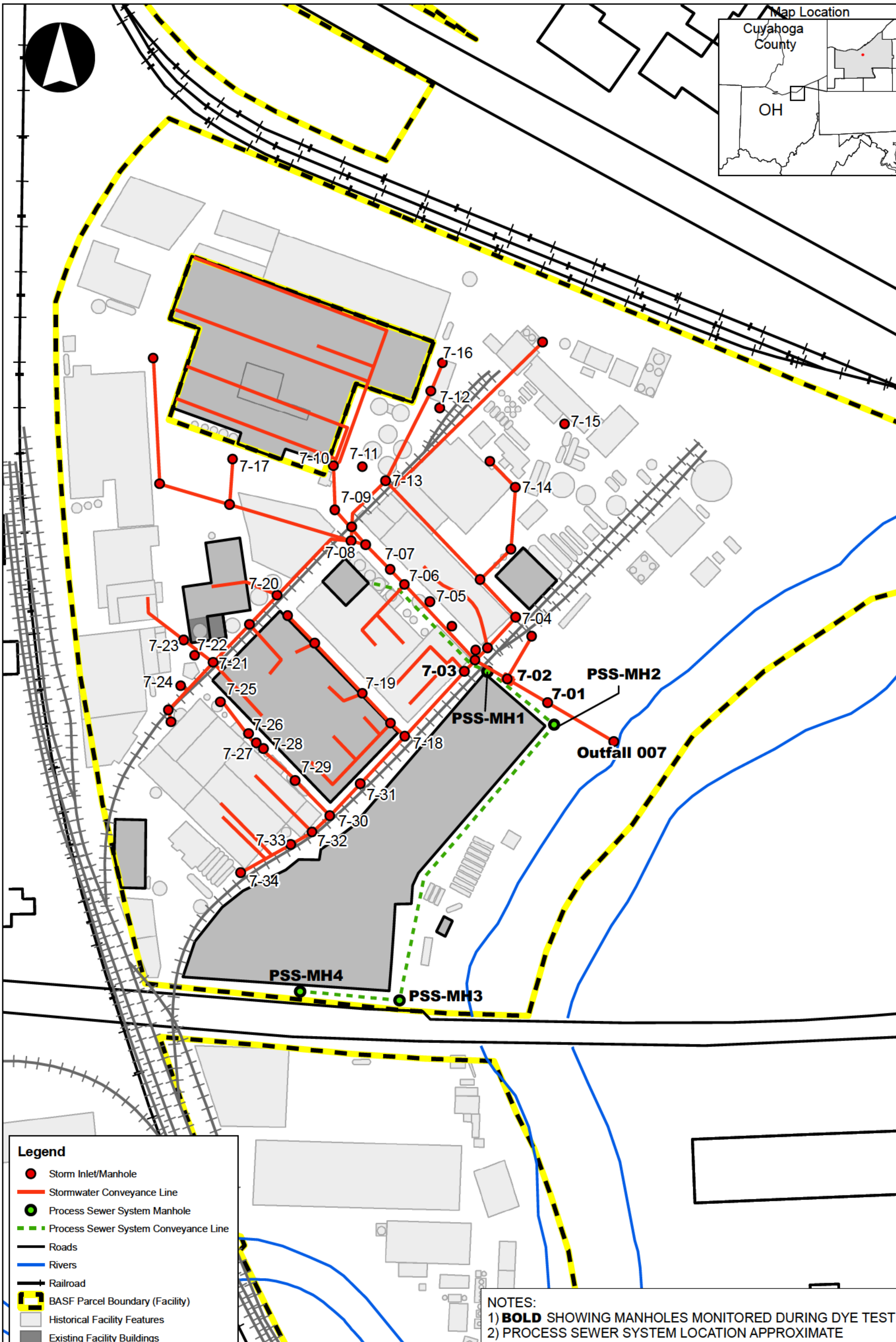


Figure B-4. Geologic Cross Sections Through G-1 Area and Cuyahoga River



NOTES:
1) **BOLD** SHOWING MANHOLES MONITORED DURING DYE TEST
2) PROCESS SEWER SYSTEM LOCATION APPROXIMATE

Drawn by: **KLP**	Site Plan with Outfall 007 Drainage and Process Sewer System	BASF The Chemical Company
Date: **07/29/11**	BASF Corporation - Former Harshaw Chemical Site Cleveland, Ohio	ProjectB#6015477
Checked by: **HA**		5 JULY 2011
Date: **07/29/11**	0 60 120 240 Feet	Figure 1

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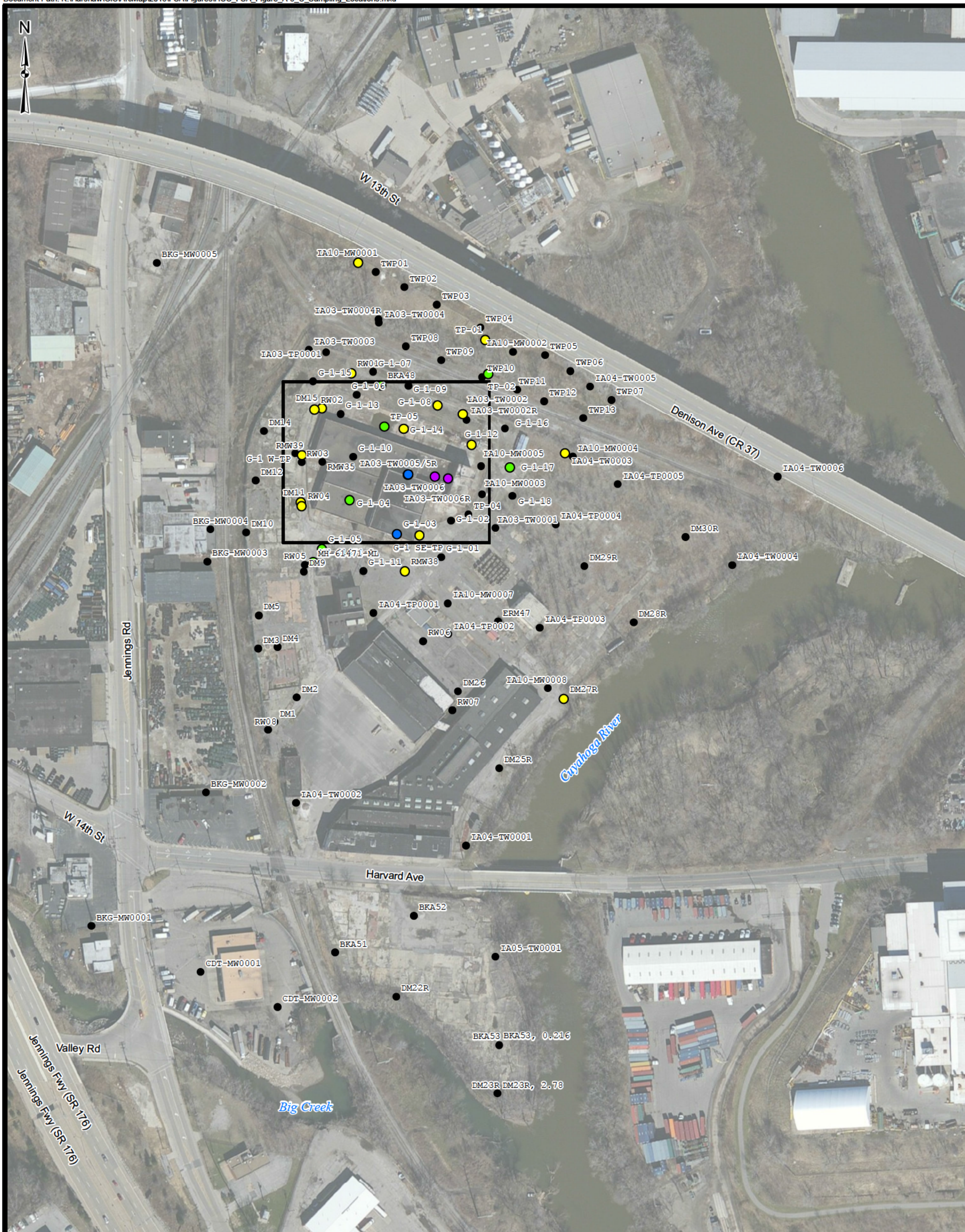

Legend

Total Uranium (ug/l)

- < 30 ug/l
- 30 - 300 ug/l
- 300 - 3,000 ug/l
- 3,000 - 30,000 ug/l
- > 30,000 ug/l

IA10-MW0008, 24.3

Location ID

Total Uranium (ug/l)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ND - Not Detected
All concentrations reported in ug/l.
ug/l - Micrograms per Liter.

0 100 200 400 Feet

US Army Corps of Engineers Buffalo District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
BUFFALO, NY

OU1 MONITORING WELLS, TEMPORARY WELL POINTS, AND TEST PITS SAMPLED FOR DISSOLVED URANIUM

Document Name:
HCC_FSA_Figure_A-6_U_Sampling_Locations.mxd
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Date Saved: 07 Feb 2017
Time Saved: 3:40:58 PM

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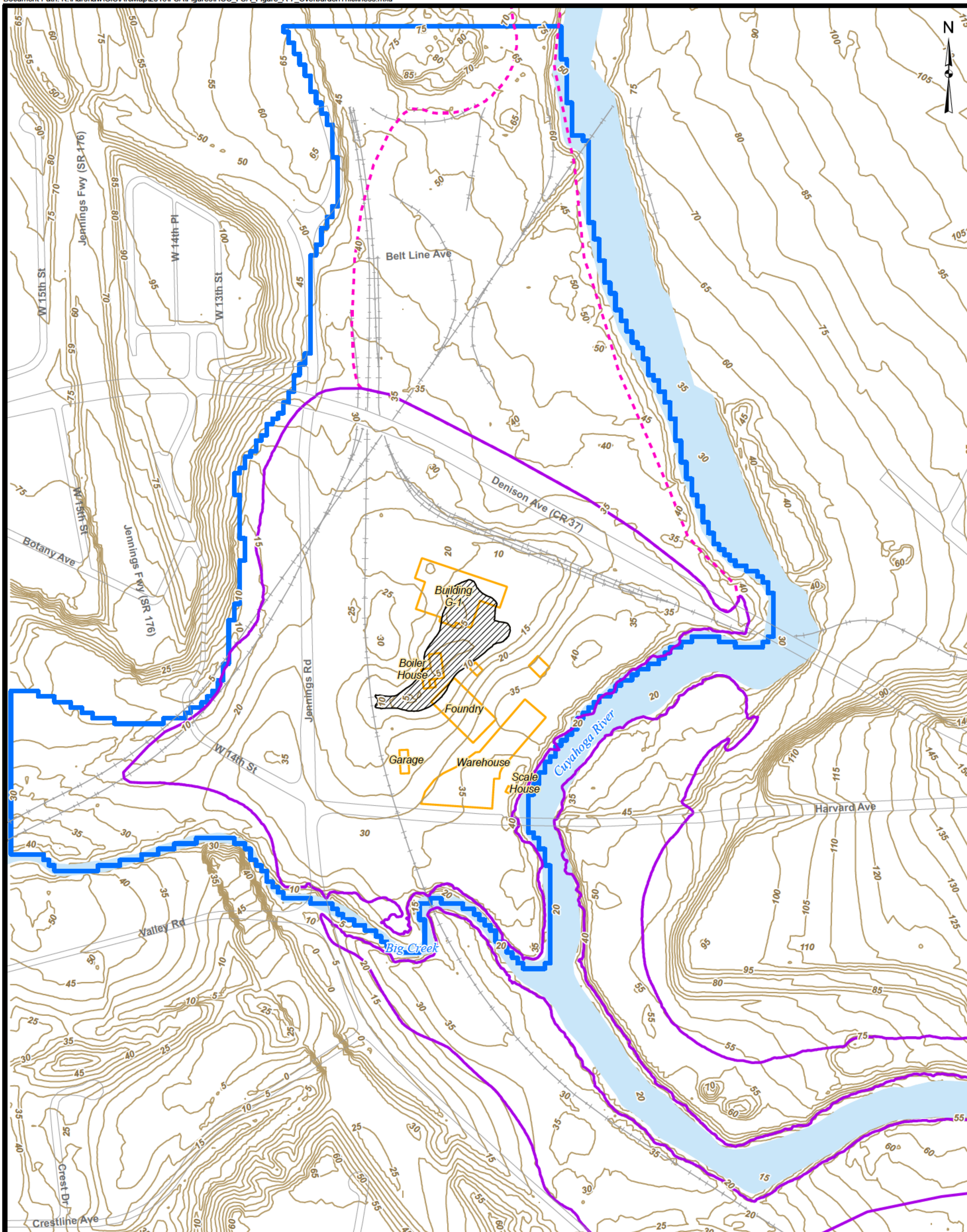
CLEVELAND, OHIO

FIGURE B-6

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-7_OverburdenThickness.mxd



Legend

- Thickness of Overburden (5ft contour interval)
- Overburden < 10ft Thick
- Area with New Fill at Surface
- Area with Old Fill at Surface
- Groundwater Model Area
- Waterbody
- Former Site Buildings

0 175 350 700 Feet

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BUFFALO, NY

THICKNESS OF OVERBURDEN

Document Name:
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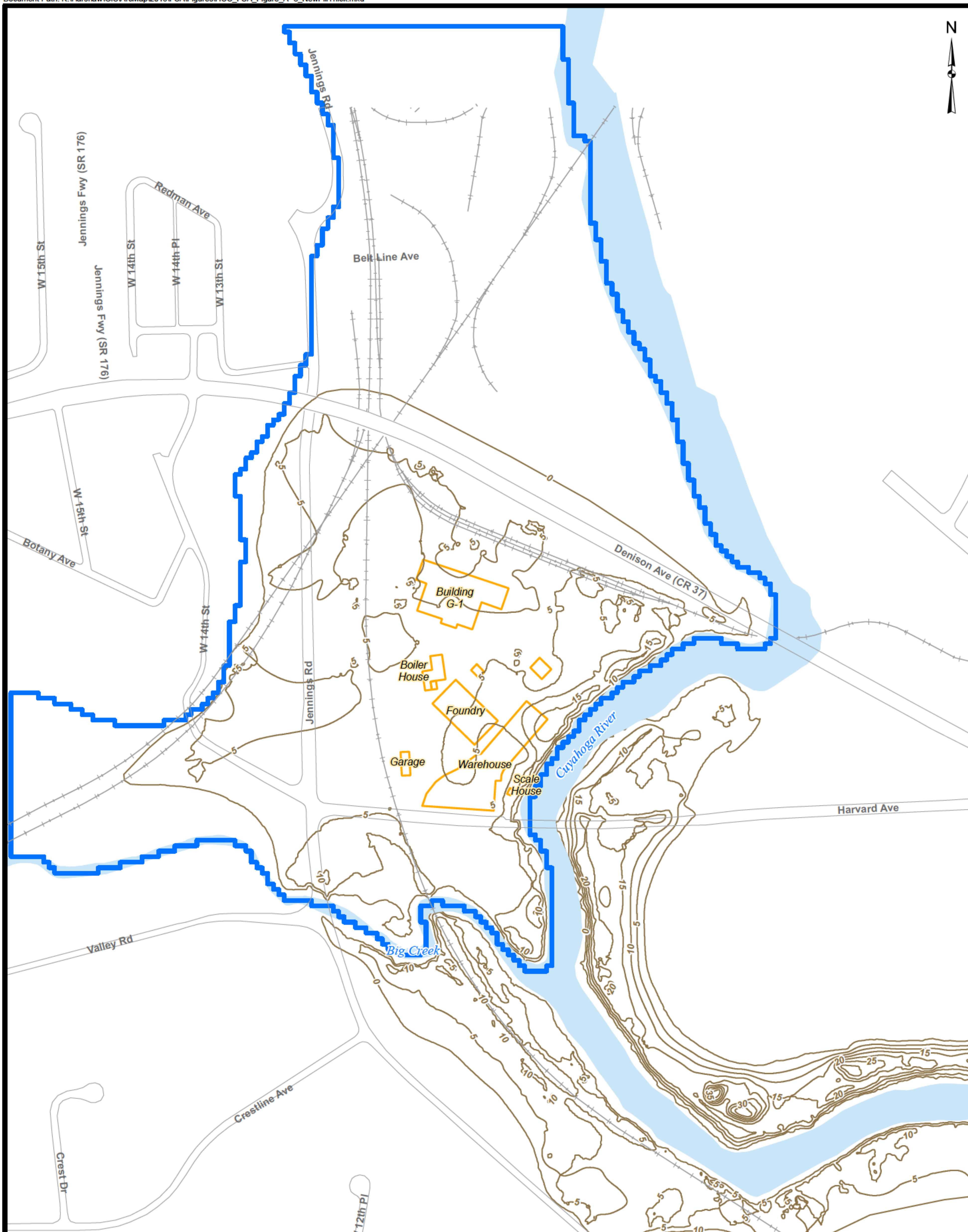
FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-7

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-8_NewFillThick.mxd



Legend

Thickness of New Fill (5ft contour interval)

Groundwater Model Area

Waterbody

Former Site Buildings

0 175 350 700 Feet

US Army Corps of Engineers Buffalo District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
BUFFALO, NY

THICKNESS OF NEW FILL

Document Name:
HCC_FSA_Figure_A-8_NewFillThick.mxd
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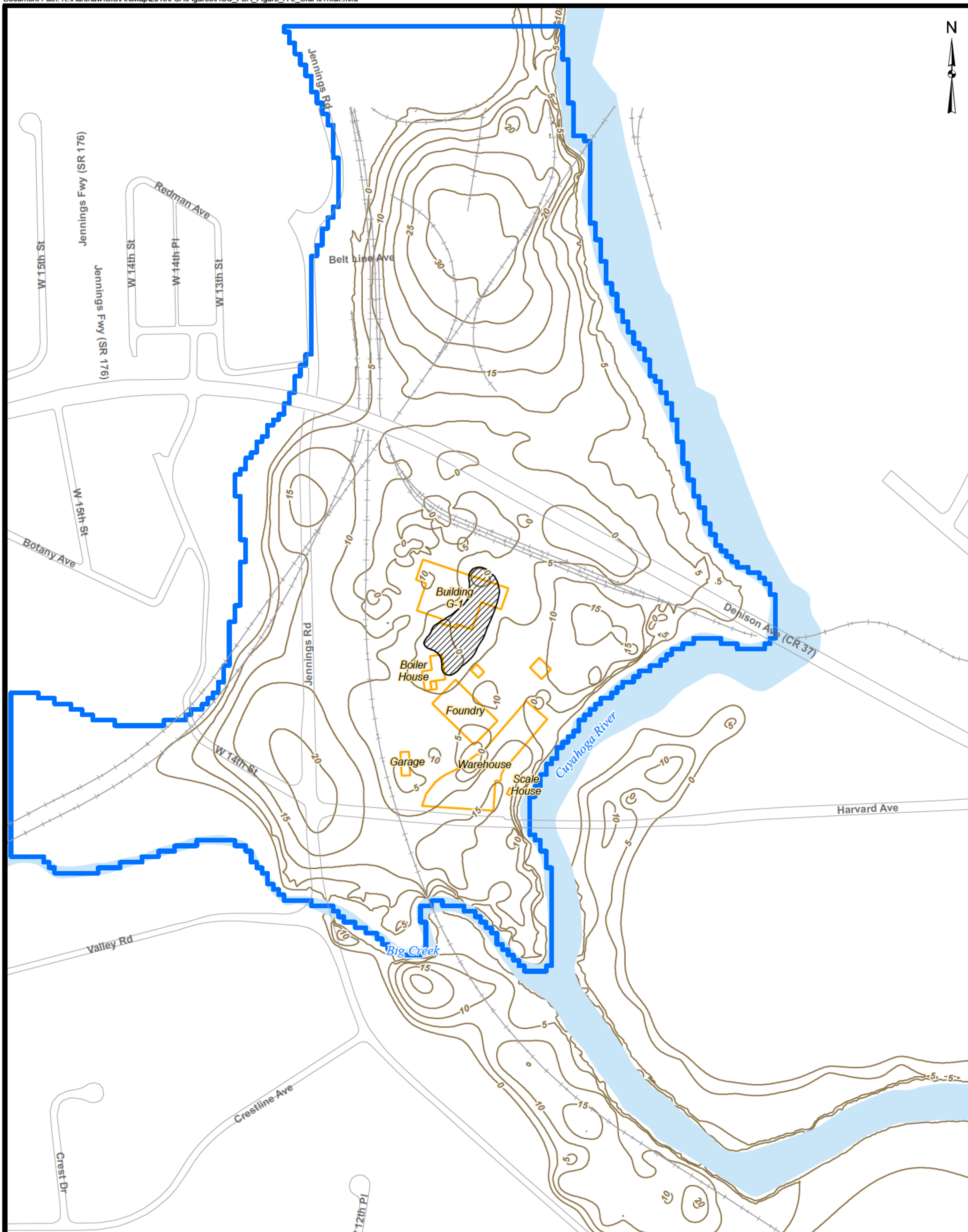
Date Saved: 07 Feb 2017
Time Saved: 3:50:09 PM

FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-8



Legend

- Thickness of Old Fill (5ft contour interval)
- Former Site Buildings
- Area of Thin Old Fill by G-1 (~0 - 3 ft)
- Groundwater Model Area
- Waterbody

0 175 350 700 Feet

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U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS BUFFALO, NY

THICKNESS OF OLD FILL

FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-9

Document Name:
HCC_FSA_Figure_A-9_OldFillThick.mxd
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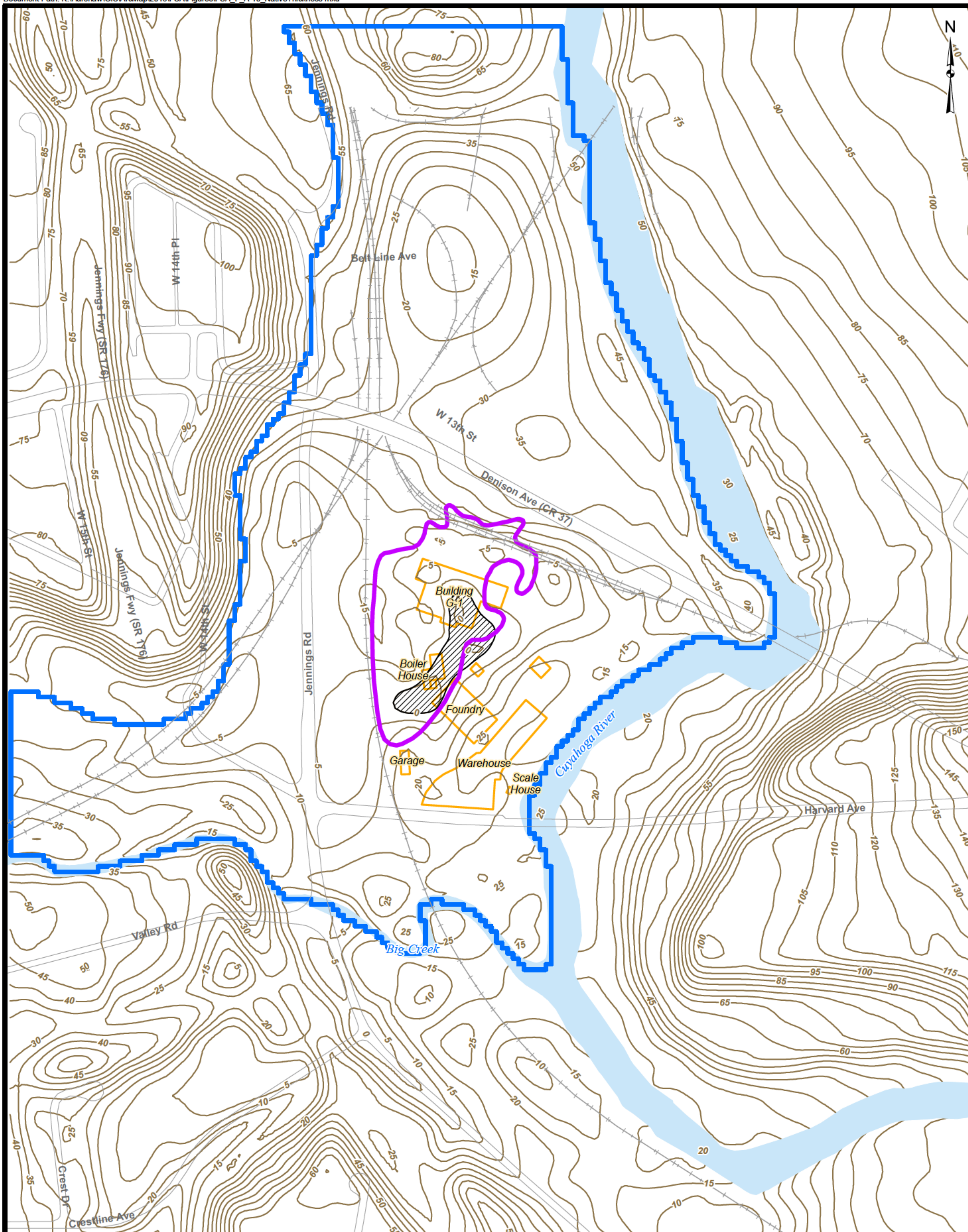

Legend

- Approximate Extent of Silty Shale Rich Gravel
- Area of Thin Native Sediment by G-1 (~0 - 2 ft thick)
- Groundwater Model Area
- Waterbody
- Thickness of Native Sediment (5ft contour interval)
- Former Site Buildings

0 175 350 700 Feet

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BUFFALO, NY

THICKNESS OF NATIVE SEDIMENT

FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-10

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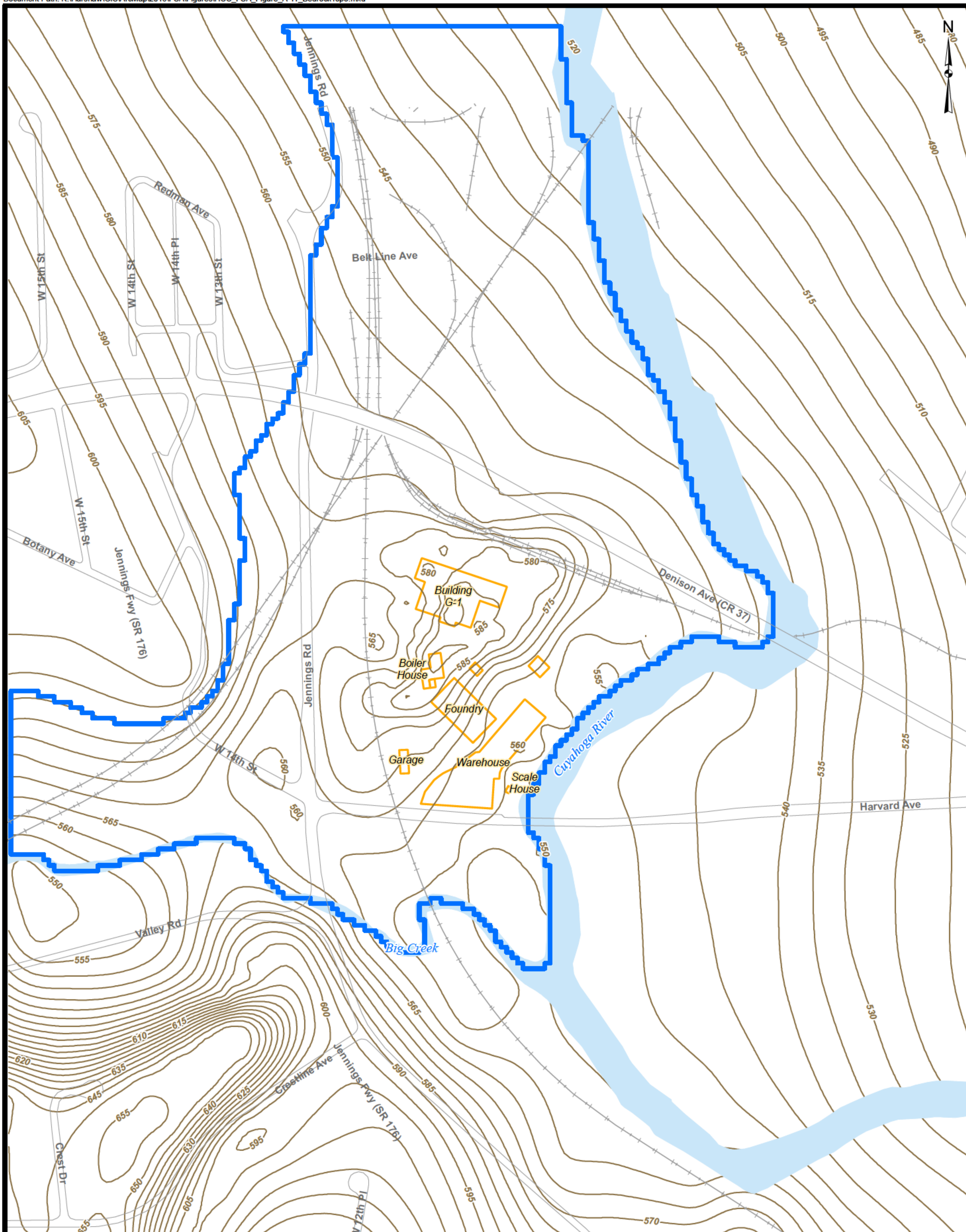

Legend

Top of Weathered Bedrock (5ft contour interval)

Groundwater Model Area

Waterbody

Former Site Buildings

0 175 350 700 Feet

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ELEVATION OF TOP OF WEATHERED BEDROCK

Document Name: HCC_FSA_Figure_A-11_BedrockTopo mxd
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Date Saved: 07 Feb 2017
Time Saved: 3:54:42 PM

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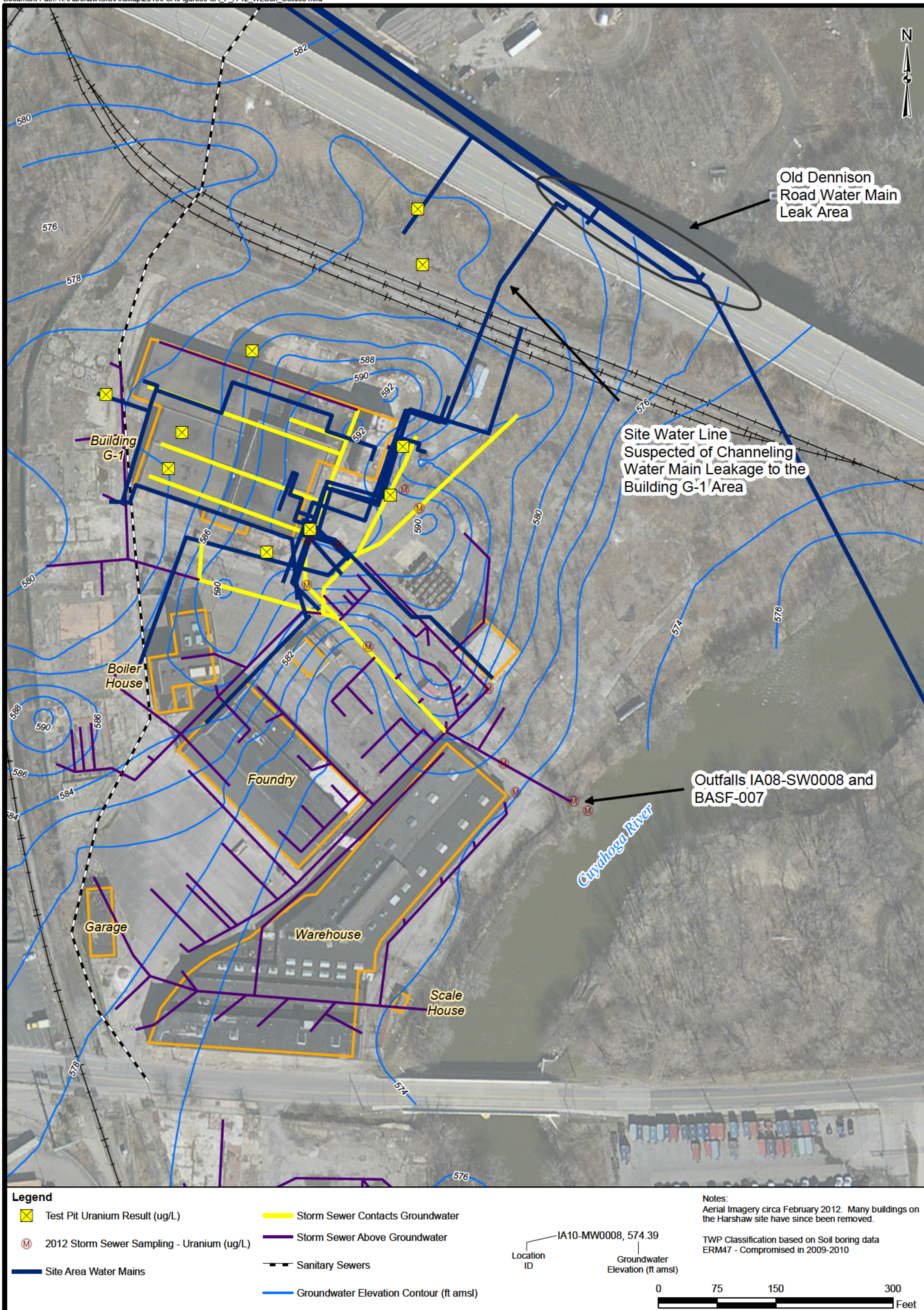
FIGURE B-11

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\FSA_F_A-12_WLCon_Utilities.mxd



Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

TWP Classification based on Soil boring data ERM47 - Compromised in 2009-2010

US Army Corps of Engineers® Buffalo District
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS BUFFALO, NY

SITE UTILITIES AND GROUNDWATER POTENTIOMETRIC SURFACE MAP (JUNE 2016)

Document Name:
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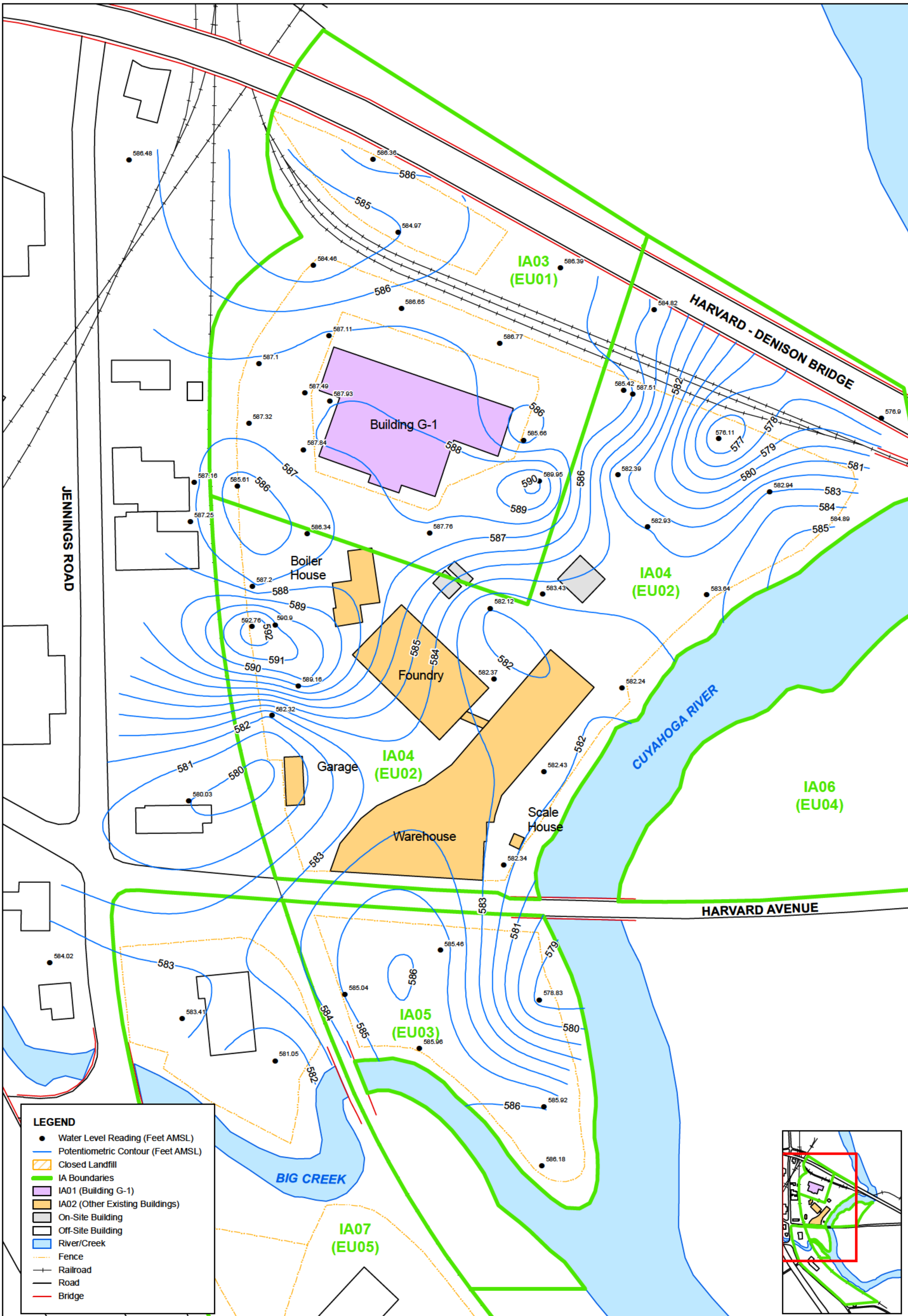
FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-12



PROJECT NAME:

Former Harshaw Chemical Site Remedial Investigation Report

DRAWING TITLE:

Figure 6-36. Groundwater Potentiometric Surface Map: May 2004

N W E S

0 45 90 180 270 Feet

DATUM: *Ohio State Plane North Zone, NAD83, US Survey Feet*

DRAWN BY:

JDV 10/17/08

CHECKED BY:

JG 10/17/08

Figure B-13

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-14_May05WgCon.mxd

Legend

- Monitoring Well
- Groundwater Elevation Contour (ft amsl)
- Former Site Buildings

IA05-TW0001, 578.66
Location ID
Groundwater Elevation (ft amsl)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

0 100 200 400 Feet

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BUFFALO, NY

GROUNDWATER POTENTIOMETRIC SURFACE MAP - MAY 2005

Document Name:
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Date Saved: 08 Feb 2017
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FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-14

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-15_May10WgCon.mxd

Legend

- Monitoring Well
- Groundwater Elevation Contour (ft amsl)
- Site Buildings

IA10-MW0008, 575.32

Location ID

Groundwater Elevation (ft amsl)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ERM47 - Compromised in 2009-2010

0 100 200 400 Feet

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BUFFALO, NY

GROUNDWATER POTENTIOMETRIC
SURFACE MAP - MAY 2010

Document Name:
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Time Saved: 11:05:58 AM

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CLEVELAND, OHIO

FIGURE B-15

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-16_Oct14WgCon.mxd

Legend

- Monitoring Well
- Groundwater Elevation Contour (ft amsl)
- Site Buildings

IA10-MW0008, 575.15
Location ID
Groundwater Elevation (ft amsl)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ERM47 - Compromised in 2009-2010

0 100 200 400 Feet

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GROUNDWATER POTENTIOMETRIC SURFACE MAP - OCTOBER 2014

Document Name: HCC_FSA_Figure_A-16_Oct14WgCon.mxd
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Date Saved: 08 Feb 2017
Time Saved: 11:09:00 AM

FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-16

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-17_Jan16WgCon mxd

Legend

Monitoring Well

Groundwater Elevation Contour (ft amsl)

Site Buildings

IA10-MW0008, 574.39

Location ID

Groundwater Elevation (ft amsl)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

TWP Classification based on Soil boring data
ERM47 - Compromised in 2009-2010

0 75 150 300 Feet

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BUFFALO, NY

GROUNDWATER POTENTIOMETRIC SURFACE MAP (JANUARY 2016)
AND WELL SEAL ASSESSMENT

Document Name:
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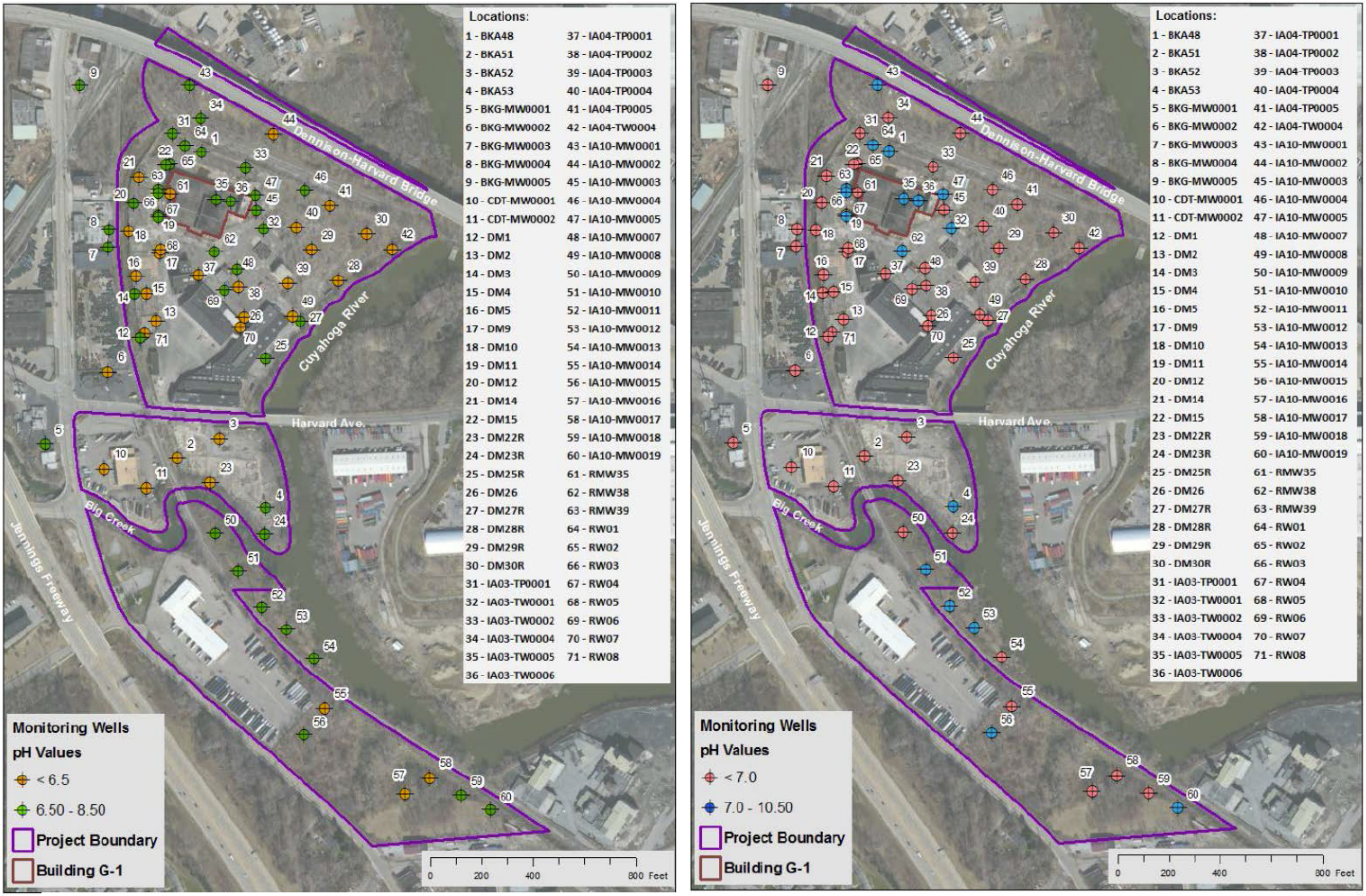
FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE B-17



Average pH Values Compared to the USEPA SDWR

Average pH Values Compared to Ohio EPA Standards

Figure B-18. Groundwater pH Distribution

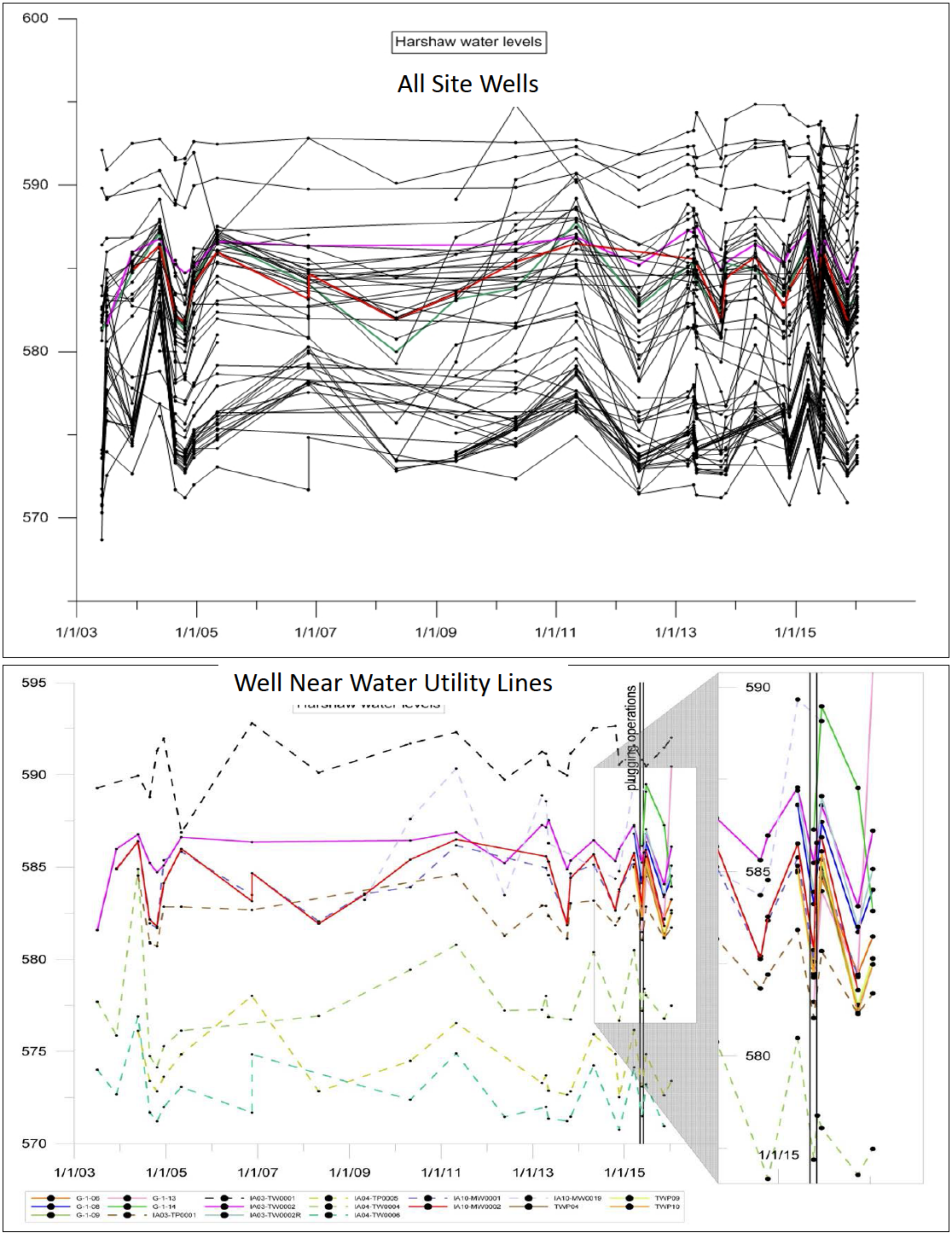
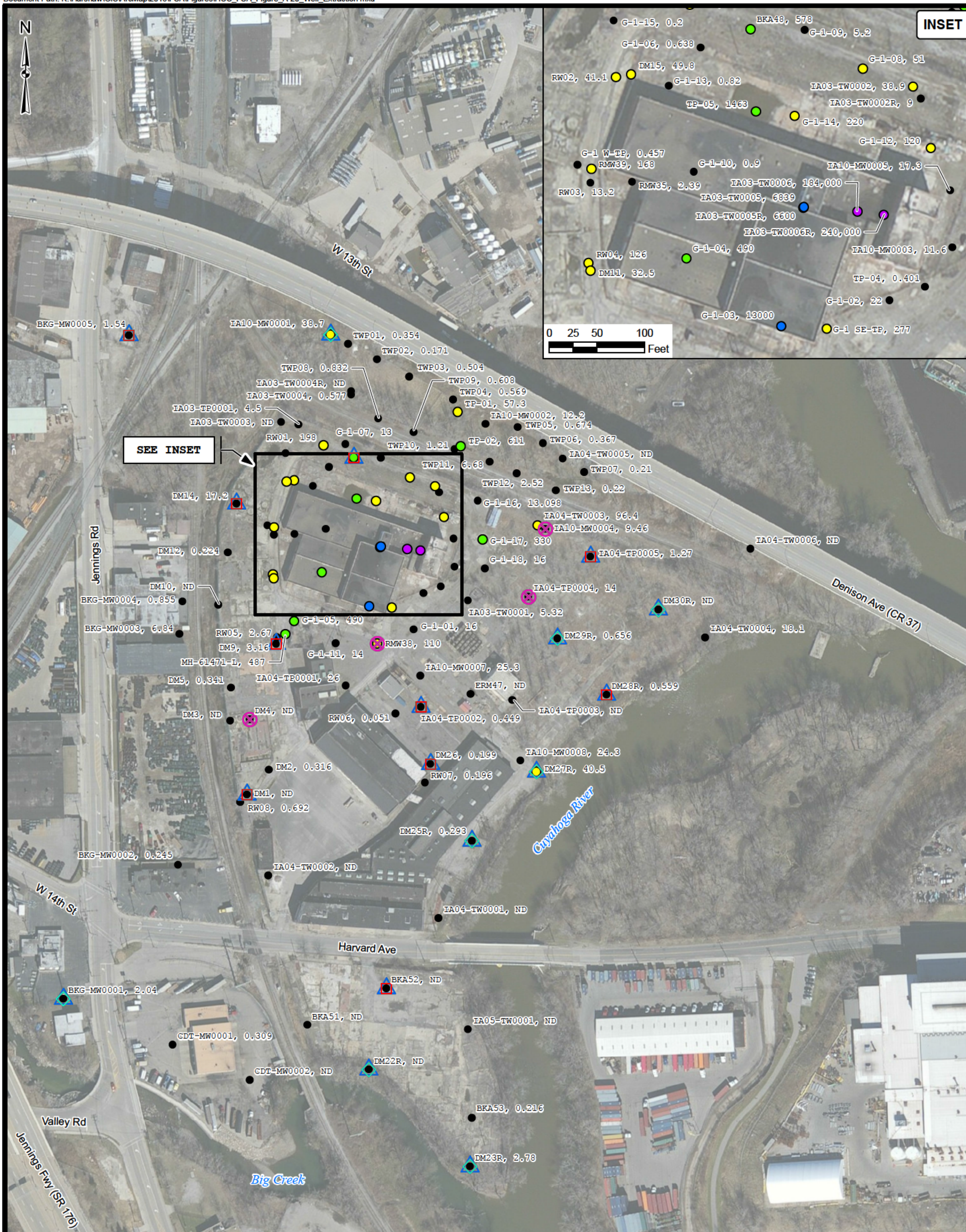


Figure B-19. Groundwater Level Trends

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-20_Well_Extraction.mxd



Legend

Total Uranium (ug/l)

- < 30 ug/l
- 30 - 300 ug/l
- 300 - 3,000 ug/l
- 3,000 - 30,000 ug/l
- > 30,000 ug/l

- Sustainable Well Production (Ohio Class B)
- Sustainable Well Production (USEPA Class III)
- Unsustainable Well Production (Ohio Class B)
- USustainable Well Production (Ohio and USEPA Classifications)

IA10-MW0008, 24.3
Location ID
Total Uranium (ug/l)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ND - Not Detected
All concentrations reported in ug/l.
ug/l - Micrograms per Liter.

0 100 200 400 Feet

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MAXIMUM DETECTED TOTAL URANIUM CONCENTRATION IN GROUNDWATER AND GROUNDWATER EXTRACTION POTENTIAL

Document Name:
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Drawn By: h5tdewtf
Date Saved: 08 Feb 2017
Time Saved: 11:18:39 AM

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CLEVELAND, OHIO

FIGURE B-20

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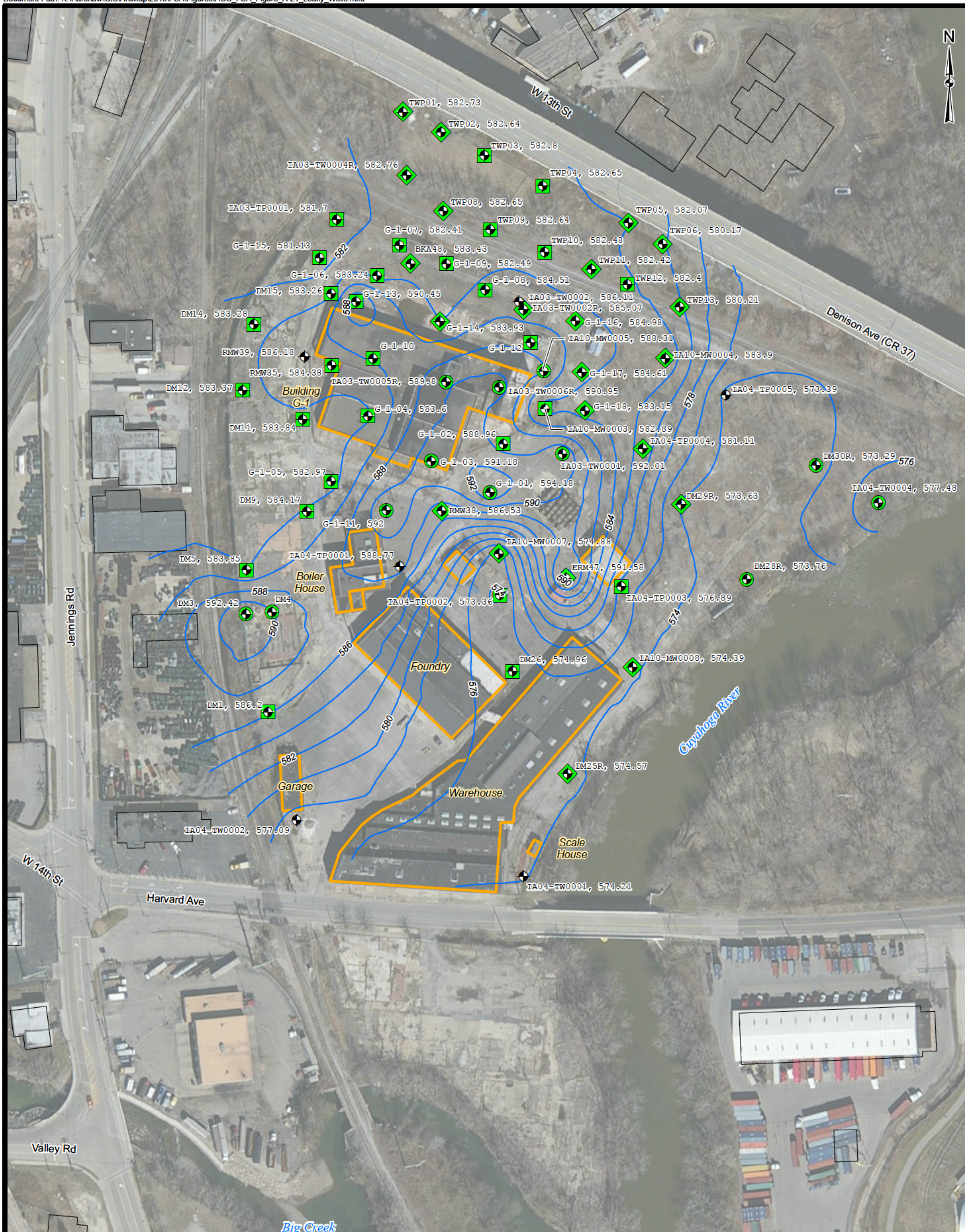

Legend

Monitoring Well

Well Seal Assessment

- Shallow Seal in Contact with or Finished in New Fill
- Shallow Seal in Old Fill
- Seal in Native Soils/Sediment

Groundwater Elevation Contour (ft amsl)

Site Buildings

IA10-MW0008, 574.39
Location ID
Groundwater Elevation (ft amsl)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

TWP Classification based on Soil boring data
ERM47 - Compromised in 2009-2010

0 75 150 300 Feet

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BUFFALO, NY

GROUNDWATER POTENTIOMETRIC SURFACE MAP (JANUARY 2016)
AND WELL SEAL ASSESSMENT

Document Name:
HCC_FSA_Figure_A-21_Leaky_Wells.mxd
Drawn By: h5tdewtf
Date Saved: 08 Feb 2017
Time Saved: 11:40:31 AM

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FIGURE B-21

Legend

- Monitoring Well Omitted from Interpretation
- Monitoring Well
- Groundwater Elevation Contour (ft amsl)
- Site Buildings

IA10-MW0008, 574.39
Location ID
Groundwater Elevation (ft amsl)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

Interpretation is withough wells with their sandpack in Shallow Fill.

0 75 150 300 Feet

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U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS BUFFALO, NY

MODIFIED GROUNDWATER POTENTIOMETRIC SURFACE MAP (JANUARY 2016)

Document Name:
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Date Saved: 12 May 2017
Time Saved: 1:40:07 PM

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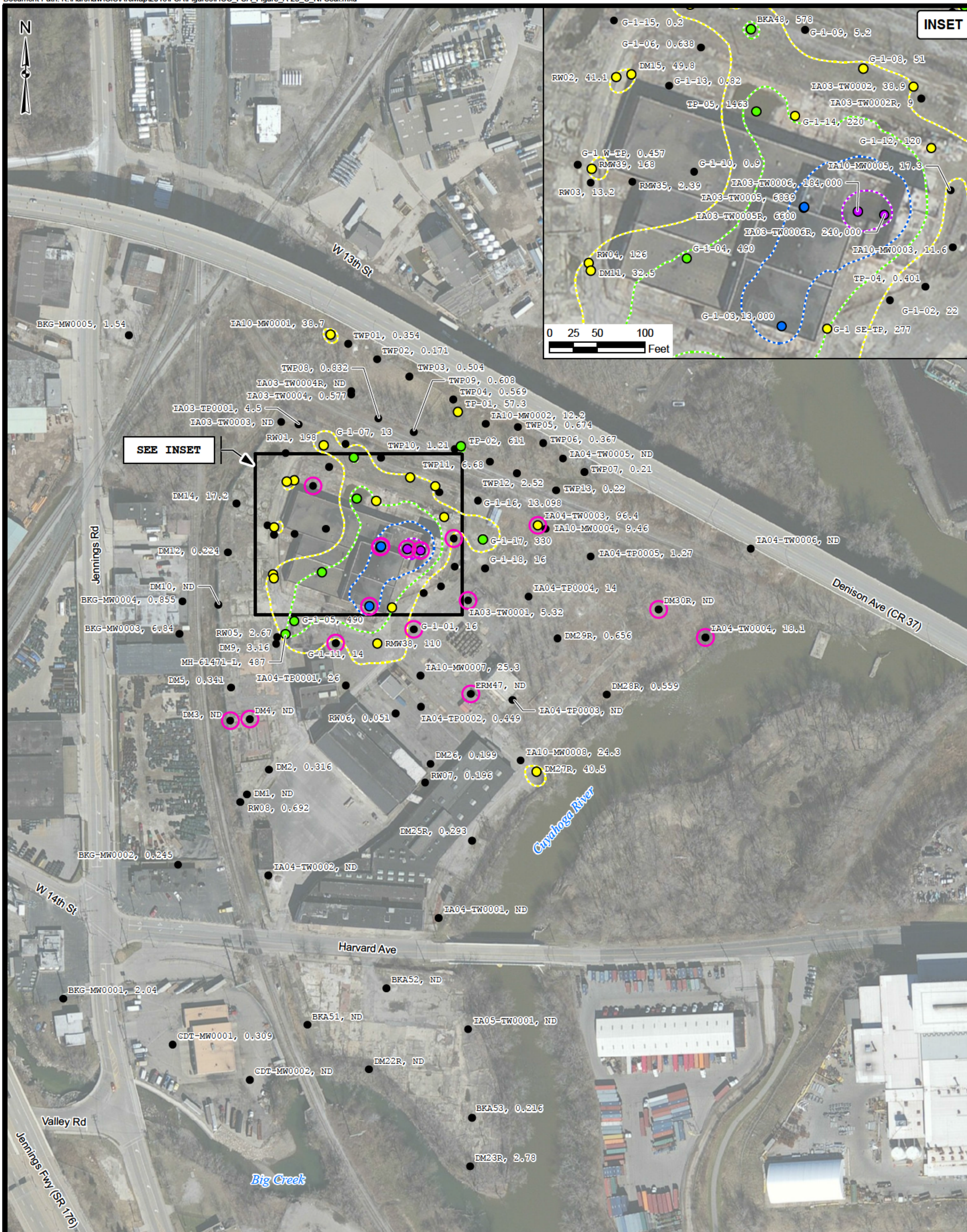
CLEVELAND, OHIO

FIGURE B-22

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-23_U_NFSeal.mxd



Legend

Total Uranium (ug/l)

- < 30 ug/l
- 30 - 300 ug/l
- 300 - 3,000 ug/l
- 3,000 - 30,000 ug/l
- > 30,000 ug/l

CONC

- 30 ug/l
- 300 ug/l
- 3,000 ug/l
- 30,000 ug/l

Wells with Shallow Seal in Contact with or Finished within New Fill

IA10-MW0008, 24.3
Location ID
Total Uranium (ug/l)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ND - Not Detected
All concentrations reported in ug/l.
ug/l - Micrograms per Liter.

0 100 200 400
Feet

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U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
BUFFALO, NY

MAXIMUM DETECTED TOTAL URANIUM CONCENTRATION IN GROUNDWATER AND SHALLOW-FILL INFLUENCED WELLS

Document Name:
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Date Saved: 08 Feb 2017
Time Saved: 11:53:35 AM

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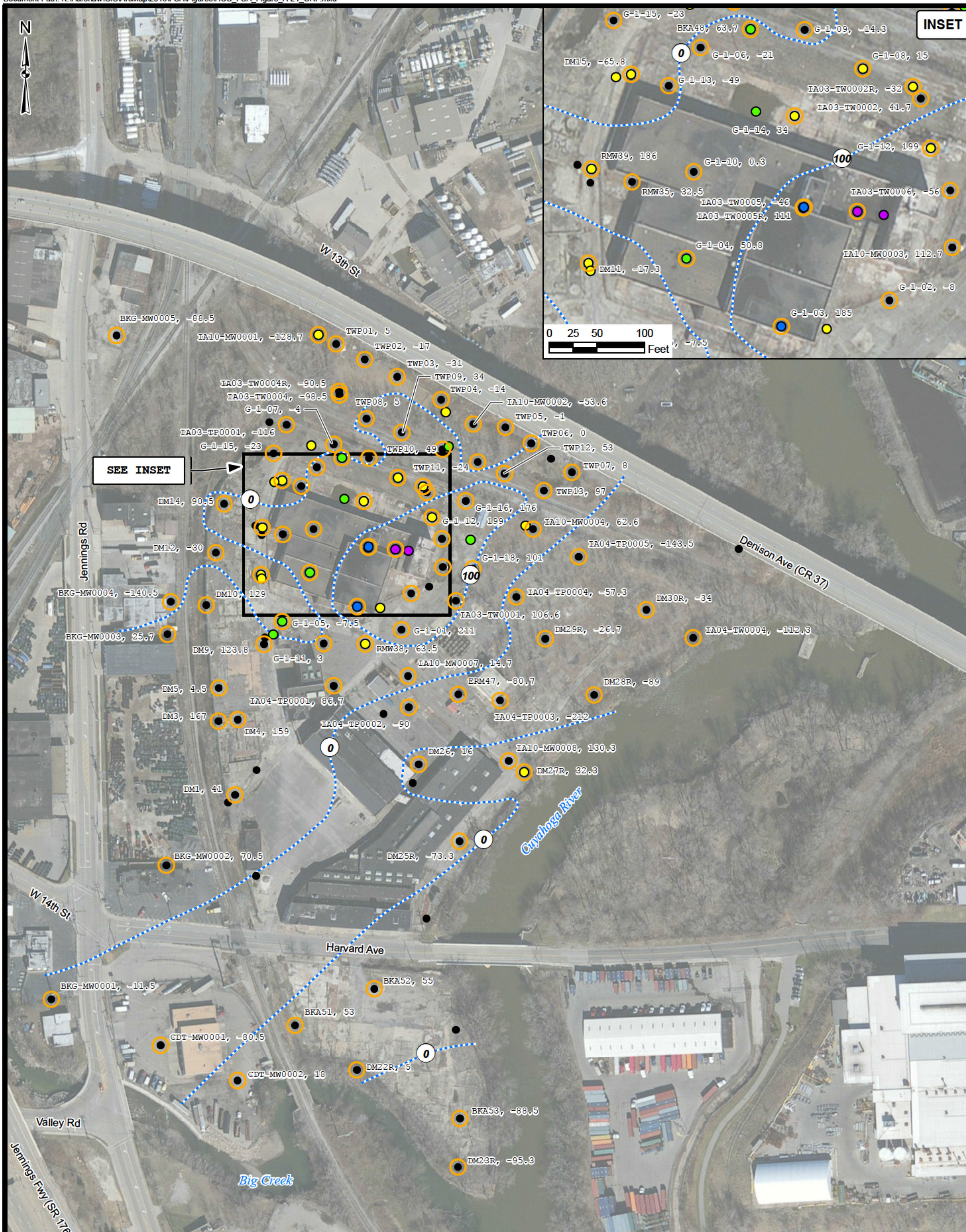
FIGURE B-23

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-24_ORP.mxd



Legend

Total Uranium (ug/l)

- < 30 ug/l
- 30 - 300 ug/l
- 300 - 3,000 ug/l
- 3,000 - 30,000 ug/l
- > 30,000 ug/l

Monitoring Well used for ORP Analysis

Approximate ORP Contour (mV)

IA10-MW0008, 130.3

Location ID — Average ORP (mV)

Notes:
Aerial Imagery circa February 2012. Many buildings on he Harshaw site have since been removed.

ND - Not Detected
All concentrations reported in ug/l.
ug/l - Micrograms per Liter.
mV - Millivolts

0 100 200 400 Feet

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CORPS OF ENGINEERS
BUFFALO, NY

MAXIMUM DETECTED TOTAL URANIUM AND AVERAGE OXYGEN REDUCTION POTENTIAL (ORP) CONCENTRATIONS IN GROUNDWATER

Document Name: HCC_FSA_Figure_A-24_ORP.mxd
Drawn By: h5tdewtf
Date Saved: 08 Feb 2017
Time Saved: 12:00:34 PM

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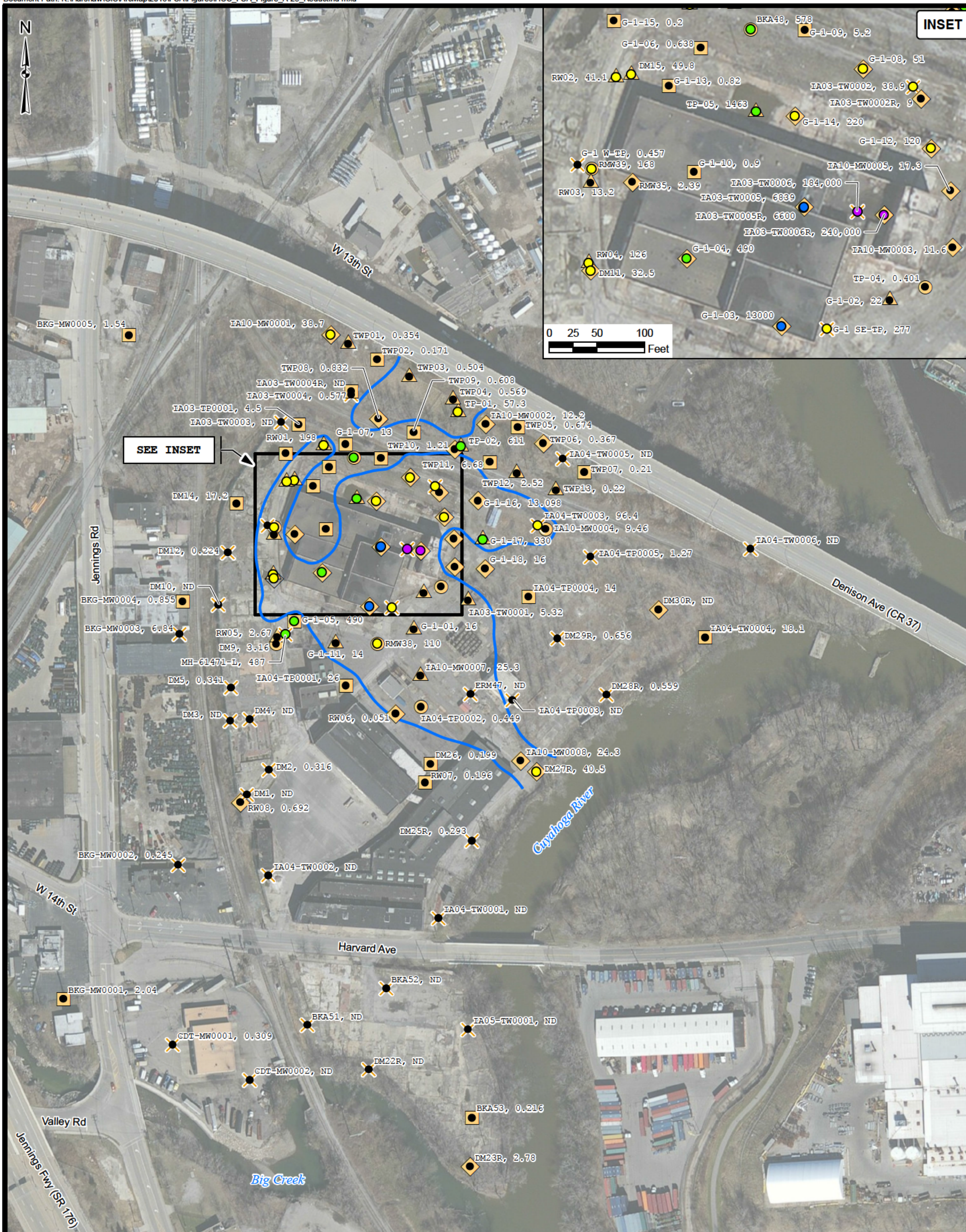
CLEVELAND, OHIO

FIGURE B-24

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-25_ReductInd.mxd



Legend

Total Uranium (ug/l)

- < 30 ug/l
- 30 - 300 ug/l
- 300 - 3,000 ug/l
- 3,000 - 30,000 ug/l
- > 30,000 ug/l
- <all other values>

- Mn Reducing
- Mn-As Reducing
- Mn-As-Fe Reducing
- Not Reducing
- Data Not Collected

Qualitative Boundary of Preferred Geochemical Transport Paths for Uranium

IA10-MW0008, 24.3
Location ID
Total Uranium (ug/l)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ND - Not Detected
All concentrations reported in ug/l.
ug/l - Micrograms per Liter.

0 100 200 400
Feet

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BUFFALO, NY

MAXIMUM DETECTED TOTAL URANIUM CONCENTRATION IN GROUNDWATER AND REDUCTIVE INDICATOR ANALYSIS

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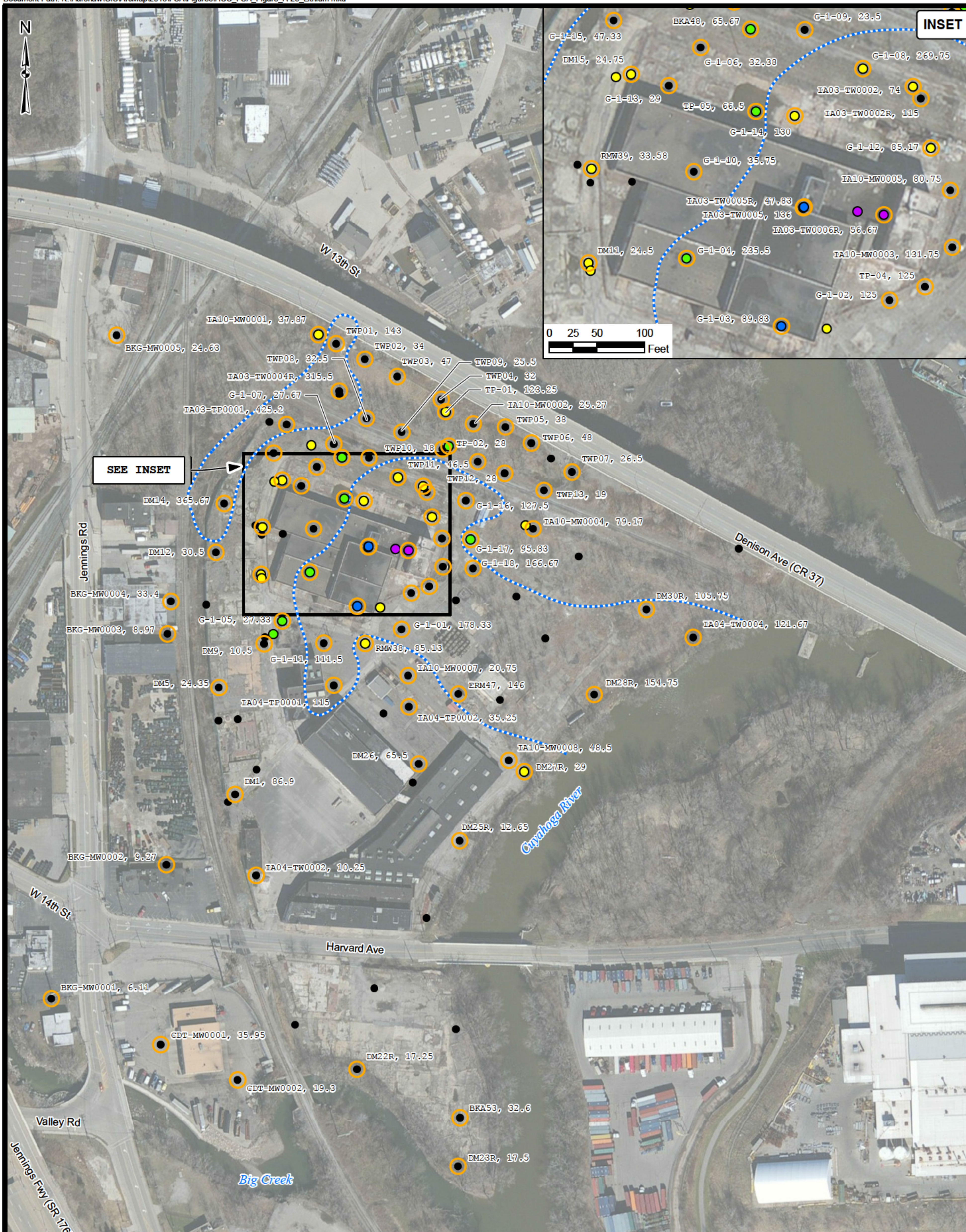
FIGURE B-25

Document Path: K:\Harshaw\GIS\ArcMap\2016\FSA\Figures\HCC_FSA_Figure_A-26_Lithium.mxd



Legend

Total Uranium (ug/l)

- < 30 ug/l
- 30 - 300 ug/l
- 300 - 3,000 ug/l
- 3,000 - 30,000 ug/l
- > 30,000 ug/l
- Monitoring Well used for Lithium Analysis
- Lithium Isoconcentration Contour (100 ug/L)

IA10-MW0008, 48.5 — Location ID; Average Lithium Concentration (ug/l)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ND - Not Detected
All concentrations reported in ug/l.
ug/l - Micrograms per Liter.

0 100 200 400 Feet

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Buffalo District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
BUFFALO, NY

MAXIMUM DETECTED TOTAL URANIUM AND AVERAGE LITHIUM CONCENTRATIONS IN GROUNDWATER

Document Name:
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Time Saved: 12:13:11 PM

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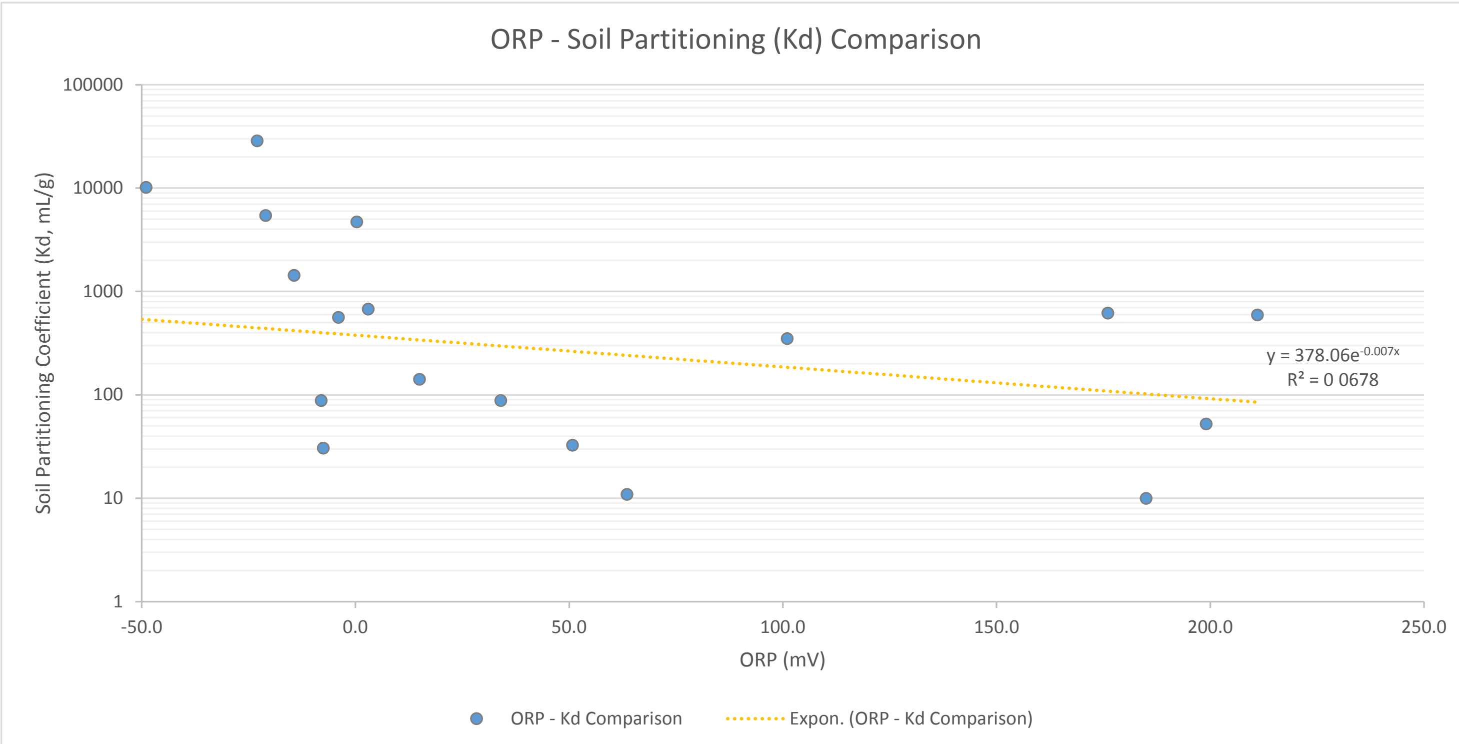
FIGURE B-26

Figure B-27. Geochemical Trend Graphs – Site-Wide Distribution

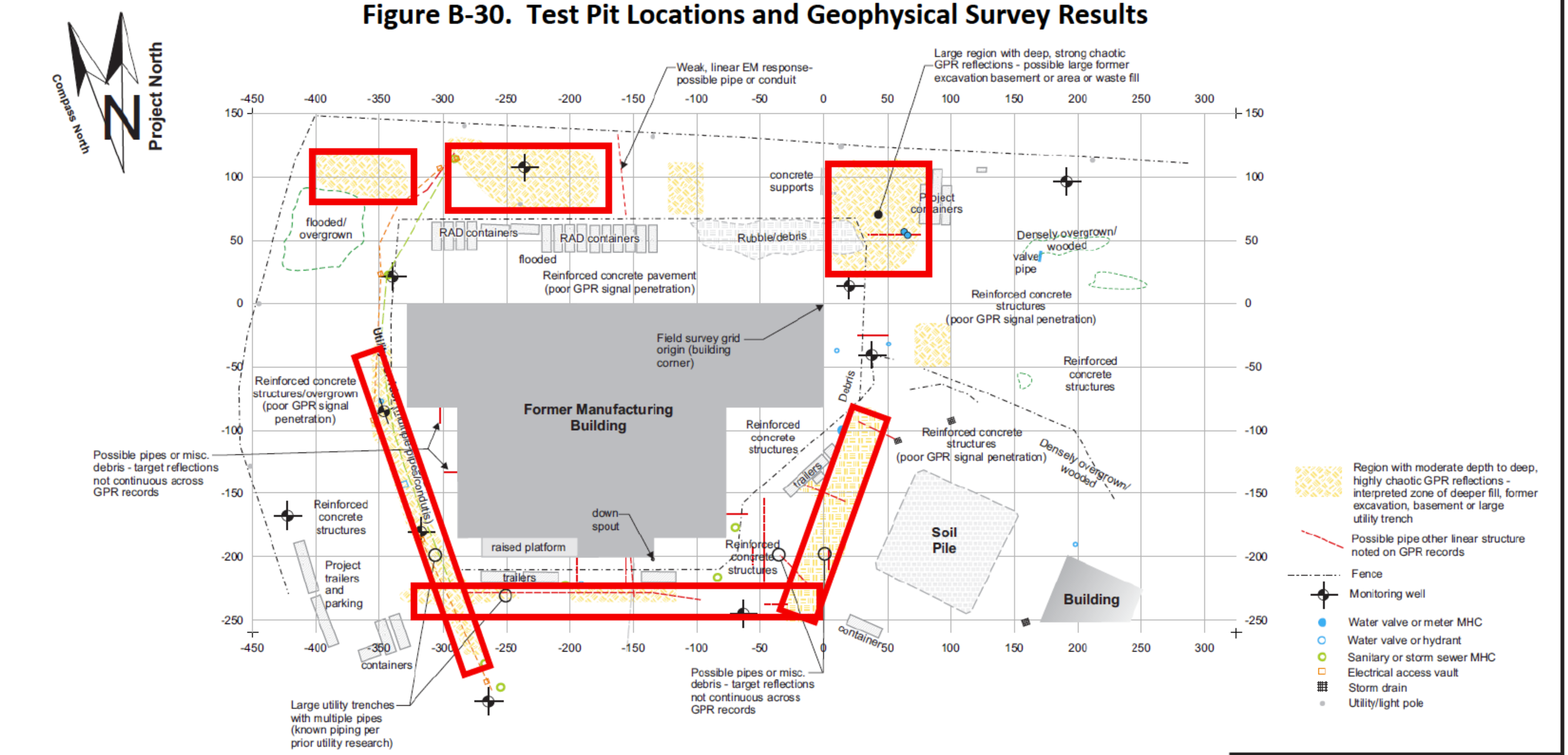
Figure B-28. Geochemical Trend Graphs – Building G-1 Area Distribution



Well ID	Average ORP (mV)	Well-Specific Total Uranium Average (ug/L)	Uranium in Soil from Screened Interval (mg/kg)	Estimated Kd (mL/g)
BKA53	-88.5	710.00	5.77	8
G-1-01	211.0	14.33	8.53	595
G-1-02	-8.0	4344.33	384.00	88
G-1-03	185.0	7670.33	76.88	10
G-1-04	50.8	383.33	12.52	33
G-1-05	-7.5	169.90	5.20	31
G-1-06	-21.0	0.50	2.70	5444
G-1-07	-4.0	9.62	5.44	565
G-1-08	15.0	48.33	6.85	142
G-1-09	-14.3	4.08	5.86	1435
G-1-10	0.3	0.73	3.42	4715
G-1-11	3.0	6.21	4.20	677
G-1-12	199.0	69.67	3.66	53
G-1-13	-49.0	0.46	4.65	10220
G-1-14	34.0	183.33	16.22	88
G-1-15	-23.0	0.18	5.02	28686
G-1-16	176.0	12.03	7.45	619
G-1-17	Not Sampled	116.20	3.36	29
G-1-18	101.0	11.00	3.87	352
RMW38	63.5	34.80	0.38	11
BKA48	63.7	214.30	4.77	22

Figure B-29. Site-Wide Soil-Water Partitioning (Kd) Analysis

Figure B-30. Test Pit Locations and Geophysical Survey Results



Utility Trench or Disturbed Areas of Enhanced Groundwater Recharge

Notes:
GSSI SIR-3000 GPR System, 400 & 270 MHz Antennae
512 samples/trace; ~10 traces/ft; 5-ft & 10-ft transect spacing
Survey dates: October 20, November 13, 17 &18, 2014
Locations of site diagram overlay and interpreted features are approximate.

Grumman Exploration, Inc.
2309 Dorset Road, Columbus, Ohio 43221
Near-surface Geophysics, Non-destructive Subsurface Exploration

Project: Harshaw Chemical Site: Geophysical Assessment			
Location: 1000 Harvard Avenue, Cleveland, Ohio			
Client: ECC/USACE	By: dlg	Date: 11/24/14	
Project No.: 01-34076	Checked:	Scale: 1"=~80-ft	

Figure 4 — Title: Site Diagram with Ground-penetrating Radar Survey Results and Interpretations

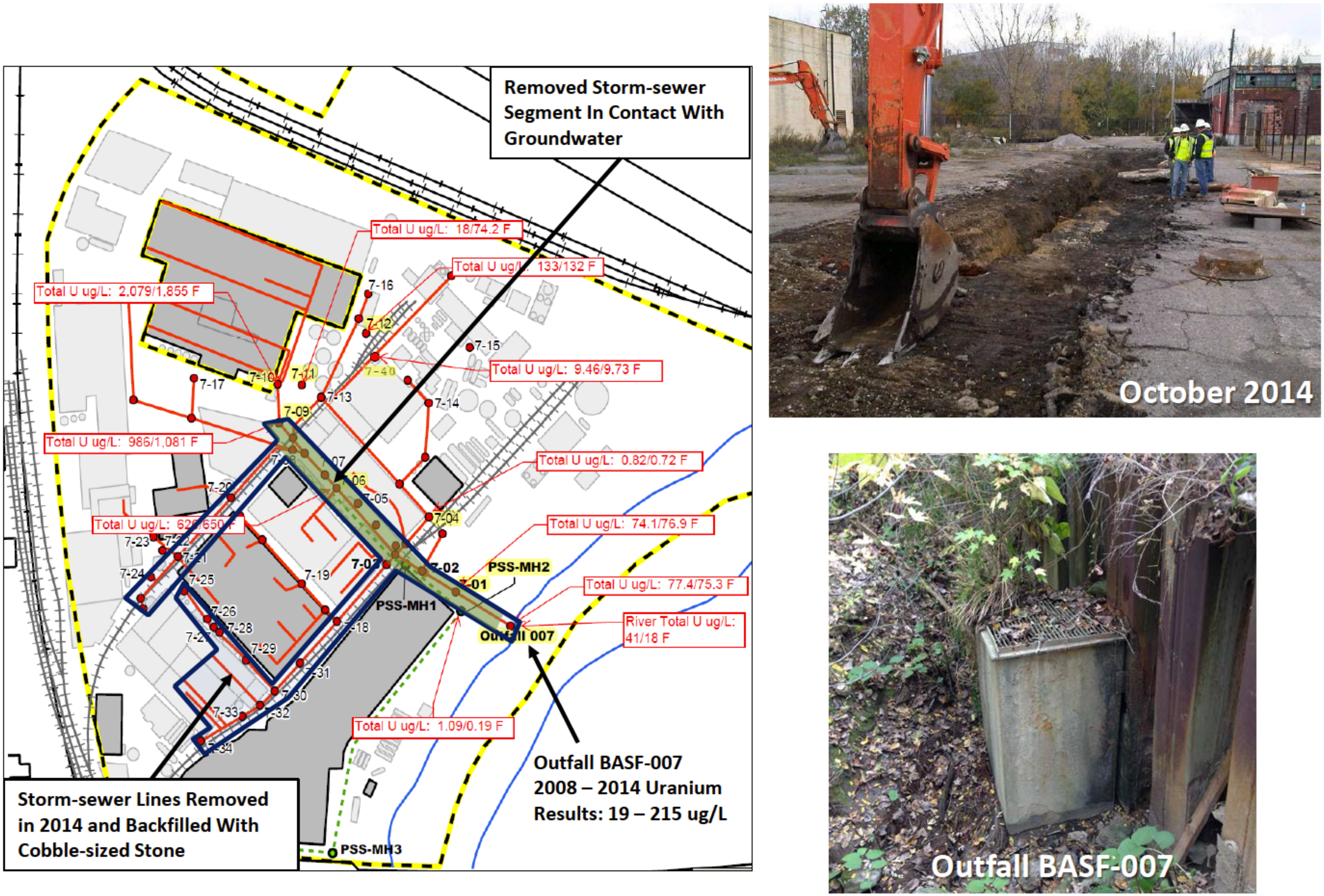


Figure B-31. Excavated Storm Sewer Trenches In Contact With Groundwater

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Legend

- BASF Monitoring Well
- Monitoring Well
- Groundwater Elevation Contour (ft amsl)
- Site Buildings

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

TWP Classification based on Soil boring data
ERM47 - Compromised in 2009-2010

0 75 150 300 Feet

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GROUNDWATER POTENTIOMETRIC SURFACE MAP (JUNE 2016) AND
BASF STORM-SEWER TRENCH WELLS

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FIGURE B-32

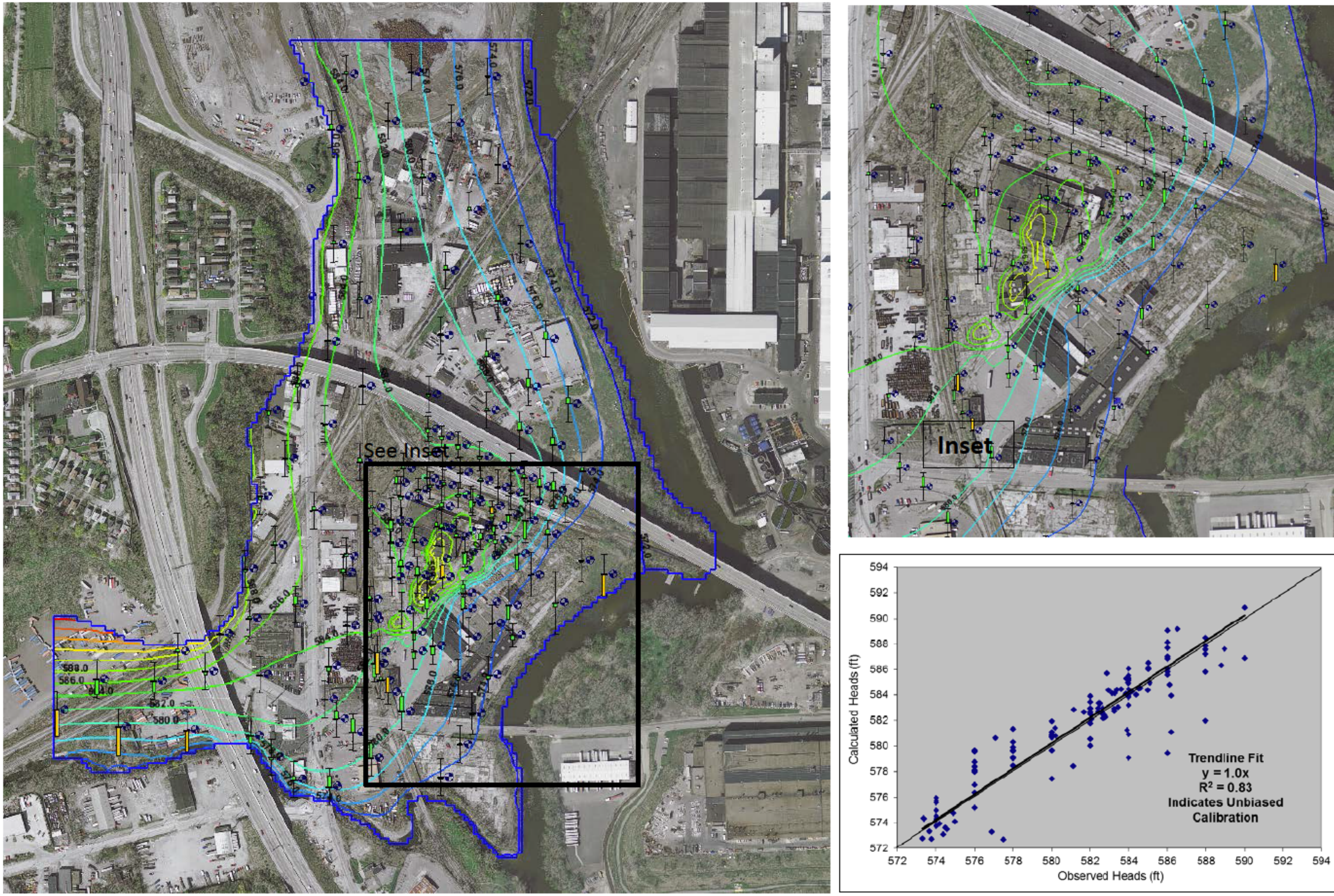

Figure B-33. Calibrated Steady State Groundwater Elevations

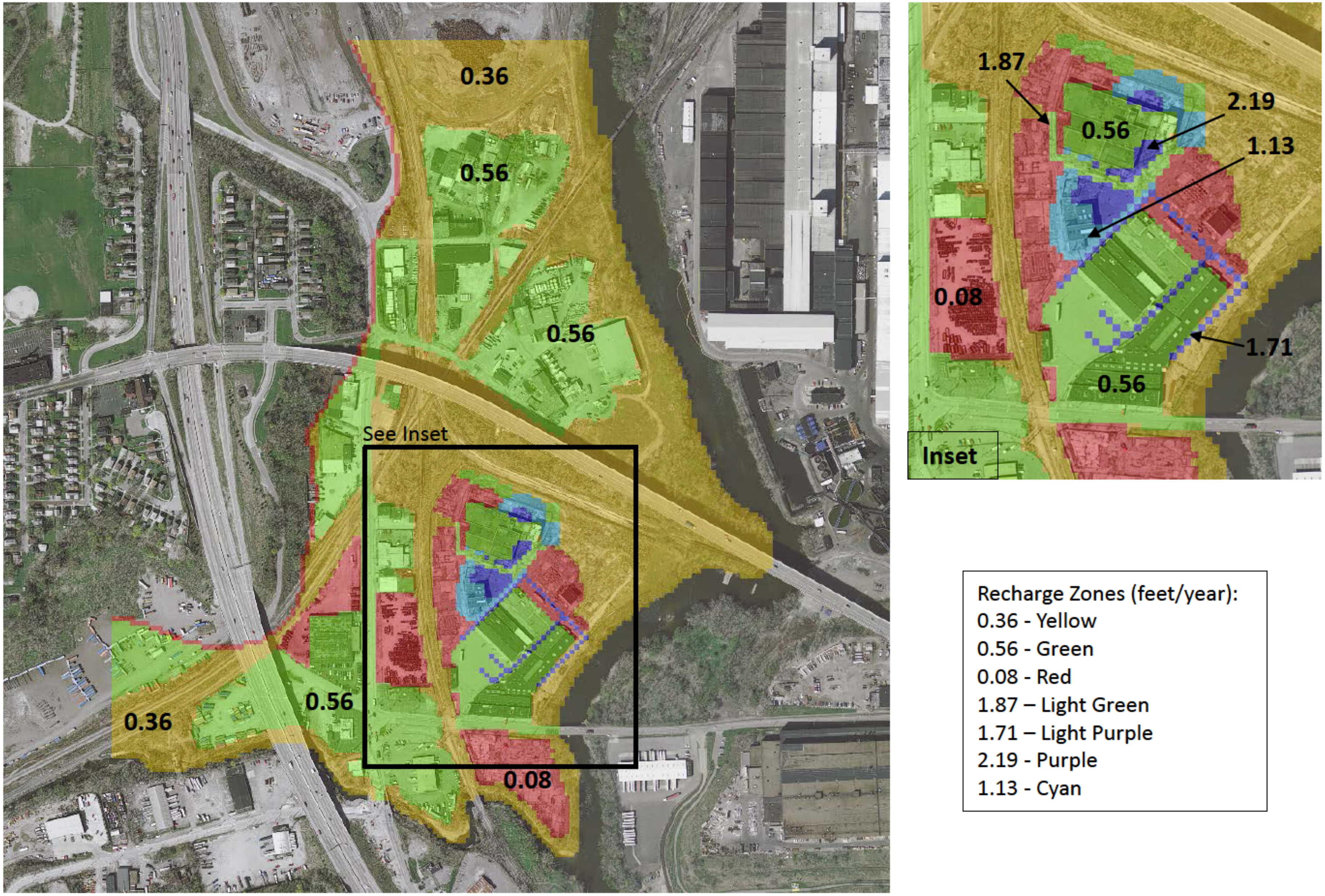

Figure B-34. Calibrated Recharge Distribution (feet per year)

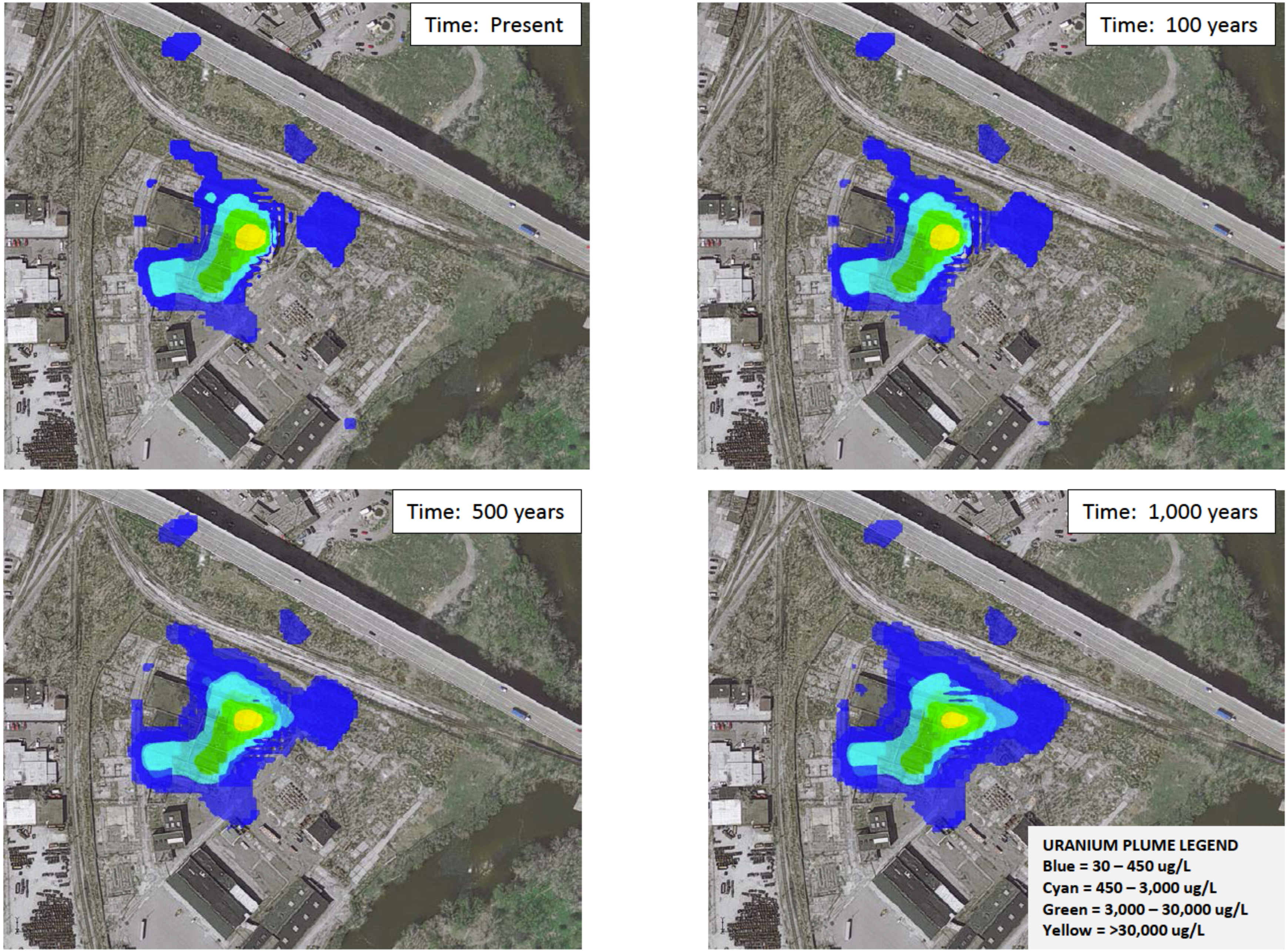

Figure B-35. Predicted Uranium Plume Migration Under Alternatives 1 and 2

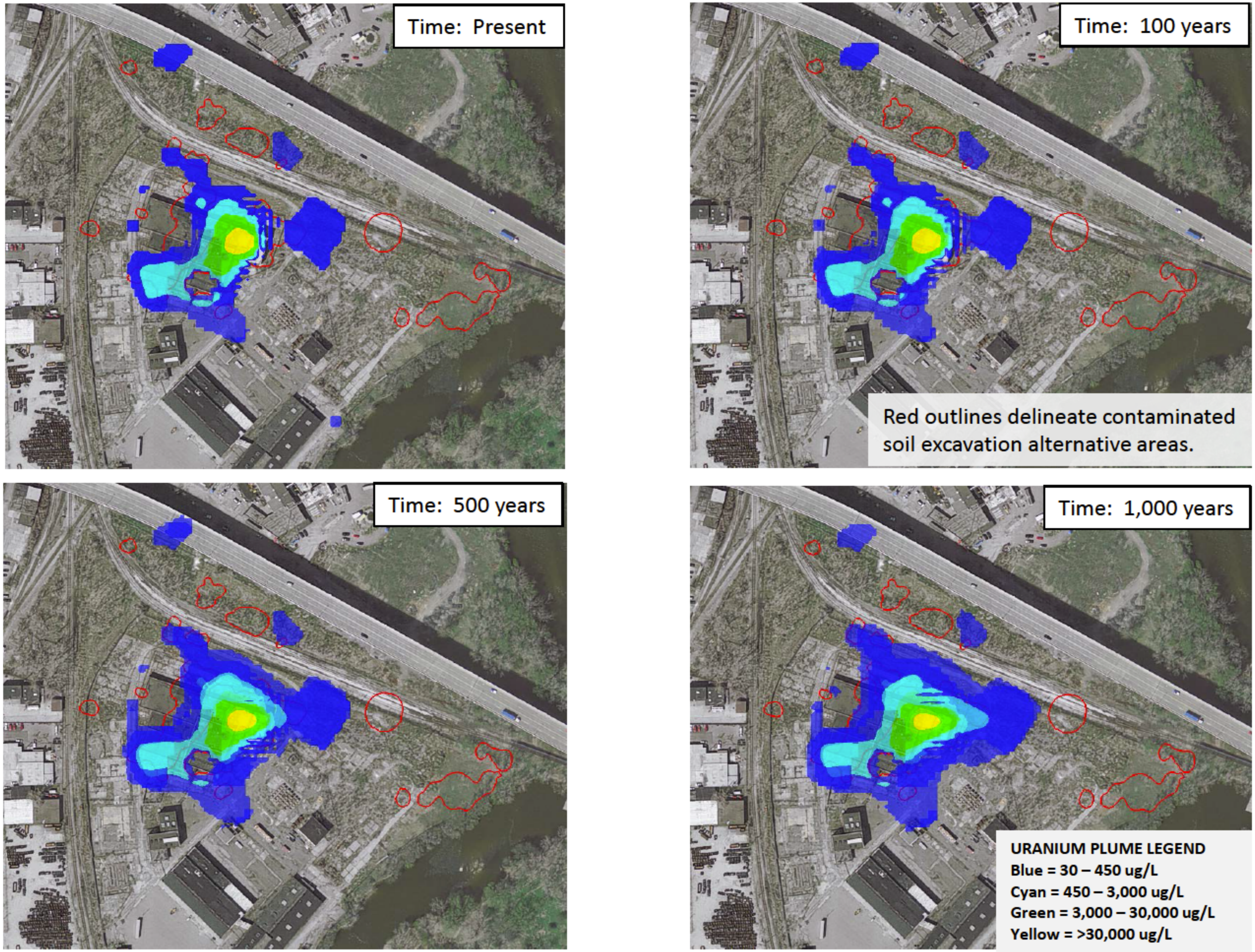

Figure B-36. Predicted Uranium Plume Migration Under Alternatives 3 and 4

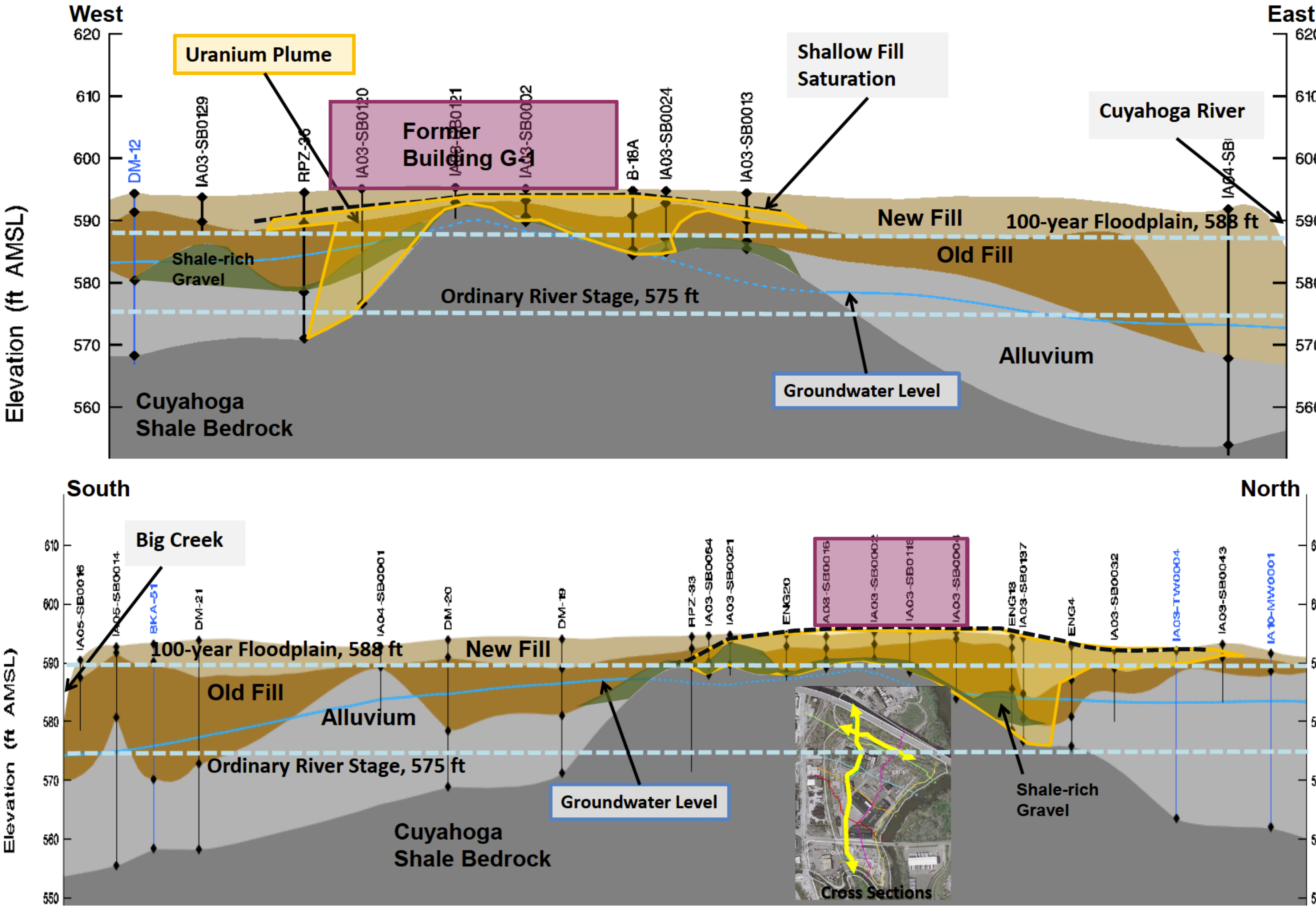

Figure B-37. Geologic Cross Sections Exhibiting Cuyahoga River Flood-Stage Elevations

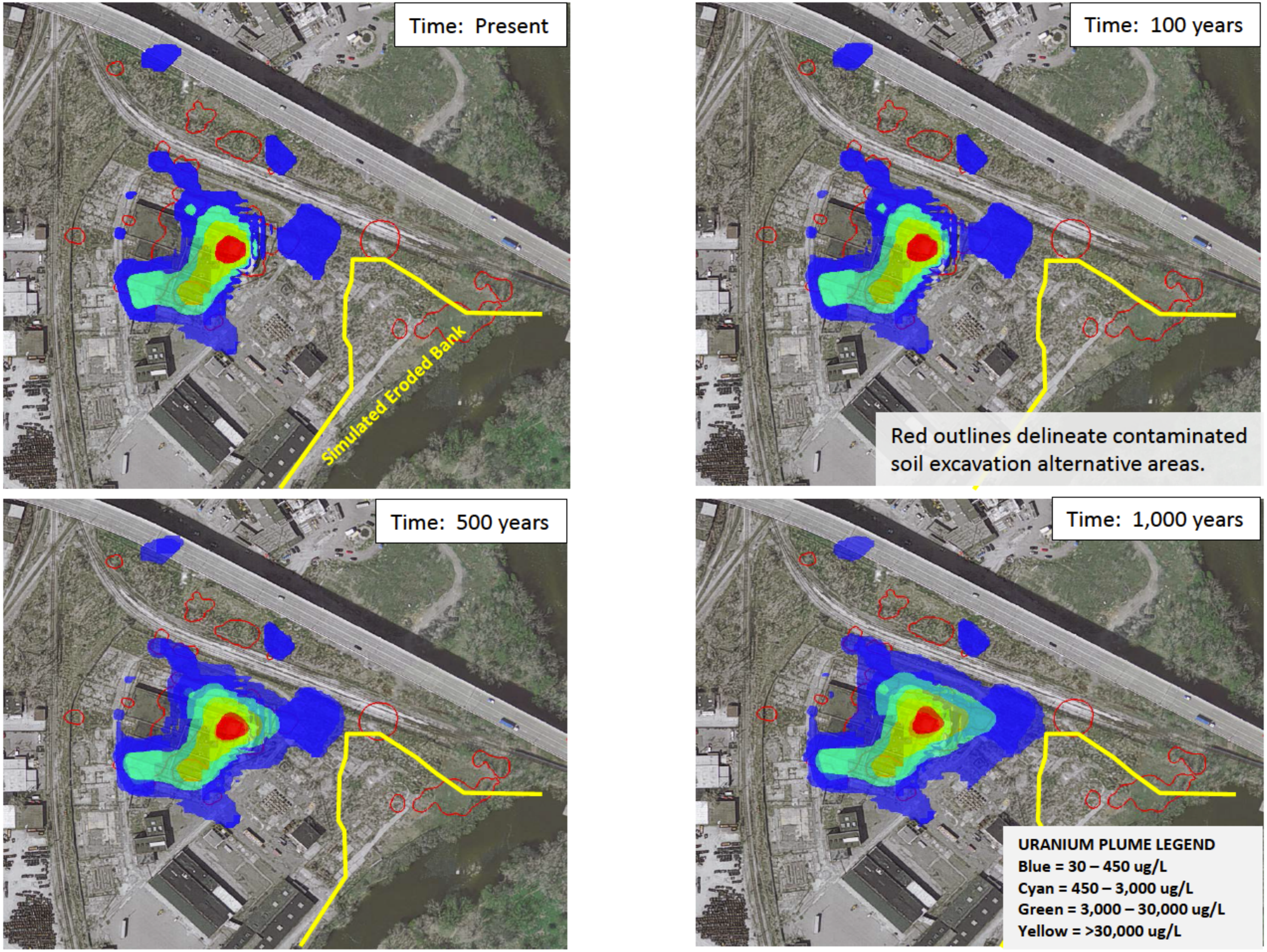

Figure B-38. Predicted Uranium Plume Migration With Potential Site Erosion

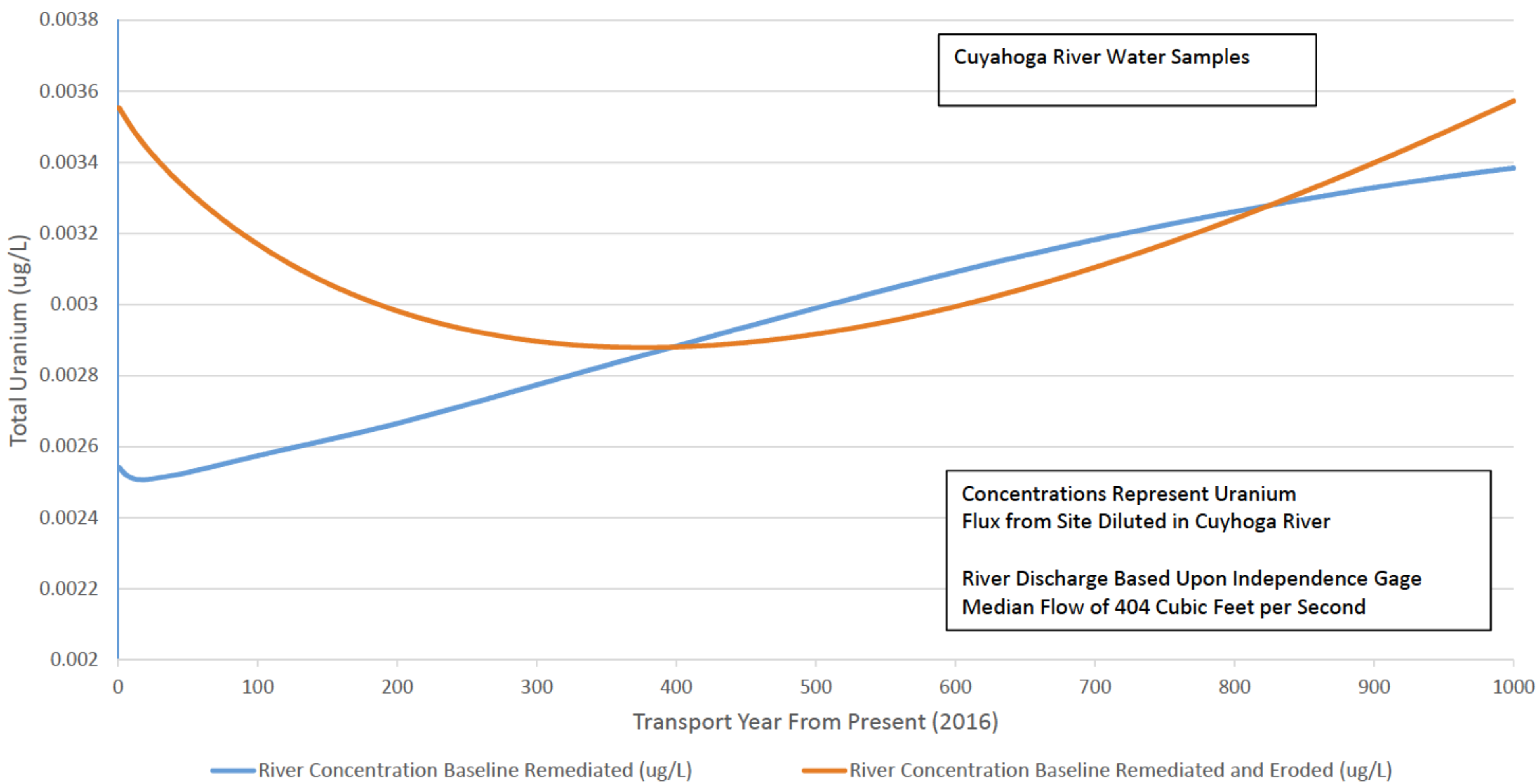

Figure B-39. Uranium Mass Discharge to the Cuyahoga River

ATTACHMENT A - Uranium Trends

Attachment A Table 1. Uranium Trend Analyses

Sampling Location	Trend	Comment
BKA48	No Trend	
BKG-MW0001	Increasing	Uranium Below MCL, Average 51 ug/L #
BKG-MW0003	Increasing	Uranium Below MCL, Average 54 ug/L #
BKG-MW0005	Stable	
DM11	No Trend	
DM14	Decreasing	
DM15	No Trend	
DM23R	No Trend	
DM26	Stable	
DM27R (Damaged)	Increasing	Uranium at MCL, Average 30 ug/L
DM5	Stable	
DM9	Increasing	Uranium Below MCL, Average 2.5 ug/L
G-1-01	Stable	
G-1-02	Stable	
G-1-03	Decreasing	
G-1-04	Probably Decreasing	
G-1-05	No Trend	
G-1-06	No Trend	
G-1-07	Decreasing	
G-1-08	Stable	
G-1-09	Decreasing	
G-1-10	Decreasing	
G-1-11	Probably Decreasing	
G-1-12	Decreasing	
G-1-13	Stable	
G-1-14	No Trend	
G-1-15	Decreasing	
G-1-16	No Trend	
G-1-17	Probably Decreasing	
G-1-18	No Trend	
IA03-TP0001	No Trend	
IA03-TW0001	Decreasing	
IA03-TW0002R	Stable	
IA03-TW0004	Stable	
IA03-TW0005	No Trend	
IA03-TW0005R	No Trend	
IA03-TW0005 Combined	No Trend	
IA03-TW0006	Stable	
IA03-TW0006R	Decreasing	
IA03-TW0006 Combined	Stable	
IA04-TP0001	Stable	
IA04-TP0002	Probably Decreasing	
IA04-TP0004	No Trend	
IA04-TW004	Stable	
IA10-MW001	Increasing	Uranium Above MCL, Average 32 ug/L
IA10-MW002	Increasing	Uranium Below MCL, Average 6 ug/L
IA10-MW003	No Trend	
IA10-MW004	Decreasing	
IA10-MW005	Stable	
IA10-MW007	No Trend	
IA10-MW008	Increasing	Uranium Below MCL, Average 17 ug/L
IA10-MW014	No Trend	
IA10-MW015	Probably Increasing	Uranium Below MCL, Average 1.6 ug/L
IA10-MW017	Stable	
IA10-MW018	Increasing	Uranium Below MCL, Average 9.6 ug/L
RMW35	No Trend	
RMW38	No Trend	
RMW39	Increasing	Uranium Above MCL, Average 71.6 ug/L
RW01	Stable	

NOTE:

Averages include one outlier value in each dataset; without outliers, the averages are 2.6 ug/L and 5.6 ug/L, respectively.

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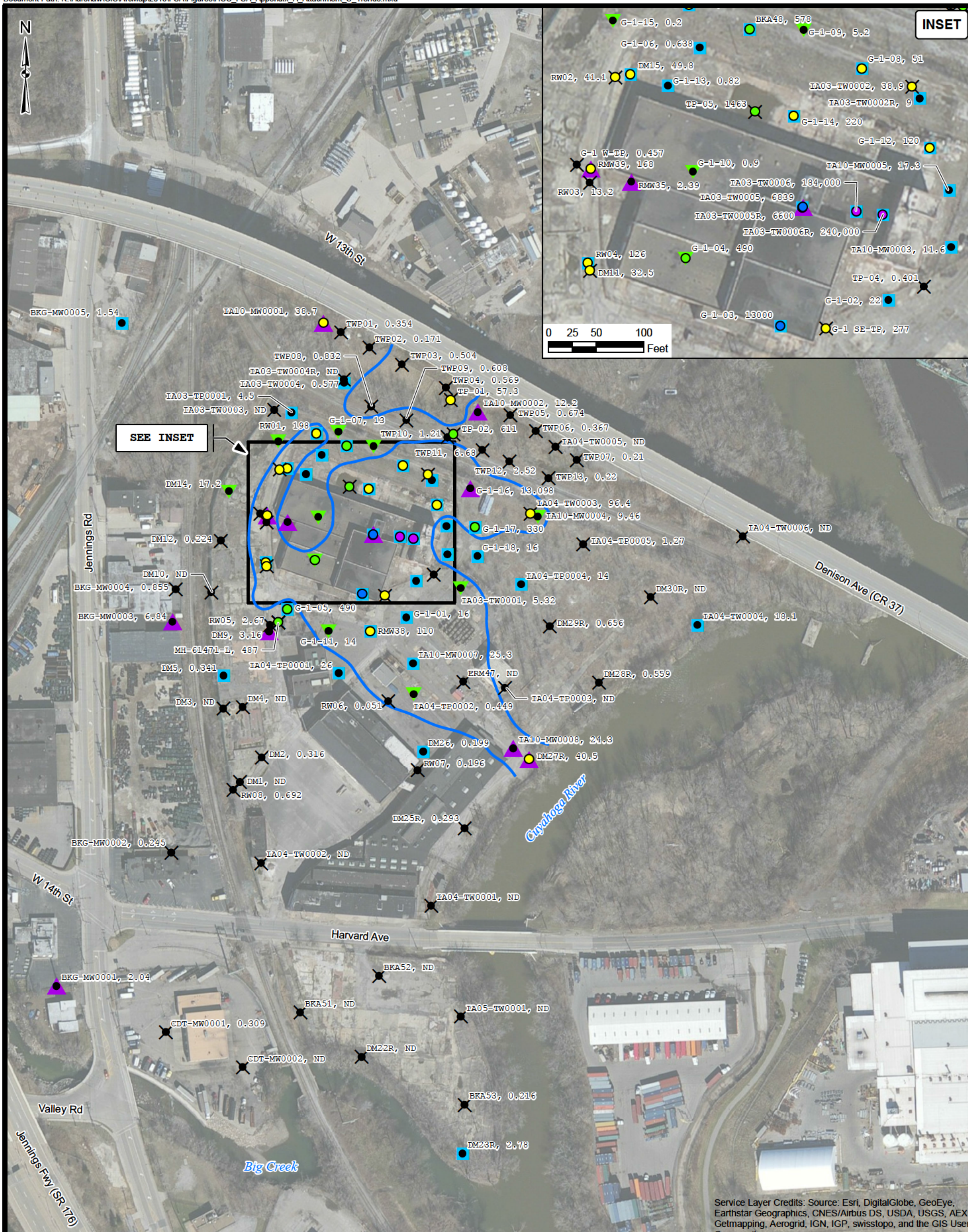

Legend

Total Uranium (ug/l)
- < 30 ug/l
- 30 - 300 ug/l
- 300 - 3,000 ug/l
- 3,000 - 30,000 ug/l
- > 30,000 ug/l

Uranium Trend Analysis
- Increasing
- Decreasing
- Stable/No Trend
- Analysis < 4 Results

Qualitative Boundary of Preferred Geochemical Transport Paths for Uranium

IA10-MW0008, 24.3
Location ID
Total Uranium (ug/l)

Notes:
Aerial Imagery circa February 2012. Many buildings on the Harshaw site have since been removed.

ND - Not Detected
All concentrations reported in ug/l.
ug/l - Micrograms per Liter.

0 100 200 400
Feet

US Army Corps of Engineers
Buffalo District
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
BUFFALO, NY

MAXIMUM DETECTED TOTAL URANIUM CONCENTRATION IN GROUNDWATER AND REDUCTIVE INDICATOR ANALYSIS

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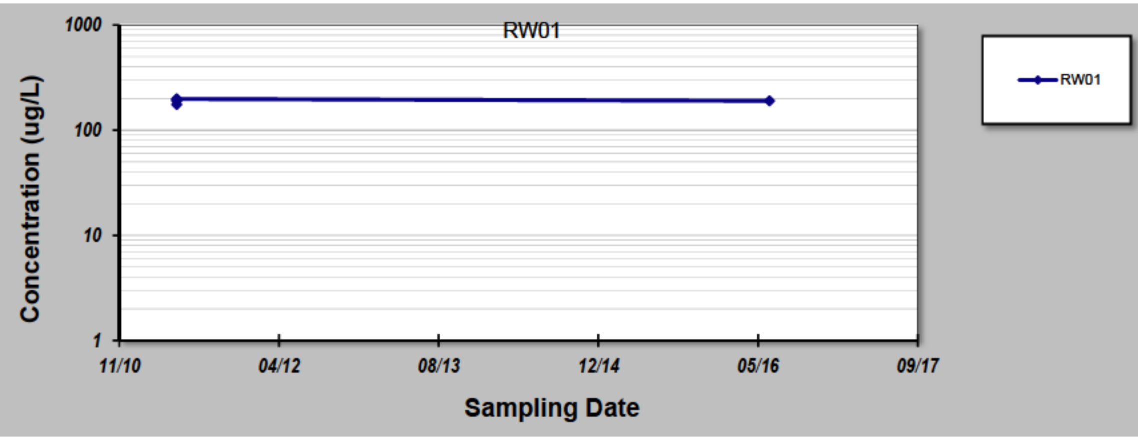
FORMER HARSHAW CHEMICAL COMPANY
CLEVELAND, OHIO

FIGURE ATTACHMENT 1

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
	Sampling Point ID:	RW01						
1	17-May-11	190.09						
2	17-May-11	175.07						
3	17-May-11	196.00						
4	17-May-11	198.00						
5	15-Jun-16	190.00						
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Coefficient of Variation:	0.41						
	Mann-Kendall Statistic (S):	-7						
	Confidence Factor:	80.9%						
	Concentration Trend:	Stable						



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

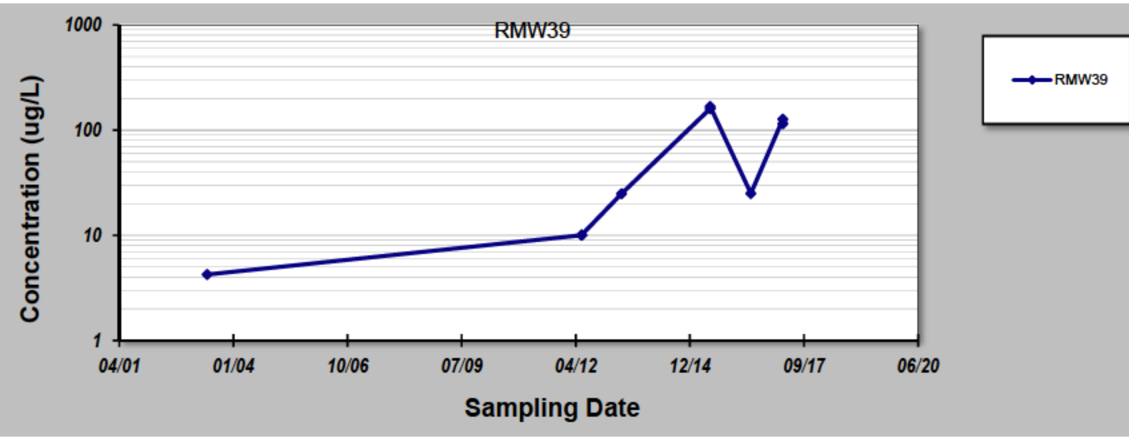
DISCLAIMER: *The GSI Mann-Kendall Toolkit is available "as is". Considerable care has been exercised in preparing this software product; however, no party, including without limitation GSI Environmental Inc., makes any representation or warranty regarding the accuracy, correctness, or completeness of the information contained herein, and no such party shall be liable for any direct, indirect, consequential, incidental or other damages resulting from the use of this product or the information contained herein. Information in this publication is subject to change without notice. GSI Environmental Inc., disclaims any responsibility or obligation to update the information contained herein.*

GSI Environmental Inc., www.gsi-net.com

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
	Sampling Point ID:	RMW39						
1	29-May-03	4.24						
2	23-May-12	10.03						
3	23-May-12	10.10						
4	08-May-13	24.90						
5	23-Jun-15	160.00						
6	23-Jun-15	168.00						
7	14-Jun-16	25.00						
8	21-Mar-17	127.00						
9	21-Mar-17	115.00						
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.89						
Mann-Kendall Statistic (S):		25						
Confidence Factor:		97.0%						
Concentration Trend:		Increasing						



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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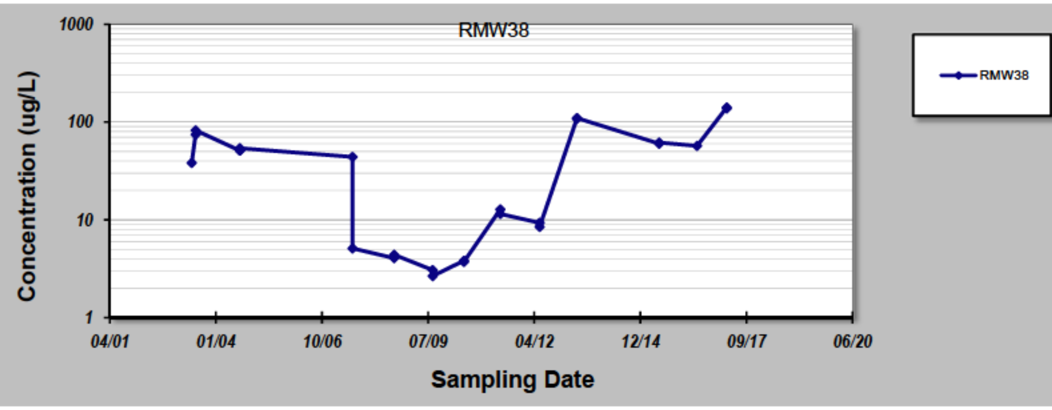
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
	Sampling Point ID:	RMW38					
1	31-May-03	38.20					
2	07-Jul-03	74.47					
3	07-Jul-03	82.30					
4	27-Aug-04	51.05					
5	27-Aug-04	51.50					
6	27-Aug-04	54.00					
7	25-Jul-07	44.00					
8	25-Jul-07	5.11					
9	20-Aug-08	4.05					
10	20-Aug-08	4.39					
11	18-Aug-09	3.06					
12	18-Aug-09	2.66					
13	08-Jun-10	3.81					
14	08-Jun-10	3.71					
15	17-May-11	12.76					
16	17-May-11	11.50					
17	22-May-12	9.31					
18	22-May-12	8.47					
19	08-May-13	108.00					
20	08-May-13	110.00					
21	23-Jun-15	60.10					
22	23-Jun-15	61.70					
23	14-Jun-16	57.10					
24	21-Mar-17	141.00					
25	21-Mar-17	138.00					
26							
27							
28							
29							
30							
	Coefficient of Variation:	0.96					
	Mann-Kendall Statistic (S):	50					
	Confidence Factor:	87.2%					
	Concentration Trend:	No Trend					



Notes

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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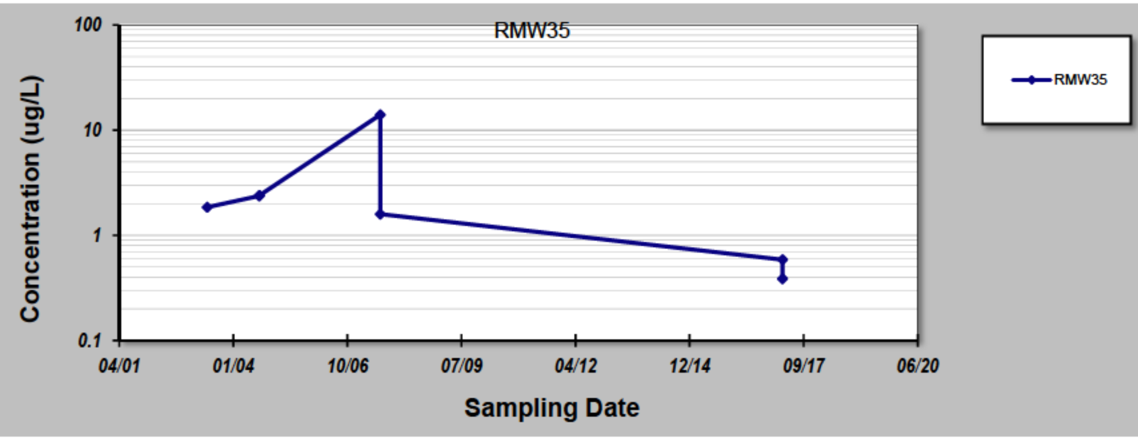
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

	Sampling Point ID:	RMW35						
Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
1	30-May-03	1.85						
2	29-Aug-04	2.37						
3	29-Aug-04	2.39						
4	25-Jul-07	14.00						
5	25-Jul-07	1.59						
6	21-Mar-17	0.59						
7	21-Mar-17	0.39						
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Coefficient of Variation:	1.27						
	Mann-Kendall Statistic (S):	13						
	Confidence Factor:	85.4%						
	Concentration Trend:	No Trend						



Notes:

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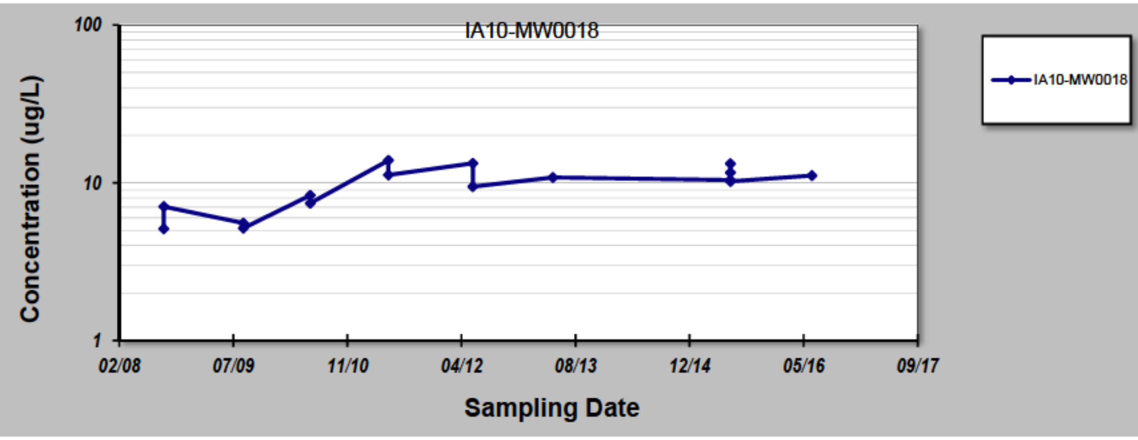
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA10-MW0018

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
		IA10-MW0018					
1	04-Sep-08	5.10					
2	04-Sep-08	7.06					
3	19-Aug-09	5.56					
4	19-Aug-09	5.15					
5	08-Jun-10	8.32					
6	08-Jun-10	7.42					
7	17-May-11	13.84					
8	17-May-11	11.20					
9	21-May-12	13.27					
10	21-May-12	9.45					
11	07-May-13	10.80					
12	24-Jun-15	10.40					
13	24-Jun-15	13.20					
14	24-Jun-15	11.60					
15	24-Jun-15	10.20					
16	15-Jun-16	11.10					
17							
18							
19							
20							
Coefficient of Variation:		0.75					
Mann-Kendall Statistic (S):		103					
Confidence Factor:		>99.9%					
Concentration Trend:		Increasing					



Notes:

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2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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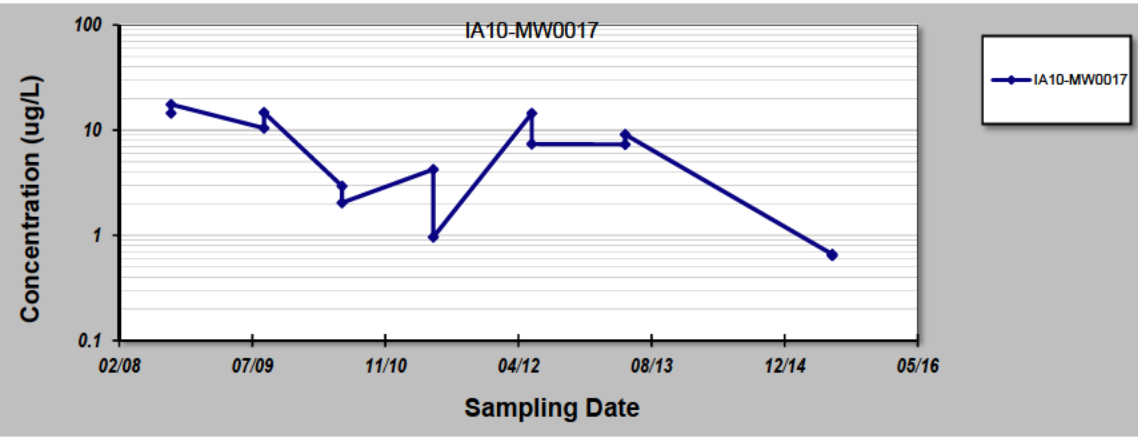
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA10-MW0017

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
1	04-Sep-08	14.50					
2	04-Sep-08	17.54					
3	19-Aug-09	10.45					
4	19-Aug-09	14.70					
5	08-Jun-10	2.94					
6	08-Jun-10	2.04					
7	17-May-11	4.23					
8	17-May-11	0.96					
9	21-May-12	14.44					
10	21-May-12	7.38					
11	07-May-13	7.32					
12	07-May-13	9.09					
13	24-Jun-15	0.66					
14	24-Jun-15	0.64					
15							
16							
17							
18							
19							
20							
Coefficient of Variation:		0.99					
Mann-Kendall Statistic (S):		0					
Confidence Factor:		48.4%					
Concentration Trend:		Stable					



Notes:
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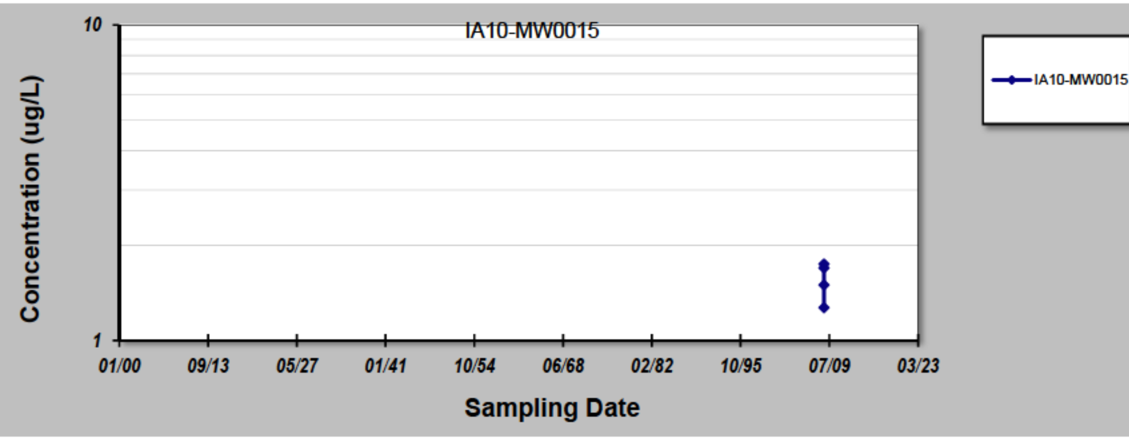
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
Sampling Point ID:		IA10-MW0015					
1	08-Sep-08	1.70					
2	08-Sep-08	1.50					
3	08-Sep-08	1.75					
4	08-Sep-08	1.27					
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
Coefficient of Variation:		1.16					
Mann-Kendall Statistic (S):		11					
Confidence Factor:		93.2%					
Concentration Trend:		Prob. Increasing					



Notes:

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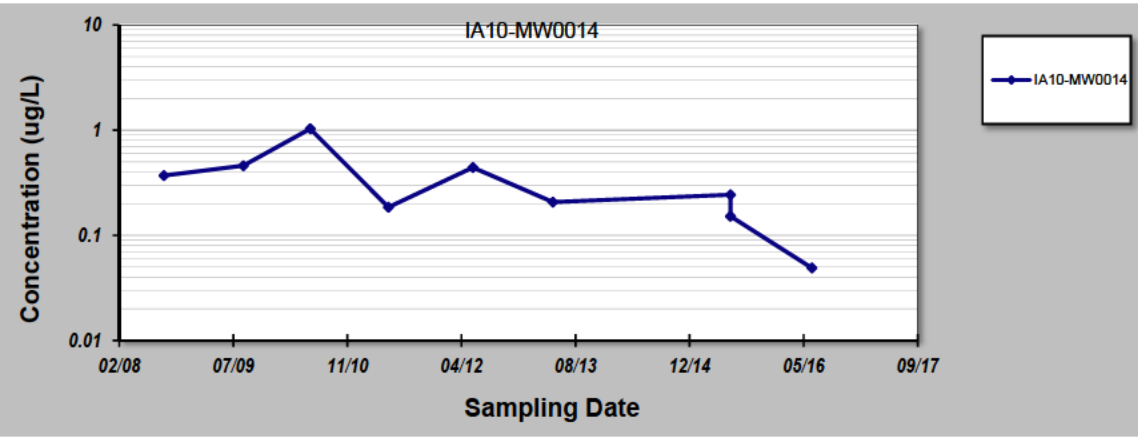
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA10-MW0014

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
		IA10-MW0014					
1	05-Sep-08	0.37					
2	19-Aug-09	0.46					
3	08-Jun-10	1.03					
4	17-May-11	0.19					
5	21-May-12	0.44					
6	07-May-13	0.21					
7	24-Jun-15	0.24					
8	24-Jun-15	0.15					
9	15-Jun-16	0.05					
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
	Coefficient of Variation:	1.78					
	Mann-Kendall Statistic (S):	8					
	Confidence Factor:	68.1%					
	Concentration Trend:	No Trend					



Notes:

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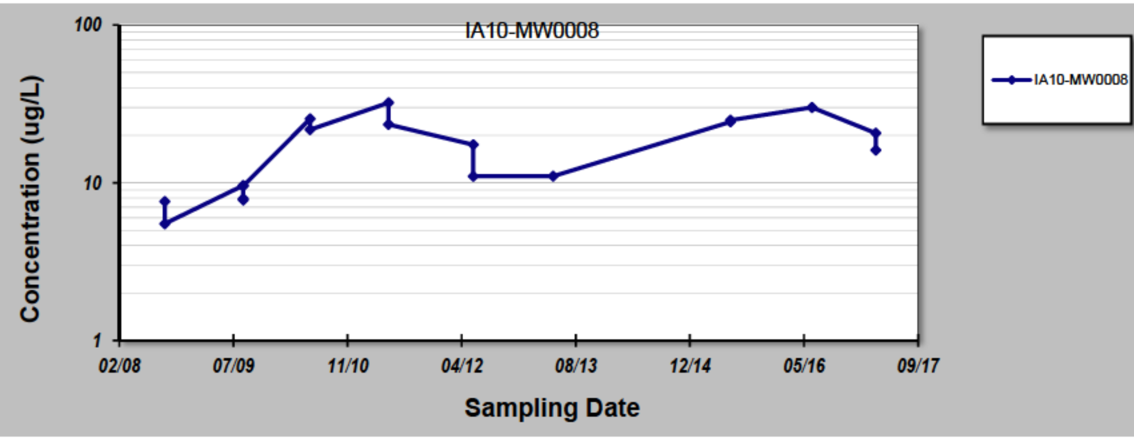
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA10-MW0008

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)
1	08-Sep-08	7.60
2	08-Sep-08	5.50
3	18-Aug-09	9.61
4	18-Aug-09	7.93
5	18-Aug-09	7.77
6	18-Aug-09	9.53
7	07-Jun-10	25.41
8	07-Jun-10	21.70
9	17-May-11	32.13
10	17-May-11	23.40
11	22-May-12	17.42
12	22-May-12	11.00
13	07-May-13	11.00
14	23-Jun-15	24.30
15	23-Jun-15	24.90
16	14-Jun-16	30.00
17	21-Mar-17	20.60
18	21-Mar-17	16.10
19		
20		
Coefficient of Variation:		0.53
Mann-Kendall Statistic (S):		115
Confidence Factor:		>99.9%
Concentration Trend:		Increasing



Notes:

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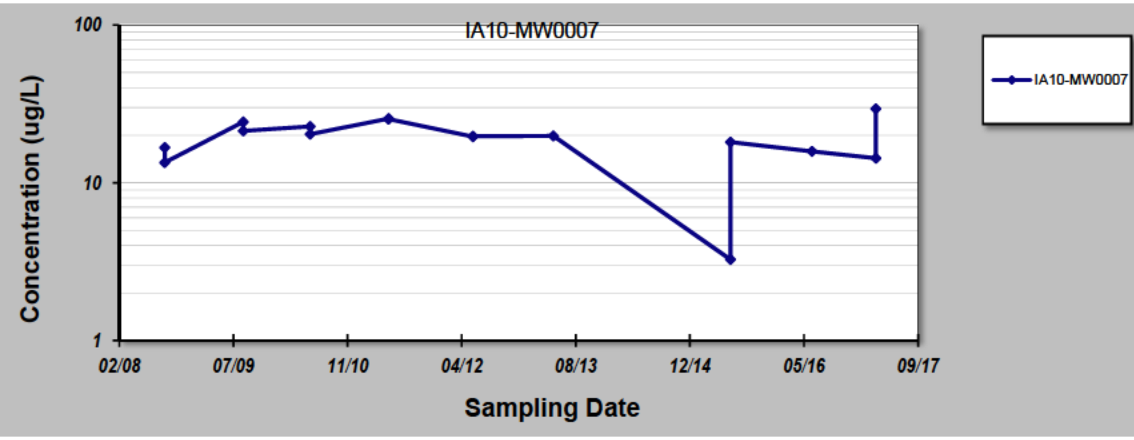
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		IA10-MW0007						
1	08-Sep-08	16.70						
2	08-Sep-08	13.42						
3	18-Aug-09	24.29						
4	18-Aug-09	21.30						
5	07-Jun-10	22.73						
6	07-Jun-10	20.30						
7	17-May-11	25.50						
8	17-May-11	25.30						
9	21-May-12	19.58						
10	21-May-12	19.70						
11	08-May-13	19.80						
12	23-Jun-15	3.26						
13	23-Jun-15	18.10						
14	14-Jun-16	15.80						
15	21-Mar-17	14.30						
16	21-Mar-17	29.40						
17								
18								
19								
20								
Coefficient of Variation:		0.39						
Mann-Kendall Statistic (S):		28						
Confidence Factor:		82.5%						
Concentration Trend:		No Trend						



Notes:

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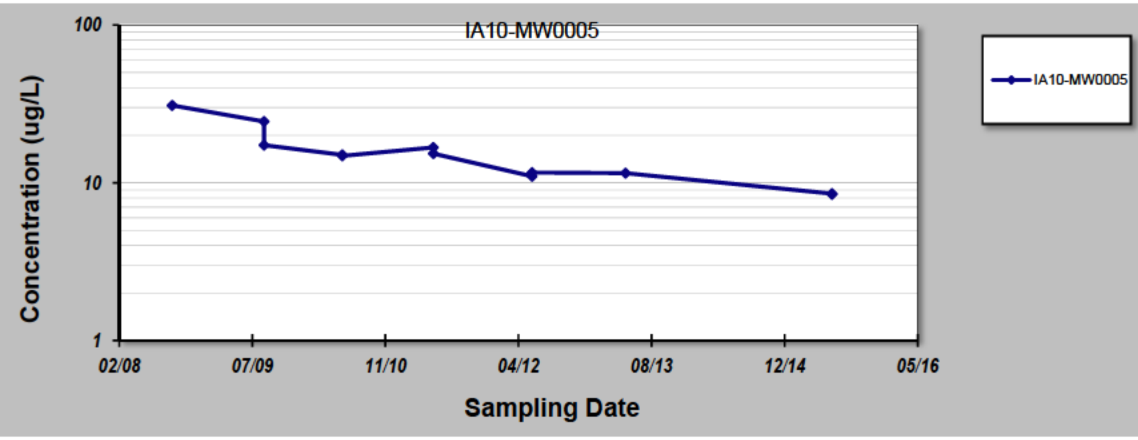
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA10-MW0005

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		IA10-MW0005						
1	08-Sep-08	30.90						
2	19-Aug-09	24.44						
3	19-Aug-09	17.30						
4	09-Jun-10	15.02						
5	09-Jun-10	14.80						
6	17-May-11	16.73						
7	17-May-11	15.30						
8	22-May-12	10.99						
9	22-May-12	11.60						
10	08-May-13	11.50						
11	23-Jun-15	8.53						
12	23-Jun-15	8.45						
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.53						
Mann-Kendall Statistic (S):		-19						
Confidence Factor:		81.0%						
Concentration Trend:		Stable						



Notes:

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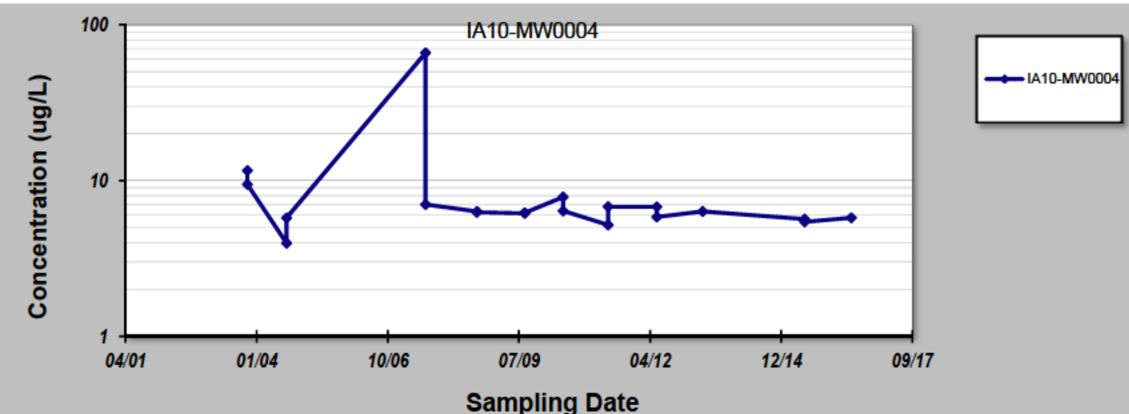
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: 3-Aug-16
Facility Name: Harshaw Site
Conducted By: Guckin
Job ID: N/A
Constituent: Total U
Concentration Units: ug/L

Sampling Point ID: IA10-MW0004

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)
1	04-Nov-03	11.59
2	04-Nov-03	9.46
3	29-Aug-04	3.96
4	29-Aug-04	5.77
5	25-Jul-07	66.00
6	25-Jul-07	7.03
7	19-Aug-08	6.34
8	19-Aug-08	6.26
9	19-Aug-09	6.16
10	19-Aug-09	6.21
11	08-Jun-10	7.84
12	08-Jun-10	6.39
13	17-May-11	5.20
14	17-May-11	6.79
15	22-May-12	6.79
16	22-May-12	5.84
17	07-May-13	6.34
18	23-Jun-15	5.66
19	23-Jun-15	5.43
20	14-Jun-16	5.77
21		
22		
23		
24		
25		
Coefficient of Variation:		1.40
Mann-Kendall Statistic (S):		-59
Confidence Factor:		97.1%
Concentration Trend:		Decreasing



Notes

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3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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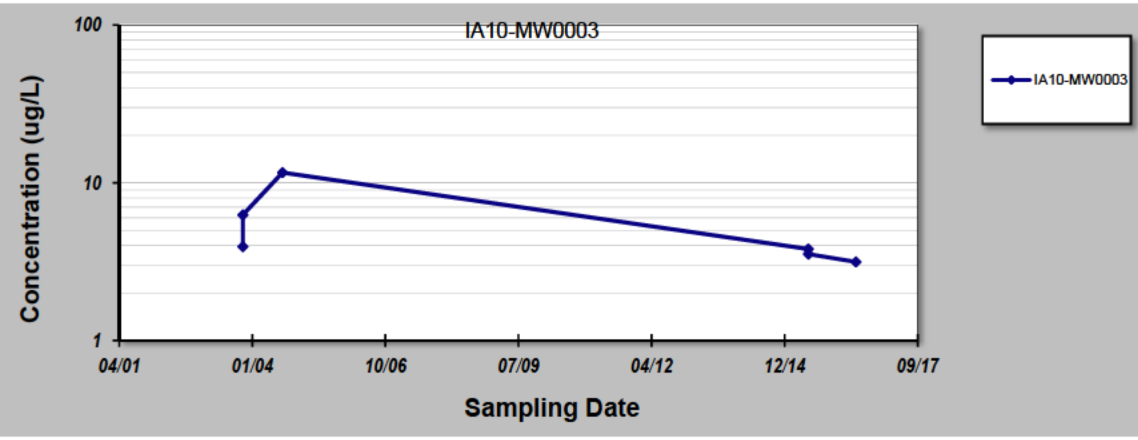
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA10-MW0003

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		IA10-MW0003						
1	04-Nov-03	3.93						
2	04-Nov-03	6.26						
3	28-Aug-04	11.60						
4	23-Jun-15	3.80						
5	23-Jun-15	3.53						
6	15-Jun-16	3.15						
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		1.02						
Mann-Kendall Statistic (S):		10						
Confidence Factor:		82.1%						
Concentration Trend:		No Trend						



Notes:

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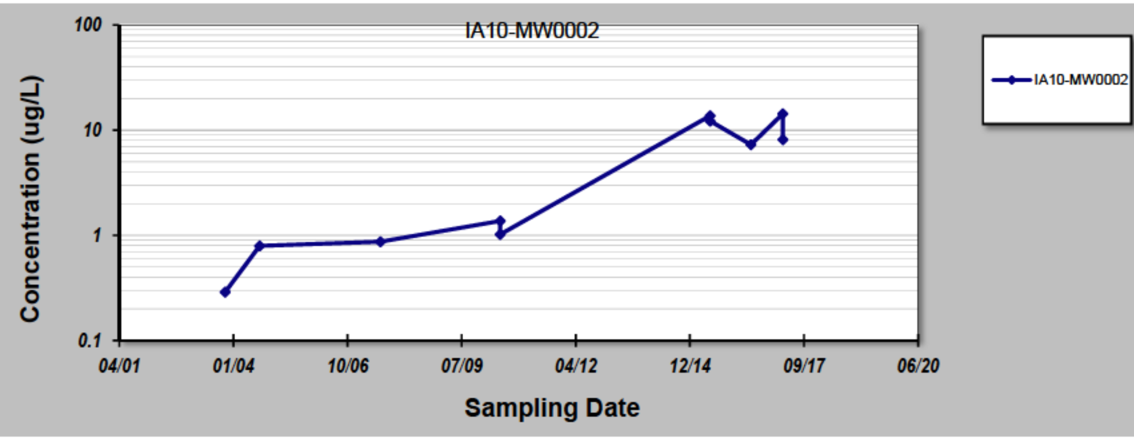
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID:		IA10-MW0002						
Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
1	03-Nov-03	0.29						
2	31-Aug-04	0.79						
3	26-Jul-07	0.87						
4	09-Jun-10	1.37						
5	09-Jun-10	1.02						
6	23-Jun-15	13.70						
7	23-Jun-15	12.20						
8	14-Jun-16	7.27						
9	21-Mar-17	14.30						
10	21-Mar-17	8.12						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		1.11						
Mann-Kendall Statistic (S):		62						
Confidence Factor:		>99.9%						
Concentration Trend:		Increasing						



Notes:

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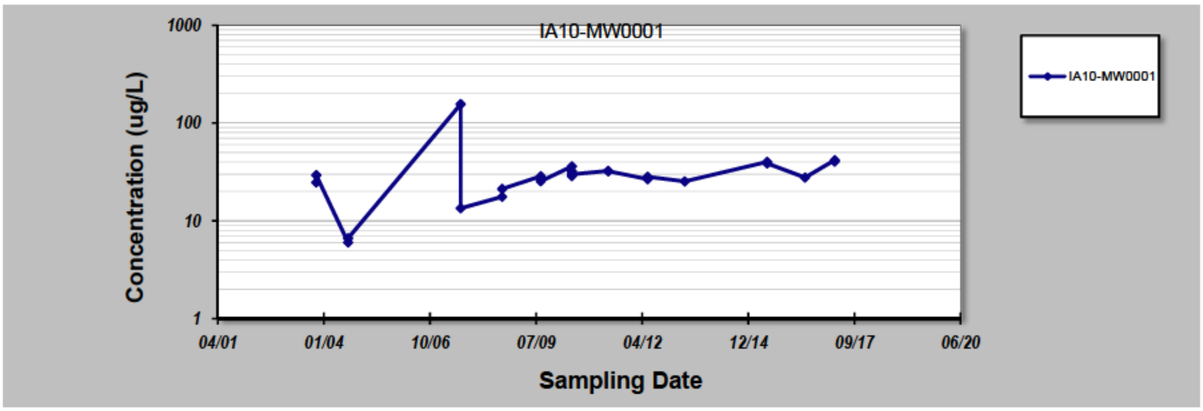
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	3-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA10-MW0001

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
1	03-Nov-03	24.74					
2	03-Nov-03	29.30					
3	29-Aug-04	6.01					
4	29-Aug-04	6.63					
5	26-Jul-07	156.00					
6	26-Jul-07	13.42					
7	20-Aug-08	17.63					
8	20-Aug-08	21.20					
9	19-Aug-09	28.59					
10	19-Aug-09	27.54					
11	19-Aug-09	26.40					
12	19-Aug-09	25.40					
13	08-Jun-10	36.04					
14	08-Jun-10	32.13					
15	08-Jun-10	28.70					
16	08-Jun-10	29.90					
17	17-May-11	32.43					
18	17-May-11	32.20					
19	23-May-12	26.67					
20	23-May-12	28.20					
21	07-May-13	25.30					
22	23-Jun-15	40.10					
23	23-Jun-15	38.70					
24	14-Jun-16	27.70					
25	21-Mar-17	41.80					
26	21-Mar-17	40.40					
27							
28							
29							
30							
	Coefficient of Variation:	0.83					
	Mann-Kendall Statistic (S):	139					
	Confidence Factor:	99.9%					
	Concentration Trend:	Increasing					



Notes

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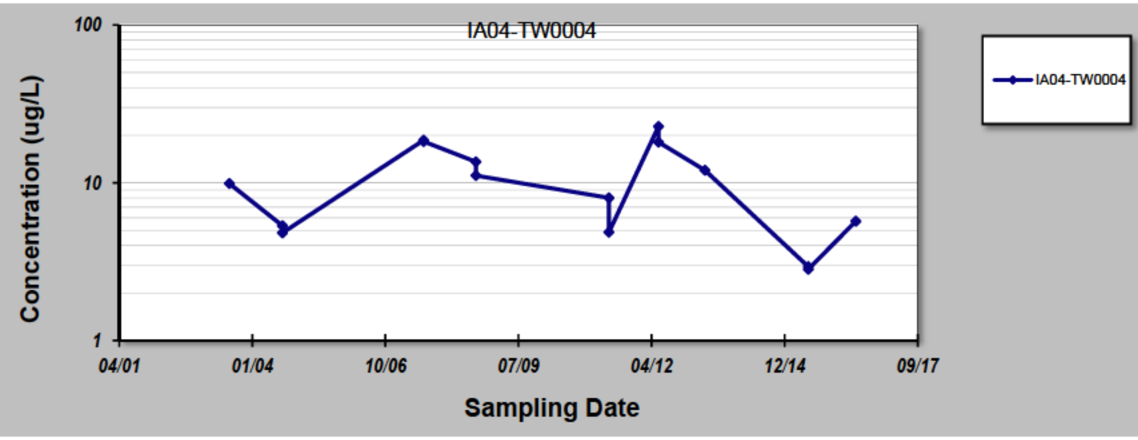
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA04-TW0004

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L) IA04-TW0004						
1	25-Jul-03	9.89						
2	27-Aug-04	5.35						
3	27-Aug-04	4.81						
4	24-Jul-07	18.60						
5	24-Jul-07	18.26						
6	20-Aug-08	13.57						
7	20-Aug-08	11.10						
8	17-May-11	8.02						
9	17-May-11	4.86						
10	23-May-12	22.70						
11	23-May-12	18.10						
12	07-May-13	12.00						
13	23-Jun-15	2.94						
14	23-Jun-15	2.83						
15	14-Jun-16	5.70						
16								
17								
18								
19								
20								
Coefficient of Variation:		0.61						
Mann-Kendall Statistic (S):		-21						
Confidence Factor:		83.6%						
Concentration Trend:		Stable						



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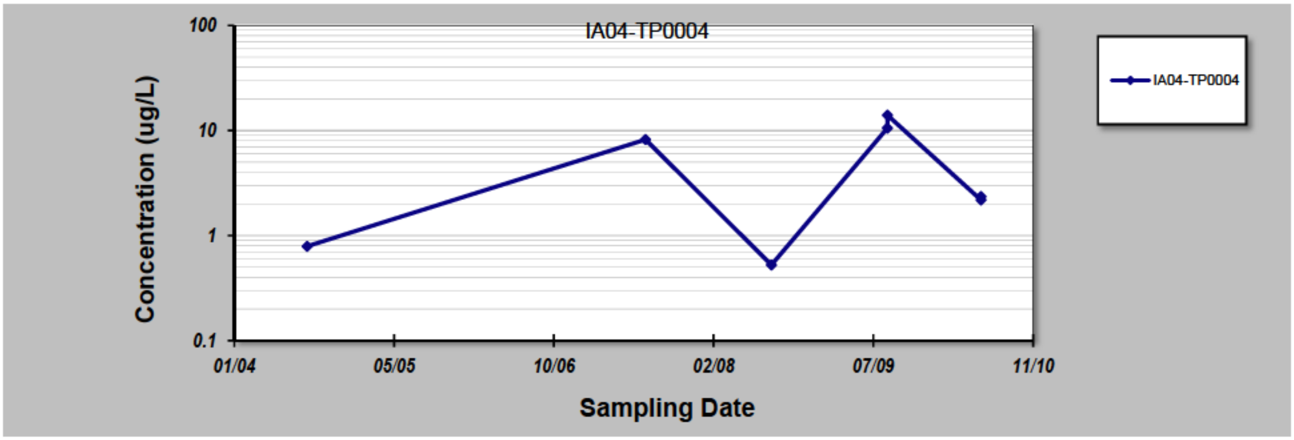
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		IA04-TP0004						
1	29-Aug-04	0.79						
2	24-Jul-07	8.20						
3	21-Aug-08	0.53						
4	19-Aug-09	10.54						
5	19-Aug-09	14.00						
6	08-Jun-10	2.18						
7	08-Jun-10	2.35						
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.97						
Mann-Kendall Statistic (S):		5						
Confidence Factor:		71.9%						
Concentration Trend:		No Trend						



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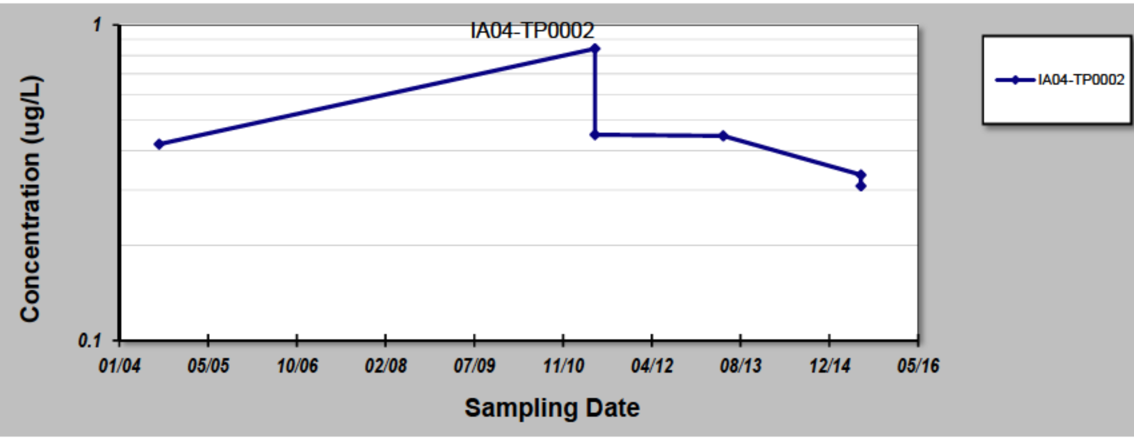
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

	Sampling Point ID:	IA04-TP0002						
Sampling Event	**Sampling Date**	**TOTAL U CONCENTRATION (ug/L)**						
1	26-Aug-04	0.42						
2	17-May-11	0.84						
3	17-May-11	0.45						
4	08-May-13	0.45						
5	23-Jun-15	0.34						
6	23-Jun-15	0.31						
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Coefficient of Variation:	0.41						
	Mann-Kendall Statistic (S):	-9						
	Confidence Factor:	93.2%						
	Concentration Trend:	Prob. Decreasing						



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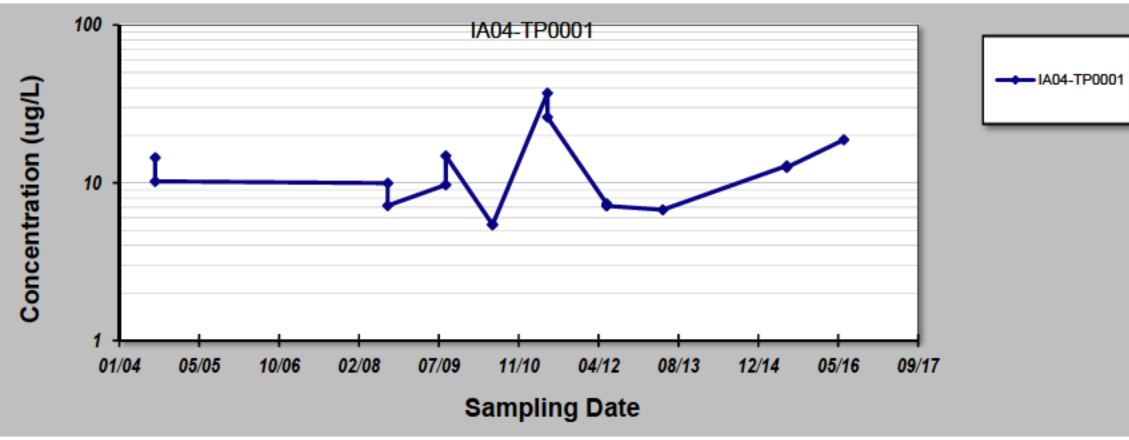
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA04-TP0001

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		IA04-TP0001						
1	26-Aug-04	14.41						
2	26-Aug-04	10.20						
3	20-Aug-08	9.94						
4	20-Aug-08	7.16						
5	19-Aug-09	9.70						
6	19-Aug-09	14.80						
7	07-Jun-10	5.44						
8	07-Jun-10	5.41						
9	17-May-11	36.94						
10	17-May-11	26.00						
11	22-May-12	7.36						
12	22-May-12	7.13						
13	08-May-13	6.74						
14	23-Jun-15	12.80						
15	23-Jun-15	12.50						
16	14-Jun-16	18.70						
17								
18								
19								
20								
Coefficient of Variation:		0.66						
Mann-Kendall Statistic (S):		0						
Confidence Factor:		48.2%						
Concentration Trend:		Stable						



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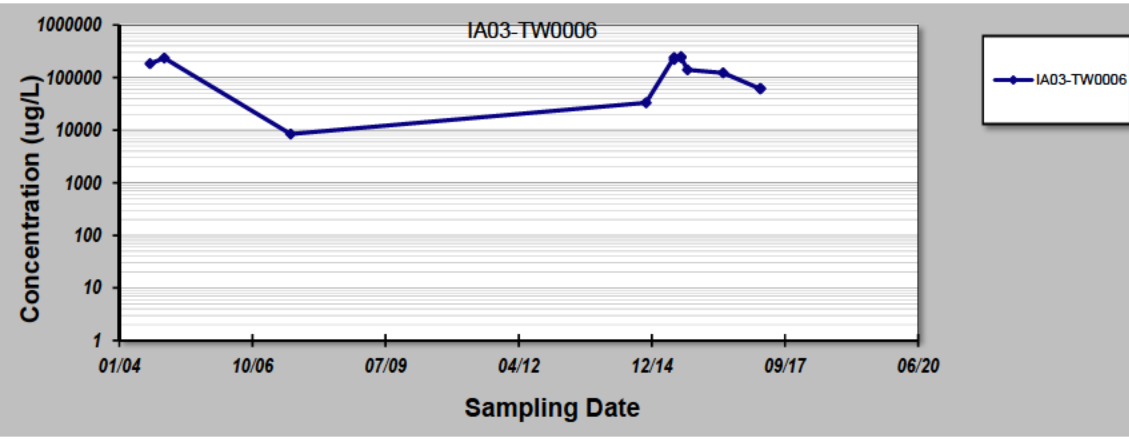
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TW0006

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
1	01-Sep-04	184000.00						
2	17-Dec-04	234534.30						
3	24-Jul-07	8440.00						
4	13-Nov-14	33180.00						
5	12-Jun-15	240000.00						
6	12-Jun-15	220000.00						
7	03-Aug-15	250000.00						
8	03-Aug-15	240000.00						
9	21-Sep-15	140000.00						
10	15-Jun-16	122500.00						
11	21-Mar-17	61030.00						
12	21-Mar-17	62200.00						
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.60						
Mann-Kendall Statistic (S):		-7						
Confidence Factor:		65.6%						
Concentration Trend:		Stable						



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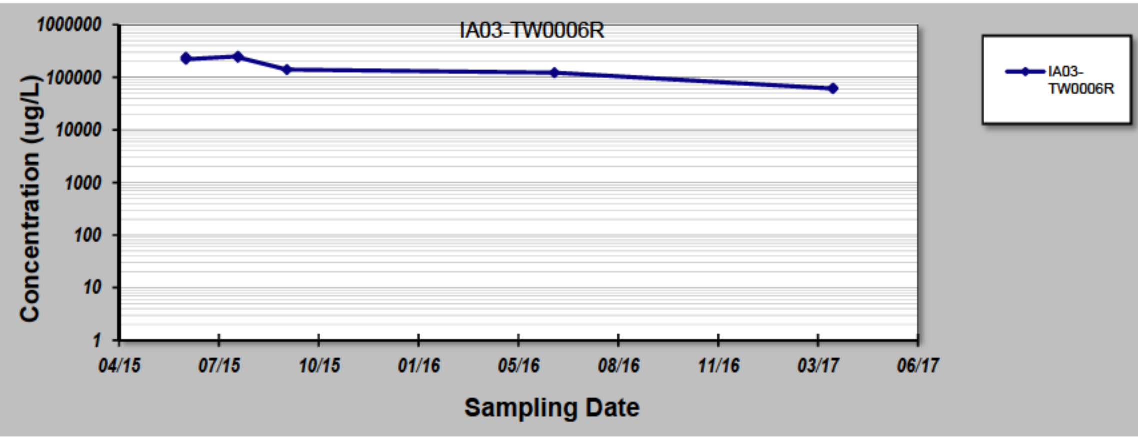
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TW0006R

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
		IA03-TW0006R					
1	12-Jun-15	240000.00					
2	12-Jun-15	220000.00					
3	03-Aug-15	250000.00					
4	03-Aug-15	240000.00					
5	21-Sep-15	140000.00					
6	15-Jun-16	122500.00					
7	21-Mar-17	61030.00					
8	21-Mar-17	62200.00					
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
Coefficient of Variation:		0.48					
Mann-Kendall Statistic (S):		-19					
Confidence Factor:		98.9%					
Concentration Trend:		Decreasing					



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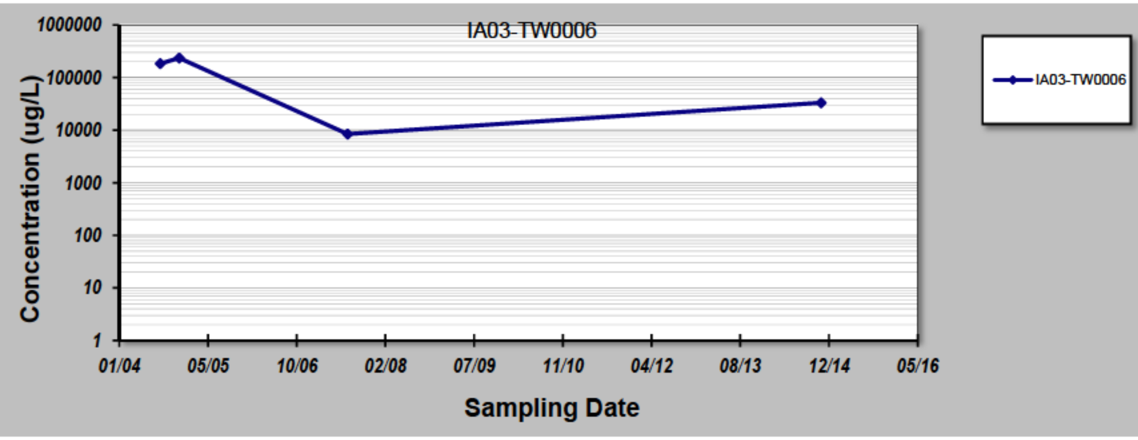
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TW0006

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
		IA03-TW0006					
1	01-Sep-04	184000.00					
2	17-Dec-04	234534.30					
3	24-Jul-07	8440.00					
4	13-Nov-14	33180.00					
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
Coefficient of Variation:		0.97					
Mann-Kendall Statistic (S):		-2					
Confidence Factor:		62.5%					
Concentration Trend:		Stable					



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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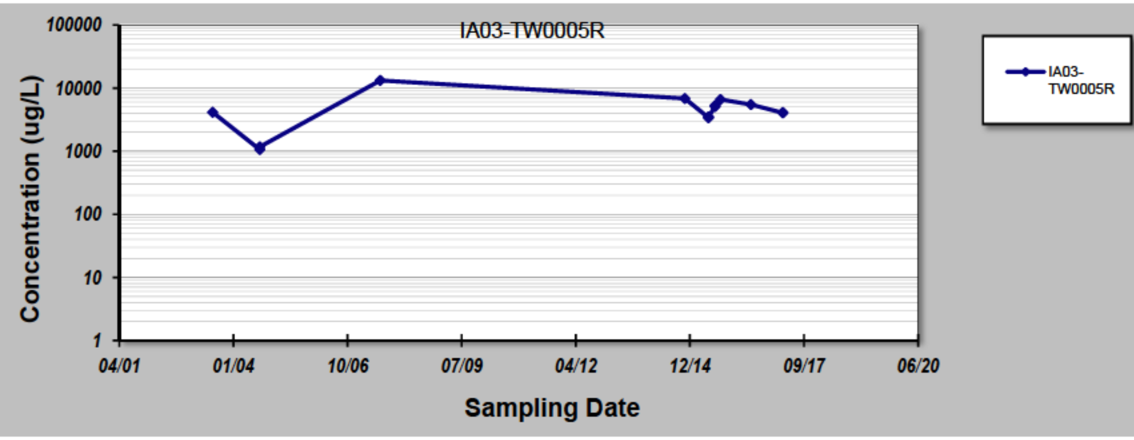
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TW0005R

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L) IA03-TW0005R					
1	16-Jul-03	4130.00					
2	01-Sep-04	1060.06					
3	01-Sep-04	1170.00					
4	24-Jul-07	13200.00					
5	13-Nov-14	6839.00					
6	08-Jun-15	3400.00					
7	08-Jun-15	3500.00					
8	05-Aug-15	5100.00					
9	05-Aug-15	5300.00					
10	22-Sep-15	6600.00					
11	14-Jun-16	5480.00					
12	3/21/2017	4047.00					
13	3/21/2017	4092.00					
14							
15							
16							
17							
18							
19							
20							
Coefficient of Variation:		0.62					
Mann-Kendall Statistic (S):		14					
Confidence Factor:		78.2%					
Concentration Trend:		No Trend					



Notes:

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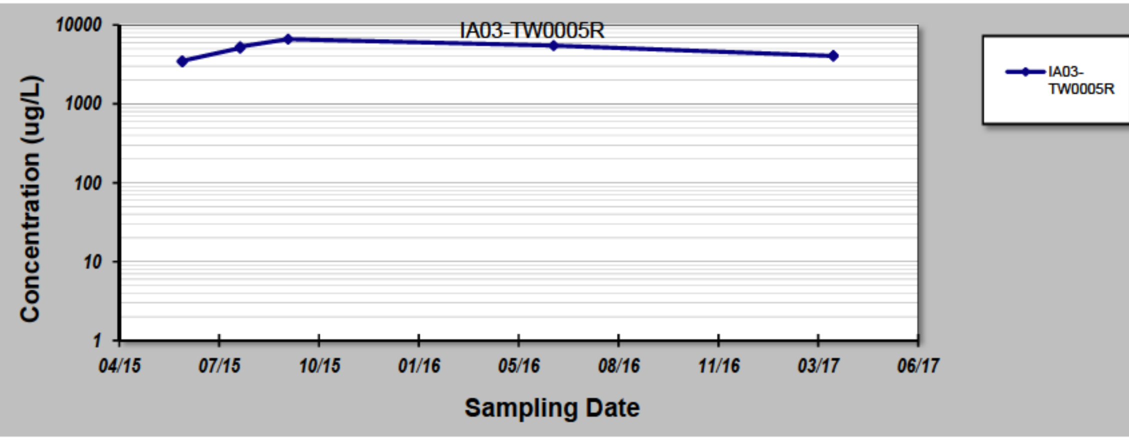
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TW0005R

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		IA03-TW0005R						
1	08-Jun-15	3400.00						
2	08-Jun-15	3500.00						
3	05-Aug-15	5100.00						
4	05-Aug-15	5300.00						
5	22-Sep-15	6600.00						
6	6/14/2016	5480.00						
7	3/21/2017	4047.00						
8	3/21/2017	4092.00						
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.24						
Mann-Kendall Statistic (S):		10						
Confidence Factor:		86.2%						
Concentration Trend:		No Trend						



Notes:

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2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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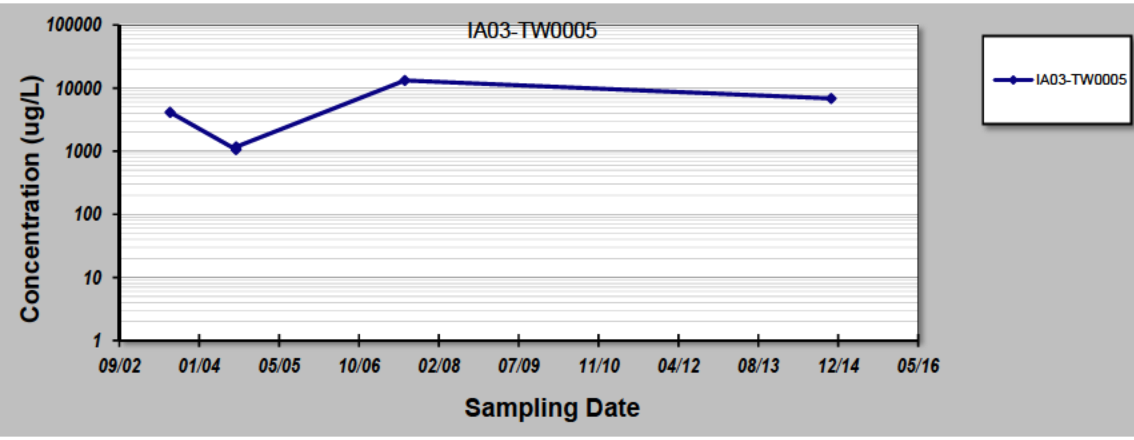
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TW0005

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		IA03-TW0005						
1	16-Jul-03	4130.00						
2	01-Sep-04	1060.06						
3	01-Sep-04	1170.00						
4	24-Jul-07	13200.00						
5	13-Nov-14	6839.00						
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.95						
Mann-Kendall Statistic (S):		4						
Confidence Factor:		75.8%						
Concentration Trend:		No Trend						



Notes:

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2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
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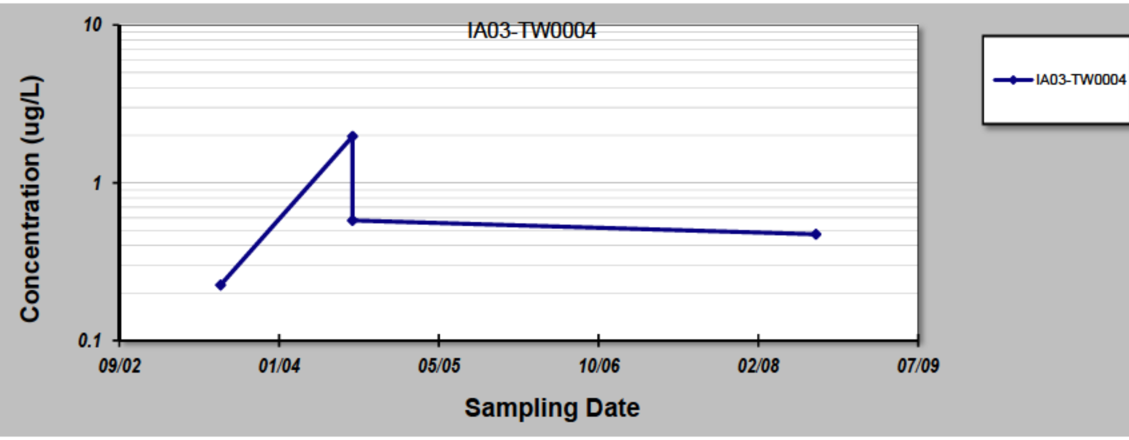
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TW0004

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
		IA03-TW0004					
1	15-Jul-03	0.23					
2	31-Aug-04	1.97					
3	31-Aug-04	0.58					
4	20-Aug-08	0.47					
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
Coefficient of Variation:		0.97					
Mann-Kendall Statistic (S):		0					
Confidence Factor:		37.5%					
Concentration Trend:		Stable					



Notes:

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2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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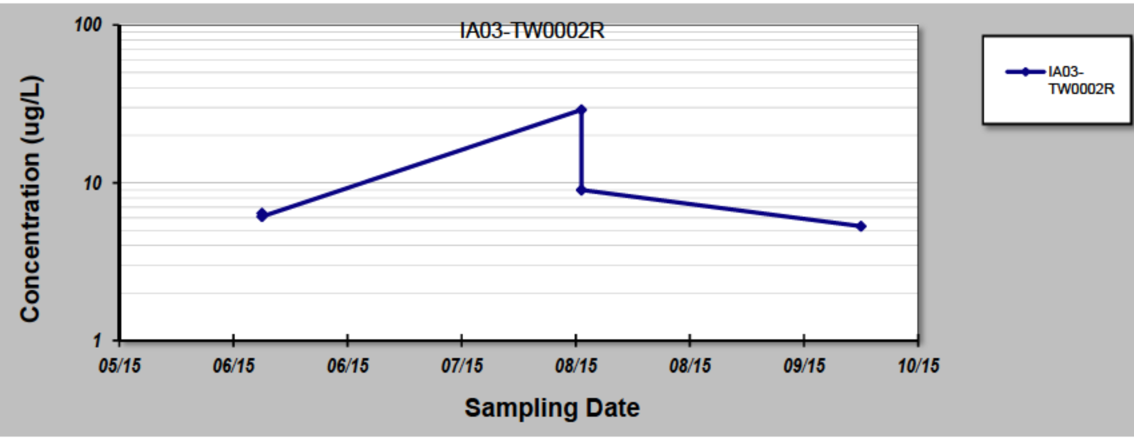
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TW0002R

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
		IA03-TW0002R					
1	10-Jun-15	6.40					
2	10-Jun-15	6.10					
3	05-Aug-15	29.00					
4	05-Aug-15	9.00					
5	23-Sep-15	5.30					
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
	Coefficient of Variation:	0.90					
	Mann-Kendall Statistic (S):	-2					
	Confidence Factor:	59.2%					
	Concentration Trend:	Stable					



Notes:
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2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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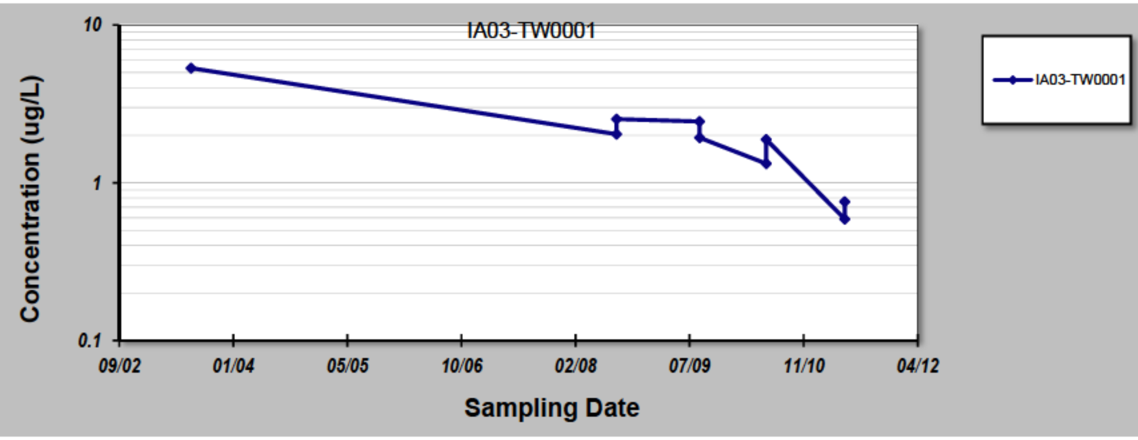
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
Sampling Point ID:		IA03-TW0001					
1	13-Jul-03	5.32					
2	20-Aug-08	2.03					
3	20-Aug-08	2.53					
4	19-Aug-09	2.44					
5	19-Aug-09	1.93					
6	07-Jun-10	1.32					
7	07-Jun-10	1.88					
8	17-May-11	0.59					
9	17-May-11	0.76					
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
Coefficient of Variation:		0.67					
Mann-Kendall Statistic (S):		-28					
Confidence Factor:		99.9%					
Concentration Trend:		Decreasing					



Notes:

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3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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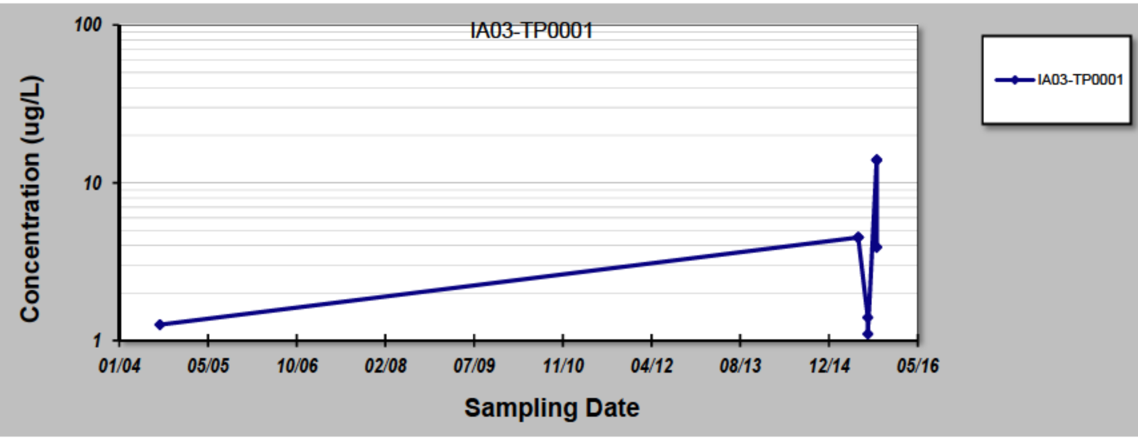
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: IA03-TP0001

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L) IA03-TP0001						
1	30-Aug-04	1.26						
2	10-Jun-15	4.50						
3	10-Jun-15	4.50						
4	03-Aug-15	1.40						
5	03-Aug-15	1.10						
6	22-Sep-15	14.00						
7	22-Sep-15	13.90						
8	22-Sep-15	3.90						
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.96						
Mann-Kendall Statistic (S):		5						
Confidence Factor:		68.3%						
Concentration Trend:		No Trend						



Notes:

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2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
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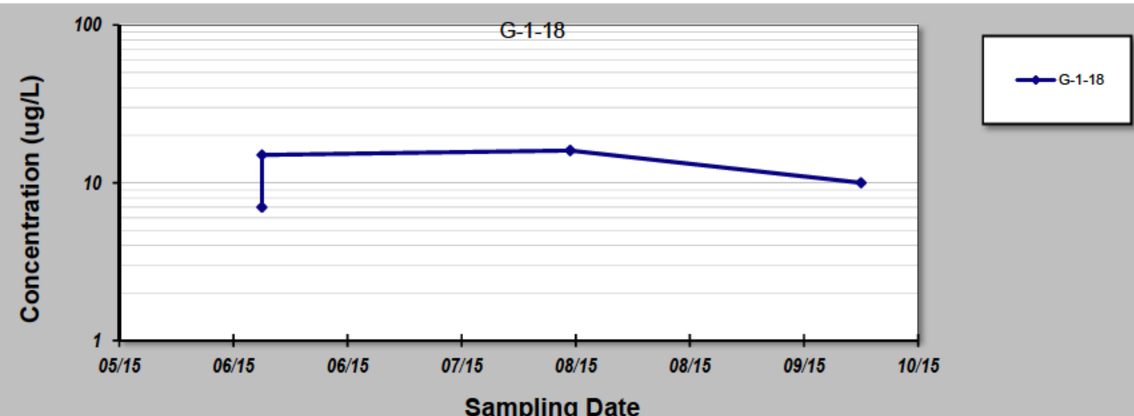
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-18						
1	10-Jun-15	7.00						
2	10-Jun-15	15.00						
3	03-Aug-15	16.00						
4	03-Aug-15	16.00						
5	23-Sep-15	10.00						
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.32						
Mann-Kendall Statistic (S):		3						
Confidence Factor:		67.5%						
Concentration Trend:		No Trend						



Notes:

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2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
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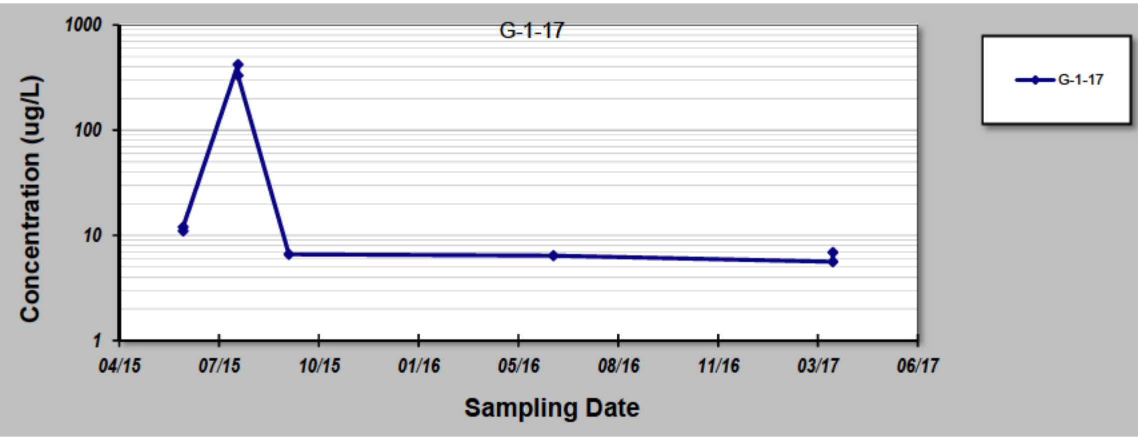
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: G-1-17

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
1	09-Jun-15	11.00						
2	09-Jun-15	12.00						
3	03-Aug-15	420.00						
4	03-Aug-15	330.00						
5	23-Sep-15	6.60						
6	14-Jun-16	6.41						
7	21-Mar-17	5.61						
8	21-Mar-17	6.89						
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Coefficient of Variation:	1.72						
	Mann-Kendall Statistic (S):	-12						
	Confidence Factor:	91.1%						
	Concentration Trend:	Prob. Decreasing						



Notes:

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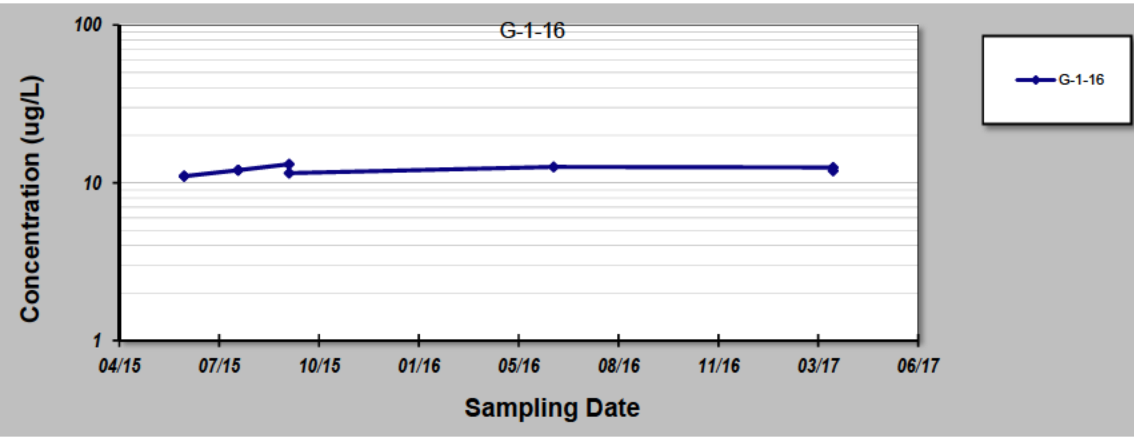
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID:		G-1-16						
Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
1	10-Jun-15	11.00						
2	10-Jun-15	11.00						
3	03-Aug-15	12.00						
4	03-Aug-15	12.00						
5	23-Sep-15	13.10						
6	23-Sep-15	11.51						
7	14-Jun-16	12.60						
8	21-Mar-17	12.50						
9	21-Mar-17	11.90						
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.06						
Mann-Kendall Statistic (S):		12						
Confidence Factor:		87.0%						
Concentration Trend:		No Trend						



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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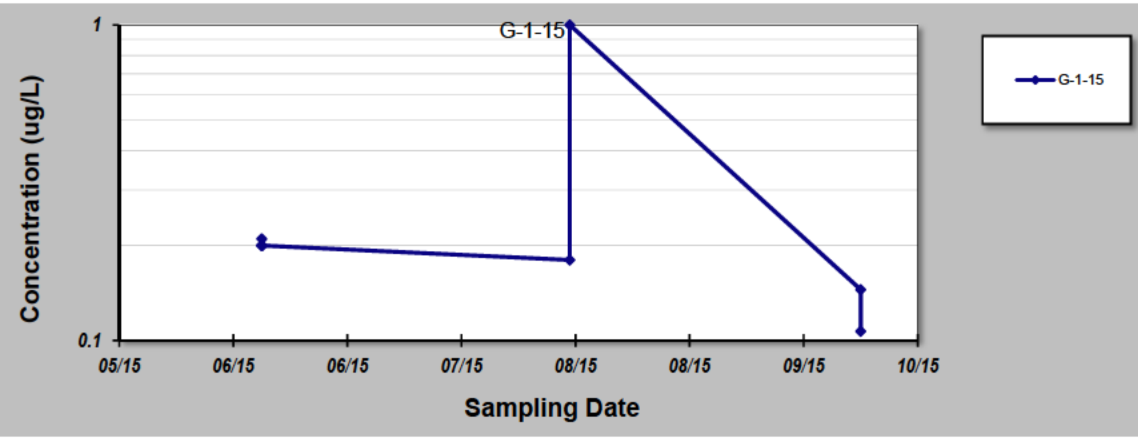
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: G-1-15

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		G-1-15						
1	10-Jun-15	0.21						
2	10-Jun-15	0.20						
3	10-Jun-15	0.20						
4	10-Jun-15	0.20						
5	03-Aug-15	0.18						
6	03-Aug-15	1.00						
7	23-Sep-15	0.15						
8	23-Sep-15	0.11						
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		1.05						
Mann-Kendall Statistic (S):		-15						
Confidence Factor:		95.8%						
Concentration Trend:		Decreasing						



Notes:

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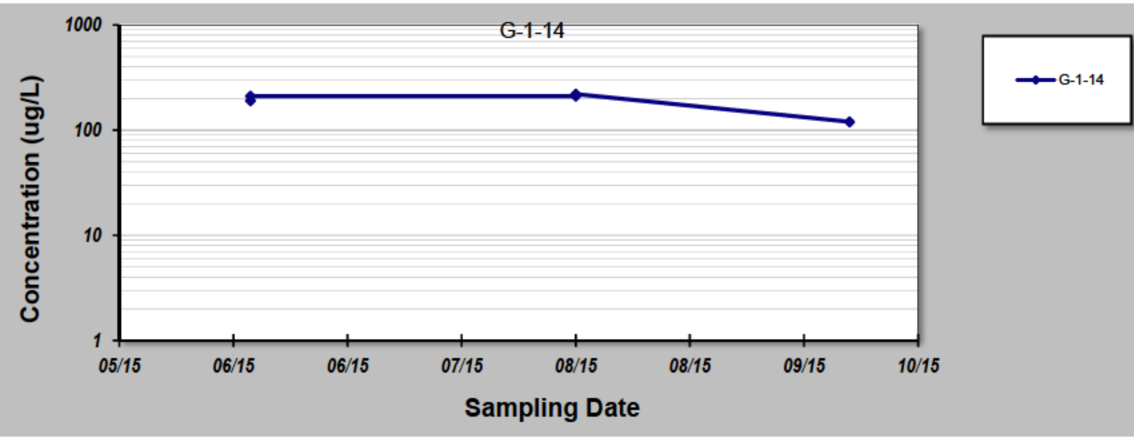
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-14						
1	08-Jun-15	190.00						
2	08-Jun-15	210.00						
3	04-Aug-15	210.00						
4	04-Aug-15	220.00						
5	21-Sep-15	120.00						
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.21						
Mann-Kendall Statistic (S):		1						
Confidence Factor:		50.0%						
Concentration Trend:		No Trend						



Notes:

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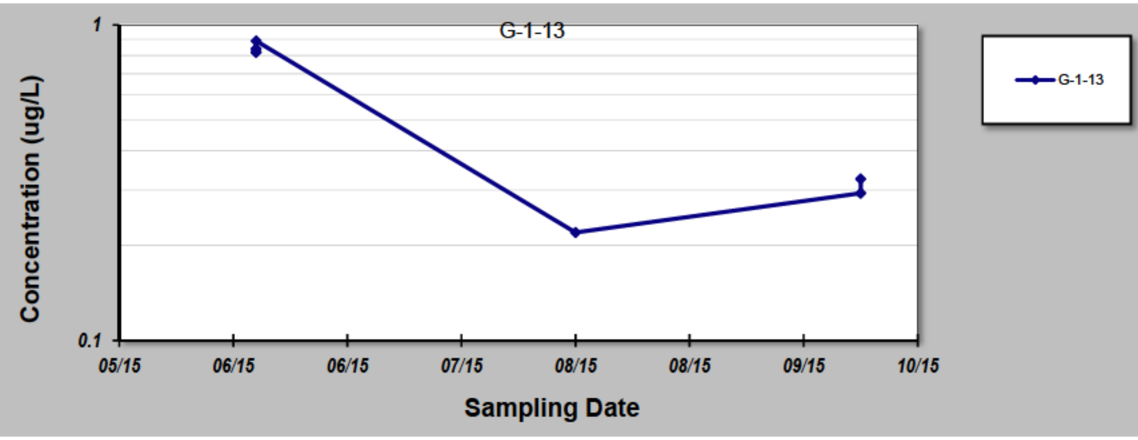
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-13						
1	09-Jun-15	0.84						
2	09-Jun-15	0.82						
3	09-Jun-15	0.82						
4	09-Jun-15	0.89						
5	04-Aug-15	0.22						
6	23-Sep-15	0.29						
7	23-Sep-15	0.33						
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.50						
Mann-Kendall Statistic (S):		-8						
Confidence Factor:		84.5%						
Concentration Trend:		Stable						



Notes:

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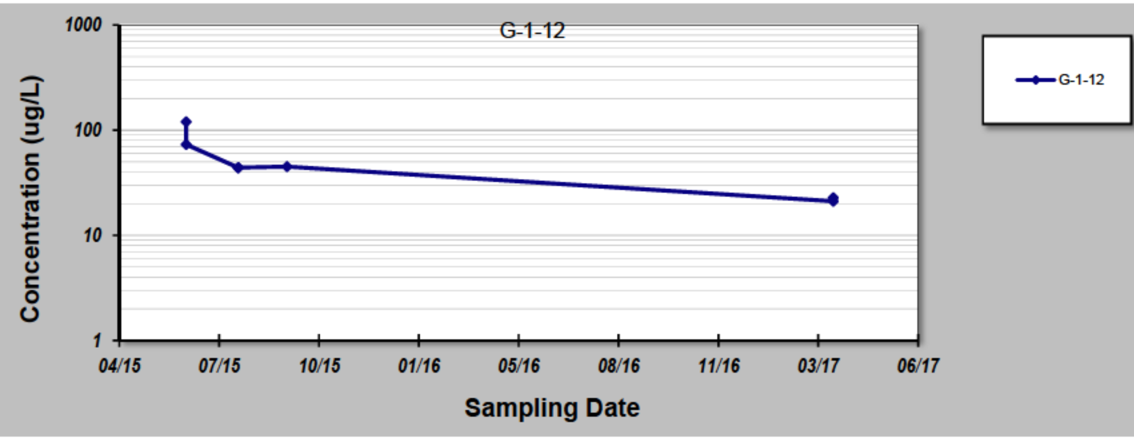
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-12						
1	12-Jun-15	120.00						
2	12-Jun-15	73.00						
3	03-Aug-15	44.00						
4	03-Aug-15	44.00						
5	21-Sep-15	45.00						
6	21-Mar-17	21.10						
7	21-Mar-17	22.80						
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.65						
Mann-Kendall Statistic (S):		-14						
Confidence Factor:		97.5%						
Concentration Trend:		Decreasing						



Notes:

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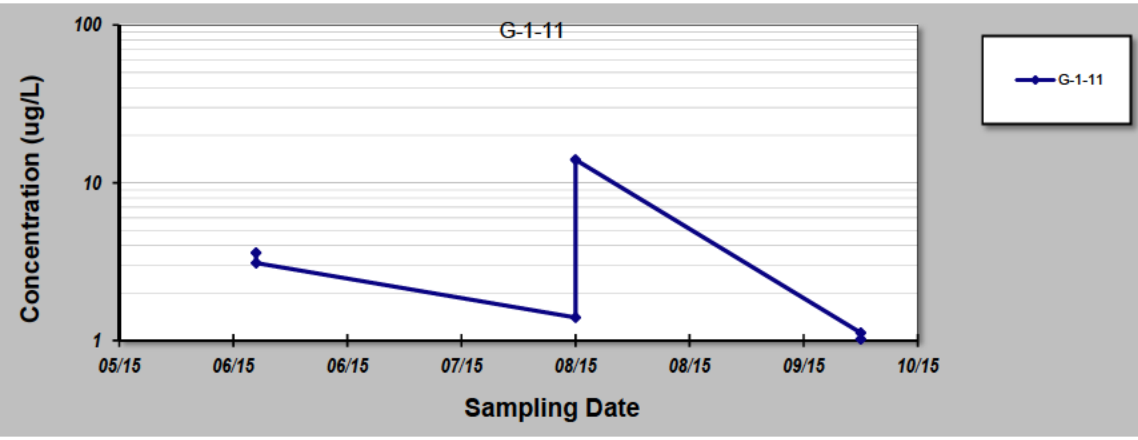
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID:		G-1-11						
Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
1	09-Jun-15	3.60						
2	09-Jun-15	3.10						
3	04-Aug-15	1.40						
4	04-Aug-15	14.00						
5	23-Sep-15	1.12						
6	23-Sep-15	1.02						
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		1.24						
Mann-Kendall Statistic (S):		-9						
Confidence Factor:		93.2%						
Concentration Trend:		Prob. Decreasing						



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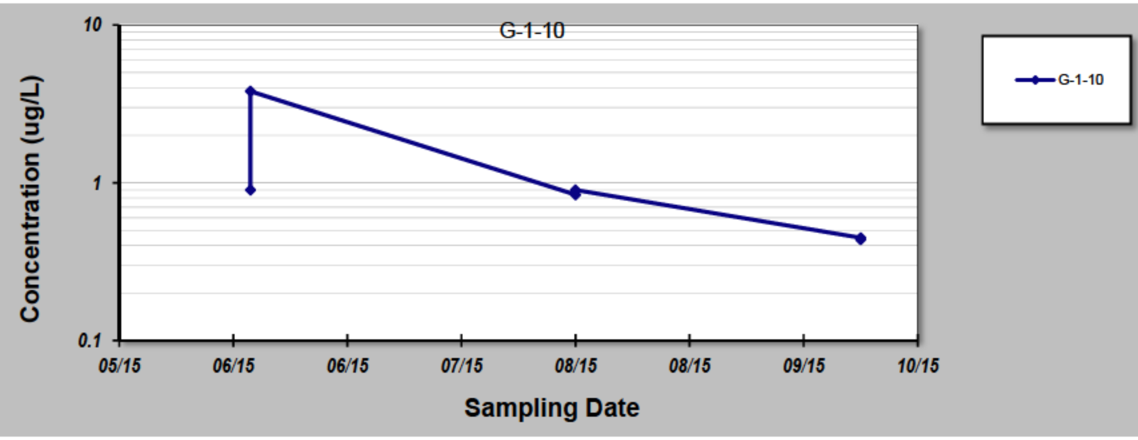
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-10						
1	08-Jun-15	0.90						
2	08-Jun-15	3.80						
3	04-Aug-15	0.84						
4	04-Aug-15	0.90						
5	23-Sep-15	0.45						
6	23-Sep-15	0.44						
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		1.05						
Mann-Kendall Statistic (S):		-10						
Confidence Factor:		95.2%						
Concentration Trend:		Decreasing						



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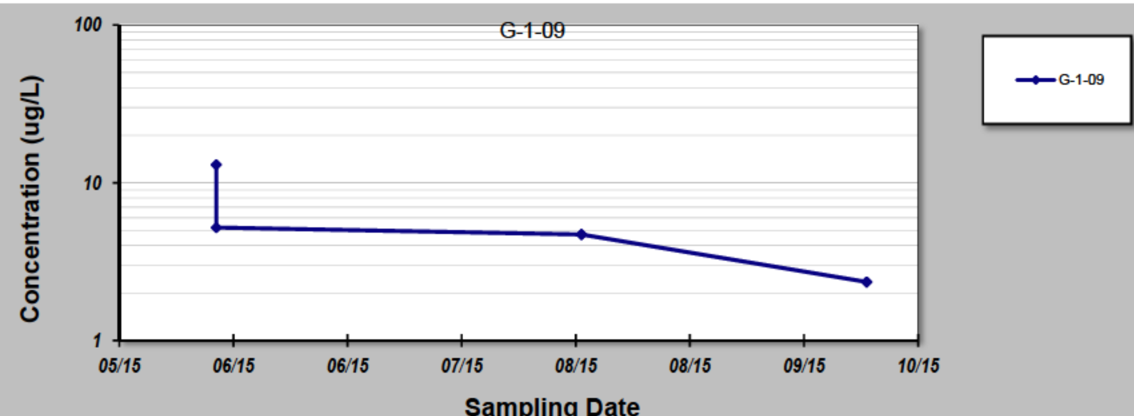
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-09						
1	02-Jun-15	13.00						
2	02-Jun-15	5.20						
3	05-Aug-15	4.70						
4	05-Aug-15	4.70						
5	24-Sep-15	2.35						
6	24-Sep-15	2.35						
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.73						
Mann-Kendall Statistic (S):		-13						
Confidence Factor:		99.2%						
Concentration Trend:		Decreasing						



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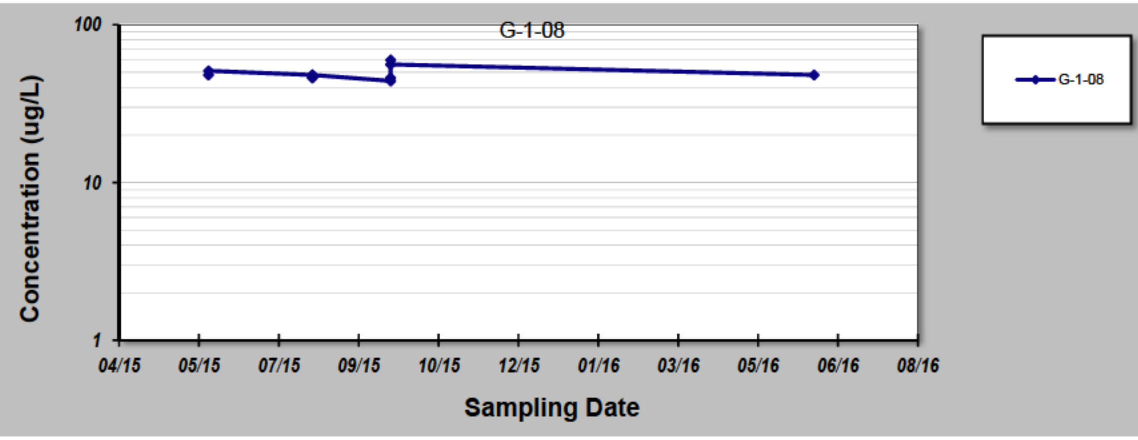
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-08						
1	01-Jun-15	48.00						
2	01-Jun-15	51.00						
3	05-Aug-15	48.00						
4	05-Aug-15	47.00						
5	05-Aug-15	46.00						
6	05-Aug-15	48.00						
7	23-Sep-15	44.00						
8	23-Sep-15	46.00						
9	23-Sep-15	59.70						
10	23-Sep-15	56.00						
11	14-Jun-16	48.00						
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.09						
Mann-Kendall Statistic (S):		0						
Confidence Factor:		45.1%						
Concentration Trend:		Stable						



Notes:

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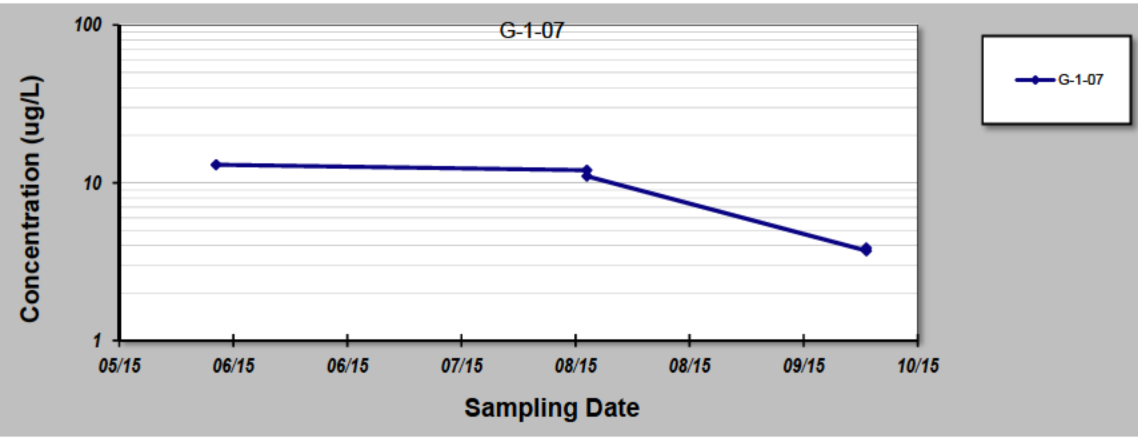
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: 2-Aug-16
Facility Name: Harshaw Site
Conducted By: Guckin

Job ID: N/A
Constituent: Total U
Concentration Units: ug/L

Sampling Point ID: G-1-07

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		G-1-07						
1	02-Jun-15	13.00						
2	06-Aug-15	12.00						
3	06-Aug-15	11.00						
4	24-Sep-15	3.71						
5	24-Sep-15	3.86						
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.52						
Mann-Kendall Statistic (S):		-8						
Confidence Factor:		95.8%						
Concentration Trend:		Decreasing						



Notes:

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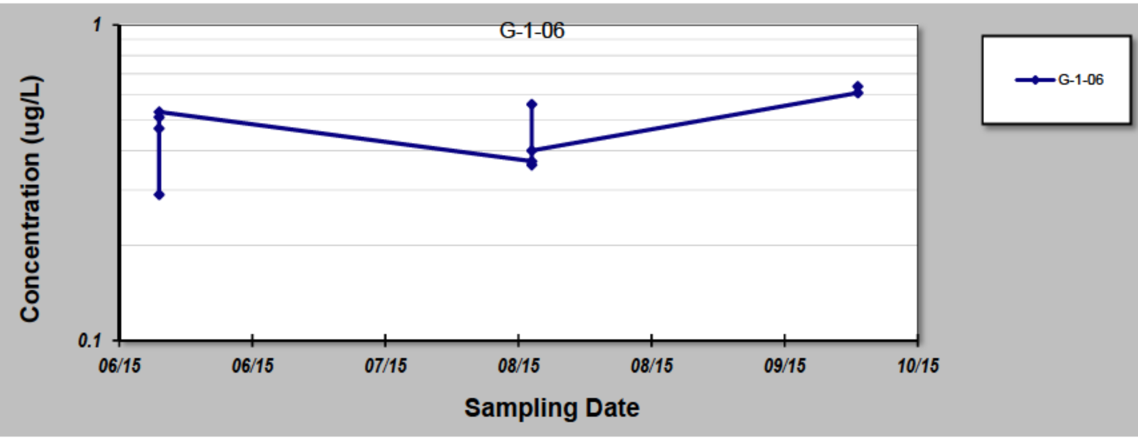
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
	Sampling Point ID:	G-1-06						
1	11-Jun-15	0.51						
2	11-Jun-15	0.47						
3	11-Jun-15	0.29						
4	11-Jun-15	0.53						
5	06-Aug-15	0.37						
6	06-Aug-15	0.56						
7	06-Aug-15	0.36						
8	06-Aug-15	0.40						
9	24-Sep-15	0.61						
10	24-Sep-15	0.64						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Coefficient of Variation:	0.24						
	Mann-Kendall Statistic (S):	15						
	Confidence Factor:	89.2%						
	Concentration Trend:	No Trend						



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3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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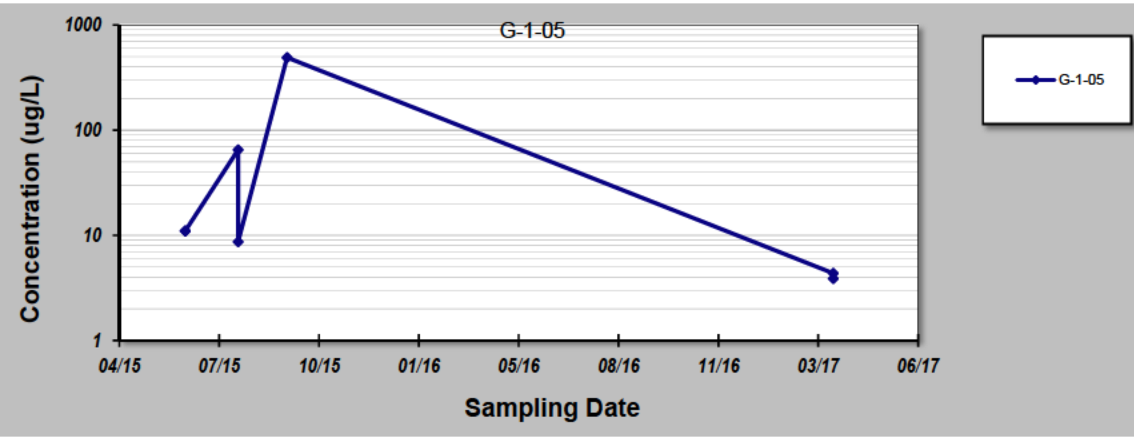
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	**Job ID:**	N/A
Facility Name:	Harshaw Site	**Constituent:**	Total U
Conducted By:	Guckin	**Concentration Units:**	ug/L

Sampling Point ID: G-1-05

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		G-1-05						
1	11-Jun-15	11.00						
2	11-Jun-15	11.00						
3	03-Aug-15	65.00						
4	03-Aug-15	8.70						
5	21-Sep-15	490.00						
6	21-Mar-17	4.36						
7	21-Mar-17	3.88						
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		2.12						
Mann-Kendall Statistic (S):		-8						
Confidence Factor:		84.5%						
Concentration Trend:		No Trend						



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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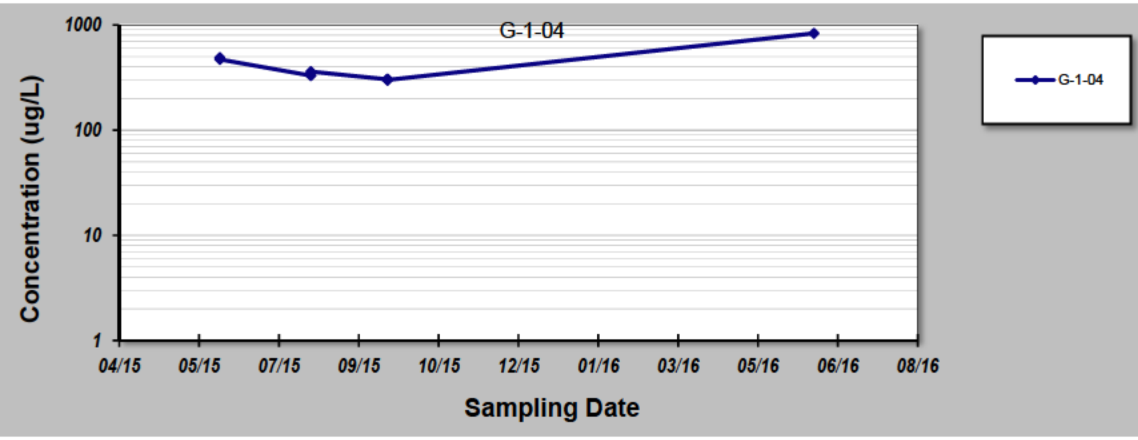
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-04						
1	08-Jun-15	490.00						
2	08-Jun-15	470.00						
3	04-Aug-15	330.00						
4	04-Aug-15	360.00						
5	21-Sep-15	304.00						
6	21-Sep-15	306.00						
7	21-Sep-15	300.00						
8	21-Sep-15	300.00						
9	14-Jun-16	832.00						
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.43						
Mann-Kendall Statistic (S):		-15						
Confidence Factor:		92.5%						
Concentration Trend:		Prob. Decreasing						



Notes:

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3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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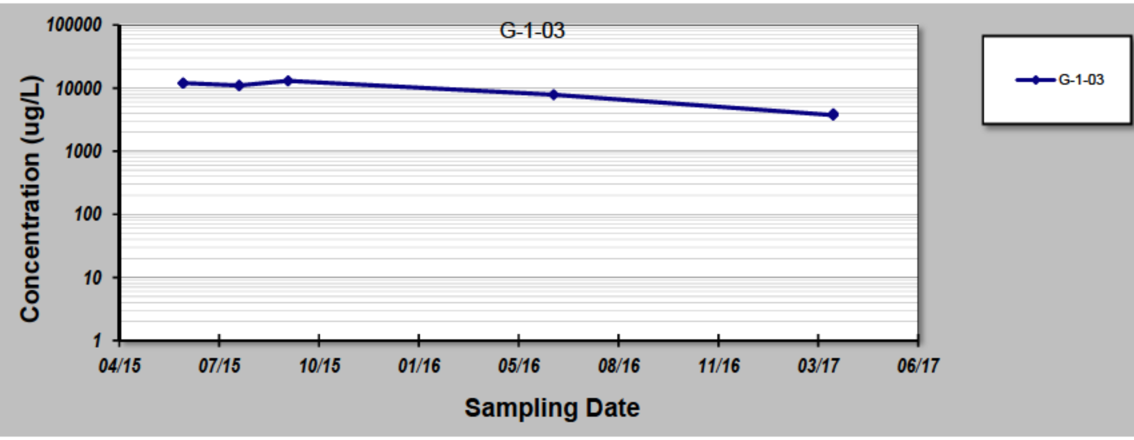
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: 2-Aug-16
Facility Name: Harshaw Site
Conducted By: Guckin
Job ID: N/A
Constituent: Total U
Concentration Units: ug/L

Sampling Point ID: G-1-03

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		G-1-03						
1	09-Jun-15	12000.00						
2	09-Jun-15	12000.00						
3	04-Aug-15	11000.00						
4	04-Aug-15	11000.00						
5	22-Sep-15	13000.00						
6	14-Jun-16	7841.00						
7	21-Mar-17	3728.00						
8	21-Mar-17	3933.00						
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.40						
Mann-Kendall Statistic (S):		-16						
Confidence Factor:		96.9%						
Concentration Trend:		Decreasing						



Notes:

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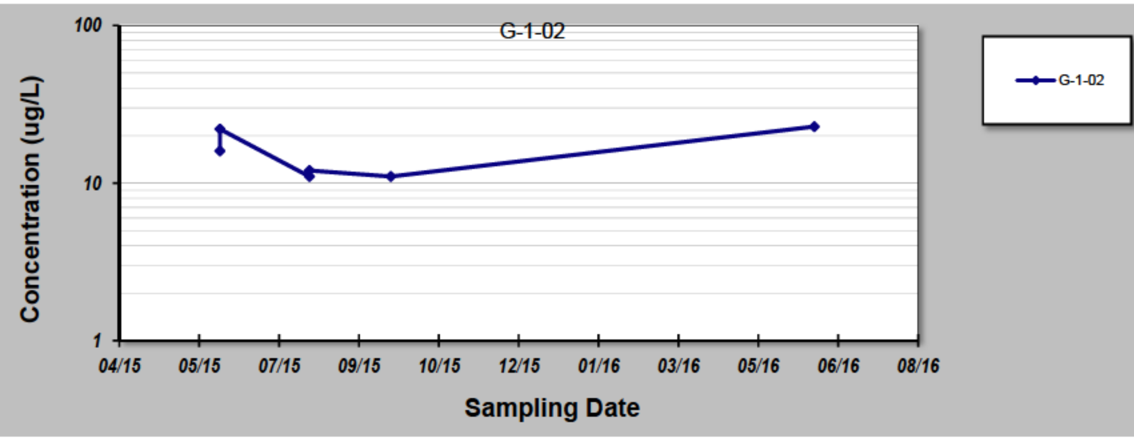
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: 2-Aug-16
Facility Name: Harshaw Site
Conducted By: Guckin
Job ID: N/A
Constituent: Total U
Concentration Units: ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		G-1-02						
1	08-Jun-15	16.00						
2	08-Jun-15	22.00						
3	03-Aug-15	11.00						
4	03-Aug-15	12.00						
5	23-Sep-15	11.00						
6	14-Jun-16	22.80						
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.34						
Mann-Kendall Statistic (S):		0						
Confidence Factor:		39.3%						
Concentration Trend:		Stable						



Notes:

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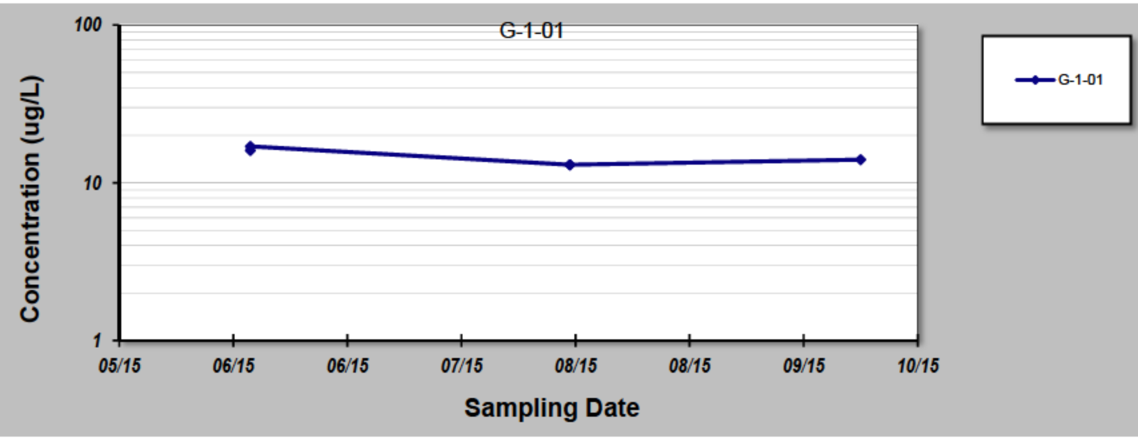
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: G-1-01

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L) G-1-01						
1	08-Jun-15	16.00						
2	08-Jun-15	17.00						
3	03-Aug-15	13.00						
4	03-Aug-15	13.00						
5	23-Sep-15	14.00						
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.12						
Mann-Kendall Statistic (S):		-3						
Confidence Factor:		67.5%						
Concentration Trend:		Stable						



Notes:

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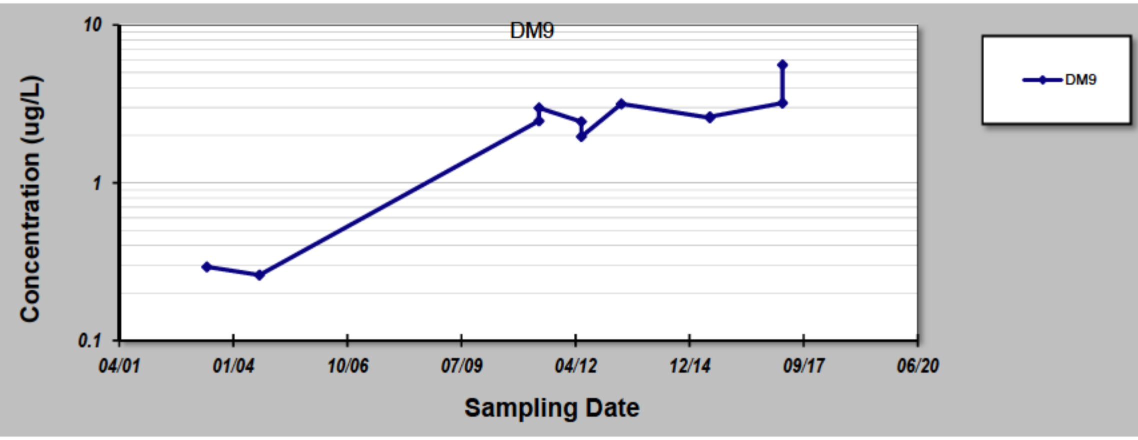
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: DM9

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		DM9						
1	27-May-03	0.29						
2	30-Aug-04	0.26						
3	17-May-11	2.47						
4	17-May-11	2.98						
5	23-May-12	2.44						
6	23-May-12	1.96						
7	08-May-13	3.16						
8	23-Jun-15	2.58						
9	23-Jun-15	2.62						
10	21-Mar-17	3.20						
11	21-Mar-17	5.58						
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.58						
Mann-Kendall Statistic (S):		35						
Confidence Factor:		99.7%						
Concentration Trend:		Increasing						



Notes:

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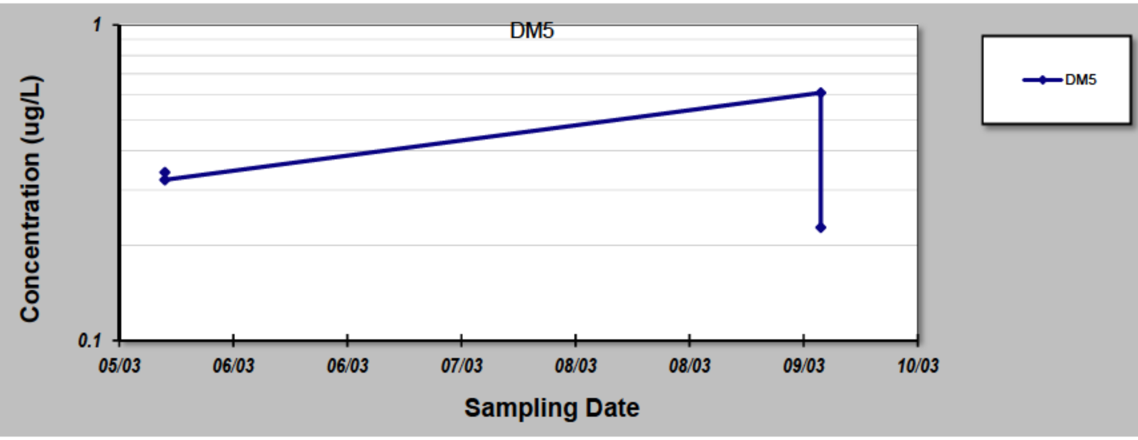
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: DM5

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		DM5						
1	27-May-03	0.34						
2	27-May-03	0.32						
3	19-Sep-03	0.61						
4	19-Sep-03	0.23						
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.44						
Mann-Kendall Statistic (S):		-2						
Confidence Factor:		62.5%						
Concentration Trend:		Stable						



Notes:

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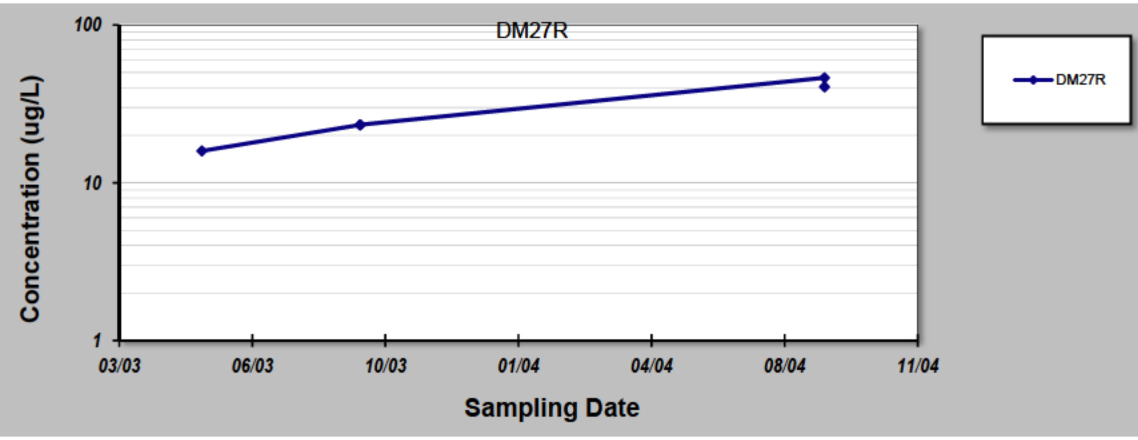
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: DM27R

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		DM27R						
1	21-May-03	15.90						
2	17-Sep-03	23.27						
3	17-Sep-03	23.30						
4	31-Aug-04	46.25						
5	31-Aug-04	40.50						
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.43						
Mann-Kendall Statistic (S):		8						
Confidence Factor:		95.8%						
Concentration Trend:		Increasing						



Notes:
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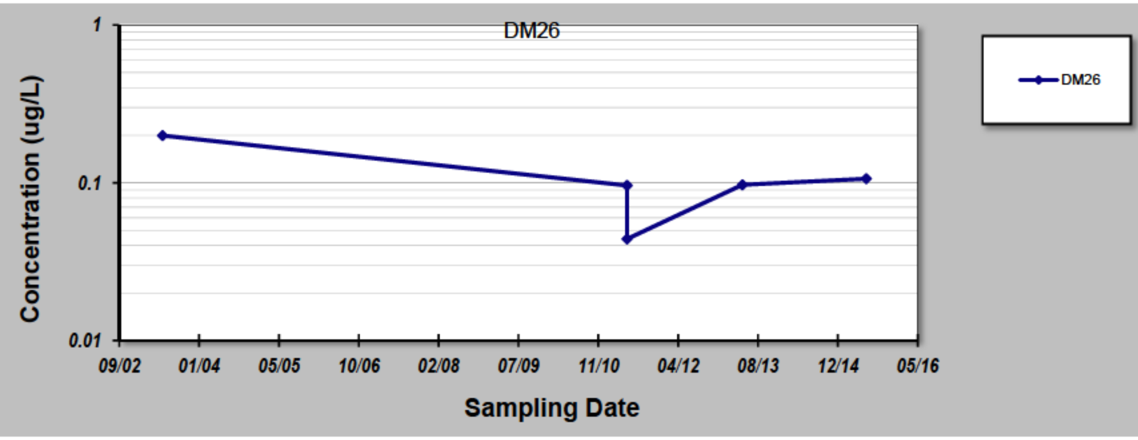
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: DM26

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		DM26						
1	30-May-03	0.20						
2	17-May-11	0.10						
3	17-May-11	0.04						
4	08-May-13	0.10						
5	23-Jun-15	0.11						
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.52						
Mann-Kendall Statistic (S):		0						
Confidence Factor:		40.8%						
Concentration Trend:		Stable						



Notes:

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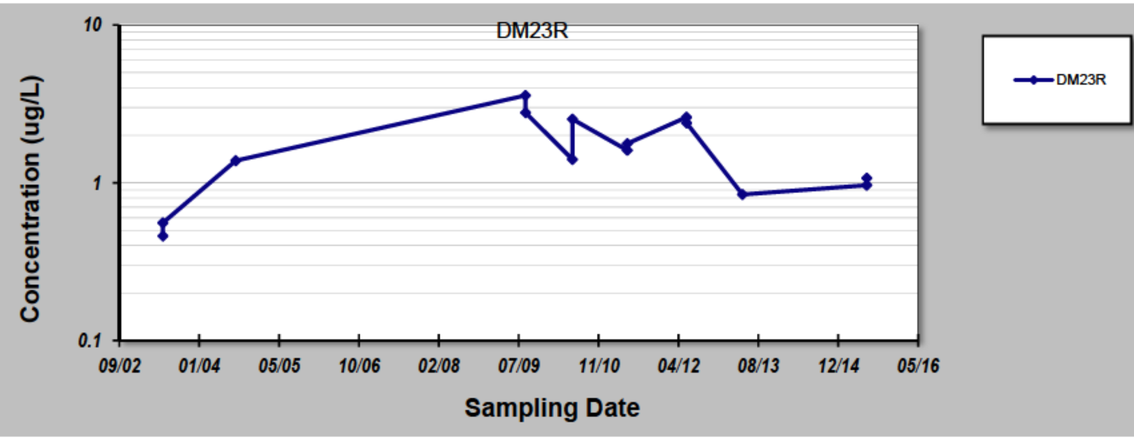
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID:		DM23R						
Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
1	01-Jun-03	0.46						
2	01-Jun-03	0.56						
3	30-Aug-04	1.38						
4	18-Aug-09	3.57						
5	18-Aug-09	2.78						
6	07-Jun-10	1.41						
7	07-Jun-10	2.53						
8	17-May-11	1.61						
9	17-May-11	1.77						
10	22-May-12	2.60						
11	22-May-12	2.39						
12	07-May-13	0.84						
13	24-Jun-15	0.96						
14	24-Jun-15	1.07						
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.55						
Mann-Kendall Statistic (S):		3						
Confidence Factor:		54.3%						
Concentration Trend:		No Trend						



Notes:

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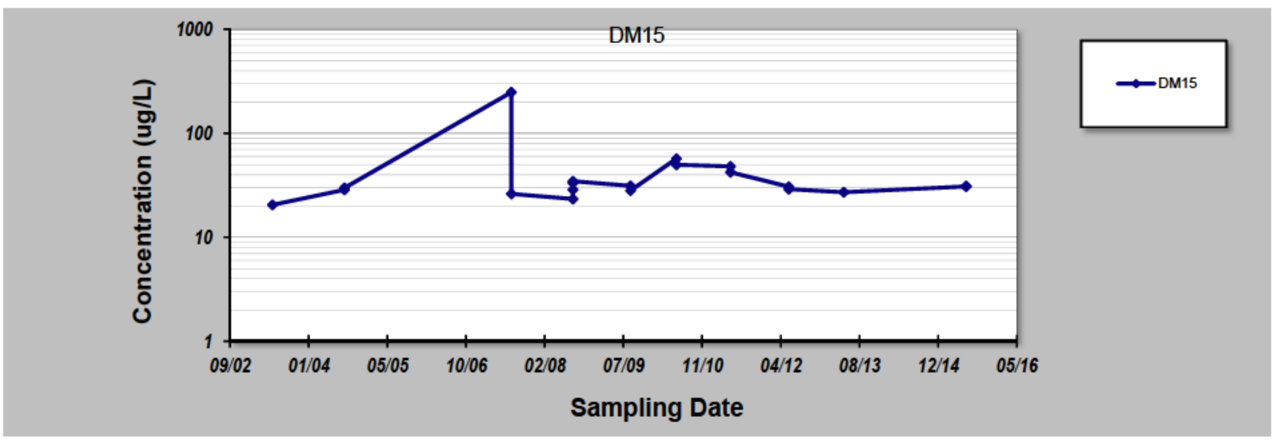
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: 2-Aug-16
Facility Name: Harshaw Site
Conducted By: Guckin
Job ID: N/A
Constituent: Total U
Concentration Units: ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
Sampling Point ID:		DM15						
1	29-May-03	20 50						
2	28-Aug-04	28 59						
3	28-Aug-04	29 80						
4	25-Jul-07	248 00						
5	25-Jul-07	26.13						
6	19-Aug-08	23 36						
7	19-Aug-08	33 33						
8	19-Aug-08	28.70						
9	19-Aug-08	34 60						
10	20-Aug-09	31.23						
11	20-Aug-09	28.10						
12	08-Jun-10	57.06						
13	08-Jun-10	49.80						
14	17-May-11	48.05						
15	17-May-11	42.20						
16	22-May-12	30.63						
17	22-May-12	29.00						
18	07-May-13	27.10						
19	23-Jun-15	30.80						
20	23-Jun-15	31.00						
21								
22								
23								
24								
25								
Coefficient of Variation:		1.11						
Mann-Kendall Statistic (S):		30						
Confidence Factor:		82.4%						
Concentration Trend:		No Trend						



Notes

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3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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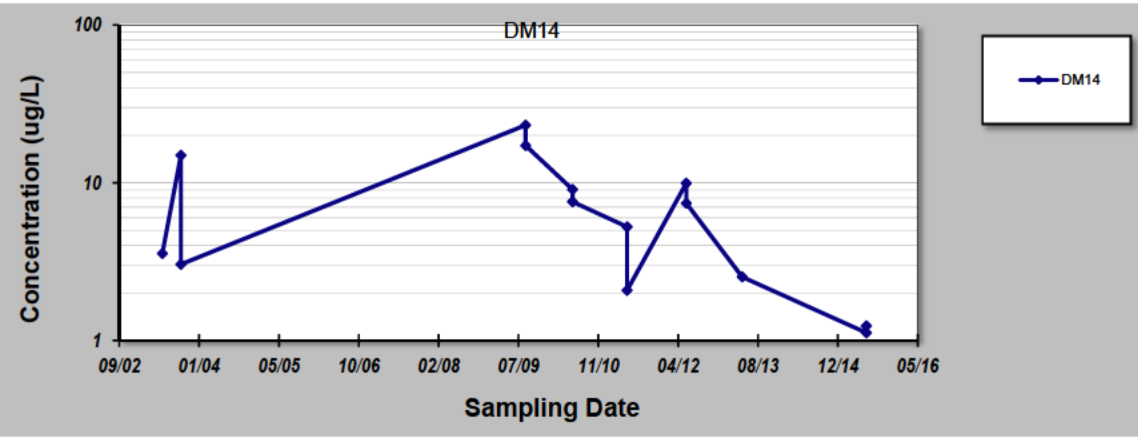
Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
	Sampling Point ID:	DM14						
1	29-May-03	3.56						
2	22-Sep-03	14.95						
3	22-Sep-03	3.04						
4	20-Aug-09	23.18						
5	20-Aug-09	17.20						
6	09-Jun-10	9.07						
7	09-Jun-10	7.58						
8	17-May-11	5.26						
9	17-May-11	2.08						
10	22-May-12	9.94						
11	22-May-12	7.41						
12	07-May-13	2.53						
13	23-Jun-15	1.12						
14	23-Jun-15	1.24						
15								
16								
17								
18								
19								
20								
	Coefficient of Variation:	0.86						
	Mann-Kendall Statistic (S):	-41						
	Confidence Factor:	98.7%						
	Concentration Trend:	Decreasing						



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3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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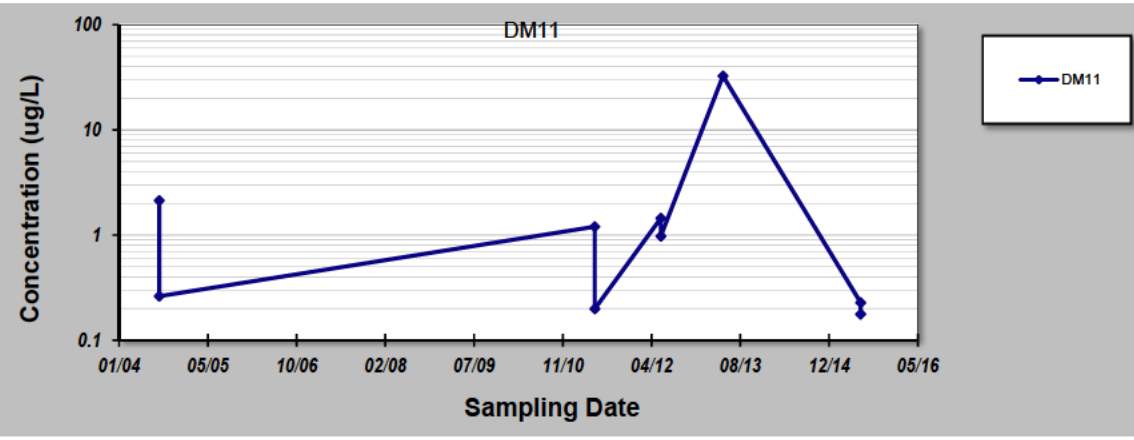
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: 2-Aug-16
Facility Name: Harshaw Site
Conducted By: Guckin

Job ID: N/A
Constituent: Total U
Concentration Units: ug/L

Sampling Point ID:		DM11						
Sampling Event	**Sampling Date**	**TOTAL U CONCENTRATION (ug/L)**						
1	27-Aug-04	2.13						
2	27-Aug-04	0.26						
3	17-May-11	1.20						
4	17-May-11	0.20						
5	23-May-12	1.45						
6	23-May-12	0.98						
7	08-May-13	32.50						
8	23-Jun-15	0.23						
9	23-Jun-15	0.18						
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		2.43						
Mann-Kendall Statistic (S):		-10						
Confidence Factor:		82.1%						
Concentration Trend:		No Trend						



Notes:

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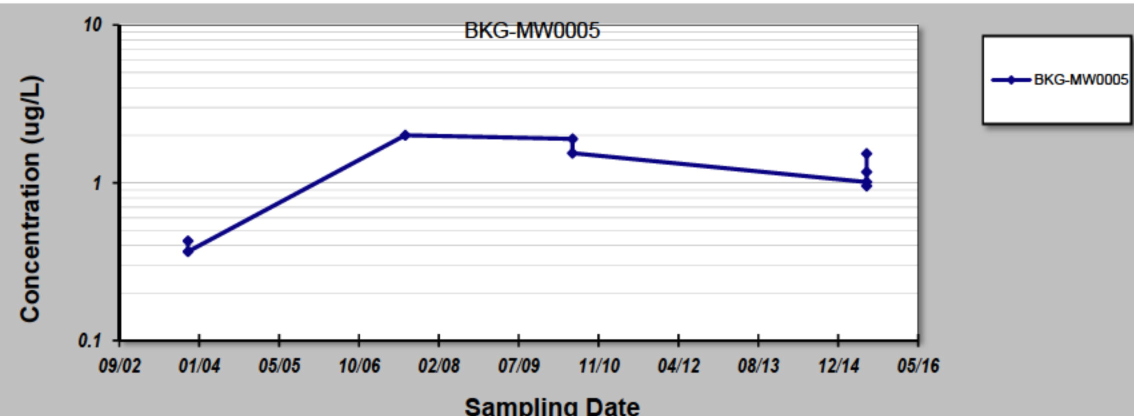
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: BKG-MW0005

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)					
		BKG-MW0005					
1	05-Nov-03	0.43					
2	05-Nov-03	0.37					
3	27-Jul-07	2.00					
4	08-Jun-10	1.89					
5	08-Jun-10	1.54					
6	23-Jun-15	1.01					
7	23-Jun-15	1.17					
8	23-Jun-15	1.53					
9	23-Jun-15	0.95					
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
Coefficient of Variation:		0.48					
Mann-Kendall Statistic (S):		-2					
Confidence Factor:		54.0%					
Concentration Trend:		Stable					



Notes:

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3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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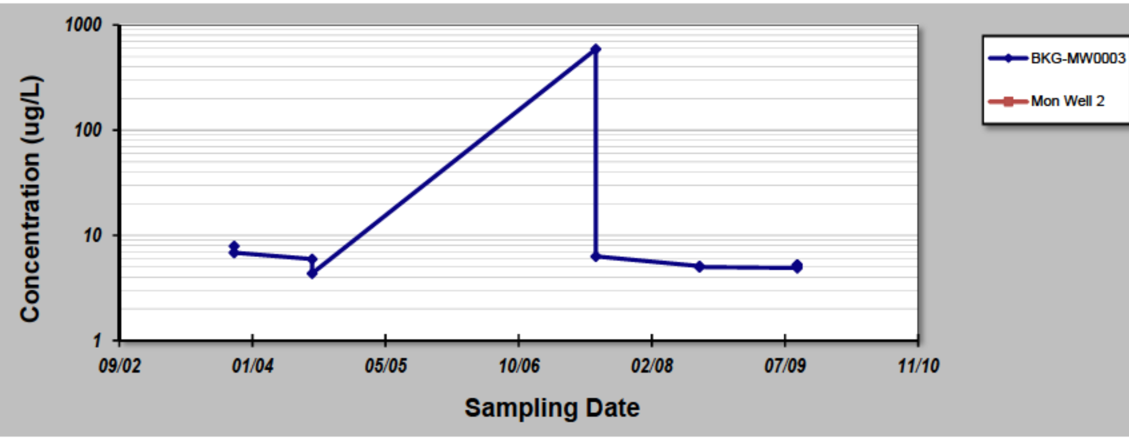
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	BKG-MW0003	Mon Well 2					
		TOTAL U CONCENTRATION (ug/L)						
1	06-Nov-03	7.90						
2	06-Nov-03	6.84						
3	25-Aug-04	5.95						
4	25-Aug-04	4.34						
5	27-Jul-07	589.00						
6	27-Jul-07	6.31						
7	19-Aug-08	5.11						
8	19-Aug-08	5.00						
9	21-Aug-09	4.89						
10	21-Aug-09	5.26						
11	21-Aug-09	5.17						
12	21-Aug-09	5.21						
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		1.22						
Mann-Kendall Statistic (S):		70						
Confidence Factor:		98.8%						
Concentration Trend:		Increasing						



Notes:

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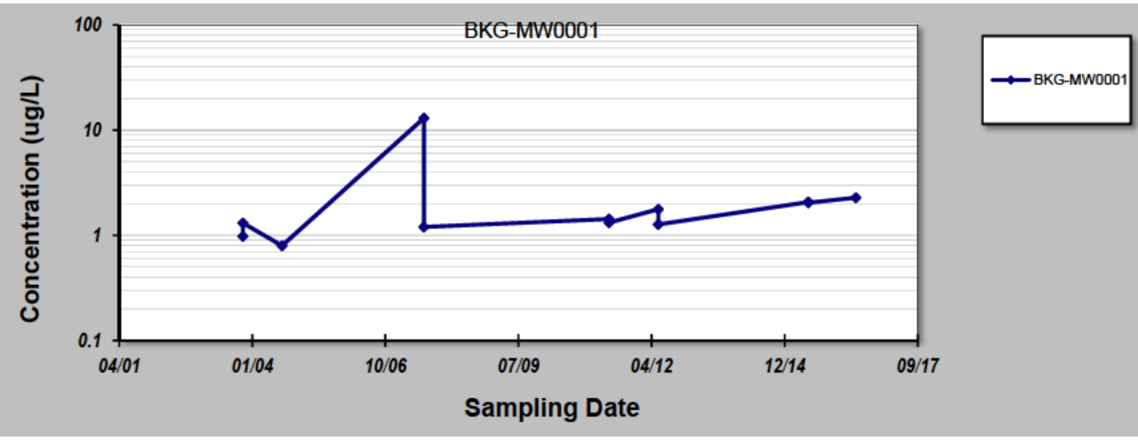
Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Point ID: BKG-MW0001

Sampling Event	Sampling Date	TOTAL U CONCENTRATION (ug/L)						
		BKG-MW0001						
1	04-Nov-03	0.98						
2	04-Nov-03	1.31						
3	24-Aug-04	0.80						
4	26-Jul-07	13.00						
5	26-Jul-07	1.20						
6	17-May-11	1.43						
7	17-May-11	1.32						
8	22-May-12	1.77						
9	22-May-12	1.27						
10	23-Jun-15	2.07						
11	23-Jun-15	2.04						
12	14-Jun-16	2.28						
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.94						
Mann-Kendall Statistic (S):		86						
Confidence Factor:		>99.9%						
Concentration Trend:		Increasing						



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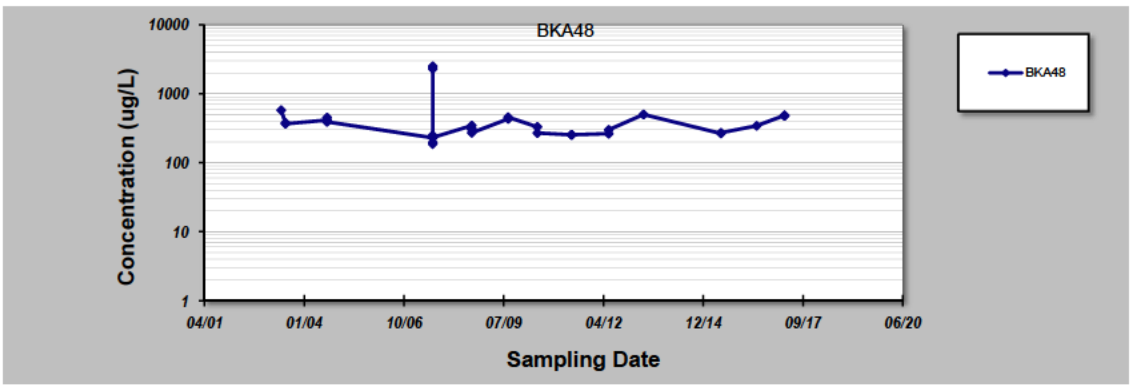
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	2-Aug-16	Job ID:	N/A
Facility Name:	Harshaw Site	Constituent:	Total U
Conducted By:	Guckin	Concentration Units:	ug/L

Sampling Event	Sampling Date	BKA48						
		TOTAL U CONCENTRATION (ug/L)						
1	28-May-03	578.00						
2	10-Jul-03	378.38						
3	10-Jul-03	367.00						
4	30-Aug-04	414.41						
5	30-Aug-04	453.00						
6	30-Aug-04	391.00						
7	25-Jul-07	230.00						
8	25-Jul-07	2300.00						
9	25-Jul-07	2500.00						
10	25-Jul-07	196.40						
11	25-Jul-07	187.09						
12	25-Jul-07	249.25						
13	25-Jul-07	232.00						
14	19-Aug-08	345.35						
15	19-Aug-08	312.31						
16	19-Aug-08	305.00						
17	19-Aug-08	271.00						
18	20-Aug-09	432.43						
19	20-Aug-09	457.00						
20	08-Jun-10	330.33						
21	08-Jun-10	270.00						
22	17-May-11	253.75						
23	17-May-11	254.00						
24	23-May-12	263.96						
25	23-May-12	300.00						
26	07-May-13	501.00						
27	23-Jun-15	265.00						
28	23-Jun-15	272.00						
29	14-Jun-16	343.00						
30	21-Mar-17	486.00						
31	21-Mar-17	478.00						
32								
33								
34								
35								
Coefficient of Variation:		1.11						
Mann-Kendall Statistic (S):		-17						
Confidence Factor:		60.6%						
Concentration Trend:		No Trend						



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APPENDIX C

CUYAHOGA RIVER MODELING

TABLE OF CONTENTS

1. CUYAHOGA RIVER MODELING

1.1 INTRODUCTION

This appendix to the Former Harshaw Chemical Company Site Feasibility Study (FS) Addendum (FSA) presents a riverbank stability assessment of the Cuyahoga River and Big Creek waterways. An existing Hydrologic Engineering Center Water Hydraulic Modeling System (HEC-HMS) model of the Cuyahoga Basin was used to estimate the near-site hydrograph associated with five annual exceedance probabilities: 10-, 2-, 1-, 0.2-, and 0.1-percent (10-, 50-, 100-, 500-, and 1,000-year) storms. An existing Hydrologic Engineering Center Water Surface Profile System (HEC-2) hydraulic model of river system geometry became input to the Hydrologic Engineering Center River Analysis System (HEC-RAS) model of river reaches along the Harshaw Site. These coupled watershed and river models simulated steady flows, estimated water surface elevations, and determined shear stresses on the riverbank along the site for each storm event.

A geographic information system used to render the inundation surfaces also defined the extent of local floodplains. A stable channel analysis then determined the representative stone particle size (d_{50}) required to prevent erosion. This stable channel analysis provided preliminary shear stresses from multiple frequency storms and design recommendations for erosion protection. The modeling did not estimate sediment or bank erosion volumes from the site during storm events but provides shear stress information, which shows the susceptibility of the Cuyahoga River banks to erosion. This information is important when considering FS Alternative 2 (Limited Action), since contamination would remain in place proximal to the river.

2. HYDRAULIC AND HYDROLOGIC SIMULATIONS

2.1 HYDRAULIC MODEL

An existing HEC-2 model of the Cuyahoga River, which was used previously for a Cuyahoga County Flood Insurance Study (USACE March 2016), was imported into HEC-RAS (Version 4.1) to simulate channel geometry. Bridge geometry used in HEC-2 was modified for compatibility with HEC-RAS; aerial photos were used to estimate the flow obstructions due to the bridge piers. Results from the updated HEC-RAS model were comparable to the output from HEC-2 model (i.e., water surface elevations were similar). The HEC-RAS was augmented with the geometry of two near-site bridges to simulate existing conditions in the Cuyahoga River; these new bridges had been built after the development of the HEC-2 model. The HEC-2 geometry also was converted from National Geodetic Vertical Datum (NGVD) 1929 elevations to a North American Vertical Datum (NAVD) 1988 by subtracting 0.7 feet (ft) (i.e., NGVD 29 – 0.7 = NAVD 88) (Federal Emergency Management Agency 2010).

The Harshaw Site is located along the left overbank (or industrial plateau) of the Cuyahoga River between river stations 37832 and 33832 (Figures C-1 and C-2). The river stations marked in orange are interpolated river stations (50 ft apart) that were added to the original HEC-2 geometry since the river stations near the Harshaw Site are approximately 1,000 ft apart.

2.2 HYDROLOGIC MODEL

The hydrologic model of the Cuyahoga River Watershed, developed in 2010 using HEC-HMS software, was calibrated to a June 2006 storm event and validated against a May 2004 storm event. Consequently, this model estimated watershed flows from the five frequency-based hypothetical storms traversing the basin. A frequency-based storm defines an event for which the precipitation depth for different durations within the storm have a consistent annual exceedance probability (USACE-HEC, 2000). Flows from each frequency-based storm became input data (hydrographs) for a steady flow analysis in HEC-RAS. Precipitation data of each frequency storm were acquired from the National Oceanic and Atmospheric Administration Atlas 14.

The peak discharges for each storm are listed below:

Table C-1. Event Discharge

Annual Exceedance Probability (percent)	Discharge (cfs)
10	12,813
2	22,332
1	27,911
0.2	44,230
0.1	53,056

2.3 STEADY FLOW ANALYSIS

Surface water accumulations and flows from the Cuyahoga River watershed for each of the frequency storms were input to a HEC-RAS steady flow analysis to estimate water surface elevations and shear stresses near the Harshaw Site. Steady-flow simulations performed for each frequency storm estimated water surface elevations that delineated the flood plain of each storm. The maximum shear stress near the Harshaw Site became the critical stress to determine the type of erosion protection to generally protect the left bank and overbank along the site. The next section provides detailed information about the preliminary stable channel design.

2.4 STABLE CHANNEL DESIGN

The steady-flow analysis estimated a maximum shear stress of approximately 2.77 lb/ft^2 during the one-percent annual exceedance probability (100-year) storm along the main channel of Cuyahoga River near the Harshaw Site. The HEC-RAS estimates the shear stress at the channel with the following equation:

$$\tau = \gamma R_{CH} S_f \qquad (1.1)$$

Where:

τ = Shear stress per unit wetted area
γ = Unit weight of water
R_{CH} = Hydraulic radius of the main channel
S_f = River channel slope

Equation 1.1 is the same equation used in the tractive force method for stable channel design (USACE-HEC 2010). This method utilizes a critical shear stress to define when the initiation of motion begins, or the point at which the channel becomes unstable, or when the tractive forces are no longer in equilibrium with friction forces. Equation 1.1 also represents the shear stress on the channel bed when the bed width-to-water depth ratio (B/D) is greater than 10, which occurs in some Cuyahoga River segments along the Harshaw Site. As the channel becomes narrower and more trapezoidal, the shear stress (or average tractive force over a wetted area) becomes non-uniform (USACE-HEC 2010). Therefore, the maximum tractive force (or shear stress) is less than the tractive force predicted by equation 1.1. Lane (1953) determined experimental reduction factors for trapezoidal channels; Figure C-3 exemplifies the adjustment factors on side channel slopes and channel bottom.

Figure C-4 illustrates the channel cross section and water surface elevation for the 1-percent annual exceedance probability (100-year) event at River Station 36622. This cross section experiences a maximum shear stress of 2.77 lb/ft^2 within the channel. The left bank side slope is approximately 1V:2H and the B/D ratio is about 2. The adjustment factor on the side slope will be 0.76 based on Figure A-3 (see yellow circle). Therefore, the maximum shear stress on the left bank slope produced by the 100-yr event is approximately 2.11lb/ft^2. The same analysis can be applied to bottom stresses, which for the same river station produce an adjustment factor of 0.89 (see orange circle on Figure C-3) and corresponding maximum shear stress of 2.47 lb/ft^2.

The adjusted bank and bed stresses for the five storm simulations are summarized below:

Table C-2. Shear Stress for Storm Events

Annual Exceedance Probability (percent)	Riverbank Side Slope Shear Stress (lb/ft^2)	Channel Bed Shear Stress (lb/ft^2)
10	1.61	1.89
2	1.94	2.27
1	2.11	2.47
0.2	1.19	1.39
0.1	1.22	1.43

The left-bank sheer-stress results were then input to the Shields method (Shields 1936) that determined a representative median particle size (d_{50}) for riprap to protect the left bank from erosion. This method is commonly used to determine the initiation of particle motion via the relationship between the shear Reynolds number (Re^*) and the critical mobility parameter (θ_{cr}) (USACE-HEC, 2010). Figure C-5 shows the Shield's Diagram (Gessel 1971) and the critical mobility parameter is:

$$\theta_{cr} = \frac{\tau_{cr}}{(\gamma_s - \gamma)d} \qquad (1.2)$$

Where:
γ_s = Unit weight of particles
γ = Unit weight of water
d = d_{50} (representative particle size)
τ_{cr} = critical shear stress

This analysis used the following quantitative assumptions:

- Unit weight of particles is 2.65 grams/centimeter^3 (165 lb/ft^3).
- Unit weight of water is 1.0 grams/centimeter^3 (62.4 lb/ft^3).
- The Reynolds number is 500 (values greater than 500 cause viscous forces to have no effect on the shearing forces).

The resulting Shields critical mobility parameter is 0.055. It was used to determine particle size requirements for each storm event included in the analysis. The recommended representative particle size derived from this input and a critical shear stress of 2.11 lb/ft^2 is approximately 120 mm (4.7 inches). Shear stresses from the other frequency storms are below 2.11 lb/ft^2, and the resulting resistive stone sizes follow.

Table C-3. Stone Sizes for Bank Protection

Annual Exceedance Probability (percent)	Shear stress on riverbank (lb/ft^2)	Stone size for bank protection (mm)	Stone size for bank protection (in)
10	1.61	90	3.4
2	1.94	110	4
1	2.11	120	4.7
0.2	1.19	70	2.5
0.1	1.22	70	2.6

The water inundation areas for the 2-, 1-, 0.2-, and 0.1-percent storm events (50-, 100-, 500-, and 1,000-year storms) are shown on Figures C-6, C-7, C-8, and C-9, respectively. Since the inundation areas for the 10-percent (10-year) and 2-percent (50-year) storms are similar, Figure C-6 also represents the 10-year event results. The 1-percent annual exceedance probability (100-year storm) event does not reach the left overbank or industrial plateau (Figure C-7), although the 0.1- and 0.2-percent annual exceedance (1,000- and 500-year events) will inundate portions of Operable Unit 1 (OU-1). The maximum shear stress on the left Cuyahoga River overbank (or the industrial plateau of OU-1) is approximately 0.4 lb/ft^2 and 0.6 lb/ft^2 during the 500-year and 1,000-year events, respectively (Figure C-9). A protective particle size of 25.4 mm (or 1-inch gravel) would inhibit erosion of unpaved site areas during such events.

2.5 SURFACE WATER MODELING CONCLUSION AND RECOMMENDATIONS

The hydrologic and hydraulic analyses described in this report indicate the maximum shear stress on the left bank along the Harshaw Site will be 2.11 lb/ft^2 during the 1-percent annual exceedance probability (100-year) event. This includes the bank segments where Manhattan Engineer District (MED)-related contamination exists within 30 feet of the bank. The Cuyahoga River overbank at the Harshaw Site (or the OU-1 plateau) will experience a maximum shear stress of 0.6 lb/ft^2 during the 0.1-percent annual exceedance probability (1,000-year event).

The representative particle sizes that would resist erosion at these shear stresses are 130 mm (5 inches) for the bank and 25 mm (1 inch) for the uplands of OU-1.

This erosion protection measure will be acceptable for existing conditions and as a cover for post-excavation conditions associated with the waste removal alternatives. However, during excavation work, other measures to protect the excavation from erosion during a large storm event would be incorporated into the remedial design for such alternatives.

3. EROSION DISCUSSION

The current conditions derived from the industrial development of the floodplain underlying the Harshaw Site also created subsurface soils that consist of one-half to one-third fill. The low to moderate flow elevation for the Cuyahoga River and Big Creek along the site is 575 ft (Figure C-10), which presents geologic cross sections of the site with river stages for specific storm events, most notably the 1-percent annual exceedance probability (100-year flood) elevation of 588 ft. This figure also outlines the area of groundwater impacts near former Building G-1.

Using Figure C-10 as a guide, the fill and native sediments between the groundwater impacts and Cuyahoga River provide an erosion buffer that will limit the discharge the high-concentration groundwater to the river. The historical site riverbanks, prior to industrial development (see native alluvium on Figure C-10), appear to be ubiquitous above the normal flow stage of 575 ft. This indicates that a mature floodplain and stable banks bordered the river before site development. In addition, the alluvium blankets bedrock along the flanks of the bedrock mound under the site, which indicates past river conditions and associated flood stages did not scour the native site soils to bedrock (i.e., native soils were resistant to flood-related scouring).

Should site erosion occur unabated (e.g., site-owner maintenance ends), the likeliest equilibrium channel would erode fill materials to the native alluvium until predevelopment conditions reestablish. The USACE believes this natural riverbank would follow the 575-ft elevation contour (or normal river level) along the surface of the alluvium. This condition would place the MED-related contamination in the northeastern corner of OU-1 in an area susceptible to erosion. Consequently, FS Alternative 2 (Limited Action) will require riverbank protection along the contamination area using a minimum of 130-mm (5-inch) diameter riprap. To ensure long-term protection and conservative designs, additional stone should be applied along the riverbank both upstream and downstream of the contamination area (nominally 50 ft in each direction and keyed into the bank to ensure long-term protection).

The other excavation-based FS alternatives (Alternatives 3 and 4) would remove the bulk of contamination in the northeastern corner of OU-1 and thus not require riverbank protections beyond common vegetative restoration once the remedy is complete.

To assess whether the probable erosion and reestablishment of a natural channel would affect residual groundwater contamination near former Building G-1, the groundwater model was configured to mimic the likely riverbank extent. Appendix B of the FSA presents the analysis that indicates a reestablished natural channel would not impact the fate of groundwater contamination near former Building G-1 (i.e., the uranium plume would not impact river water quality due to the low uranium flux compared to river flows). Consequently, FS Alternatives 3 and 4 will not require riverbank protection to limit soil or groundwater discharge to the river.

Irrespective of the selected remedy, the USACE assumes that five-year site inspections (per the CERCLA five-year review process) would document site erosion and prompt owner-initiated riverbank stabilization to prevent site property loss to the Cuyahoga River.

4. CONCLUSIONS

The greatest bank erosion potential occurs during the 1-percent annual exceedance event (100-year storm event), while the 0.1-percent annual exceedance probability event (1,000-year event) may erode exposed surface soils in OU-1. FS Alternative 2 would require bank protection (riprap) along the Cuyahoga River near the northeastern contaminated area and gravel cover over contaminated surface soils exposed on the OU-1 plateau during the 1,000-year performance period associated with FUSRAP-related monitoring. Feasibility study Alternatives 3 and 4 (soil removal alternatives) will not require erosion protections since the contaminant removal mitigates the risk of release to the environment via erosion, and the groundwater model indicates site erosion will not significantly affect the river water quality via uranium plume transport.

The risk of erosion under Alternative 2 is mitigated using erosion prevention measures that include rock structures keyed into the bank using stone gradations that are at least 5 inches in diameter. In addition, exposed site soils contaminated with MED-related constituents would be protected by covering the areas with 1-inch (or greater) diameter gravel. A design level analysis would be required to accurately size and configure the optimal erosion protection solutions, should they be required in the future.

FIGURES

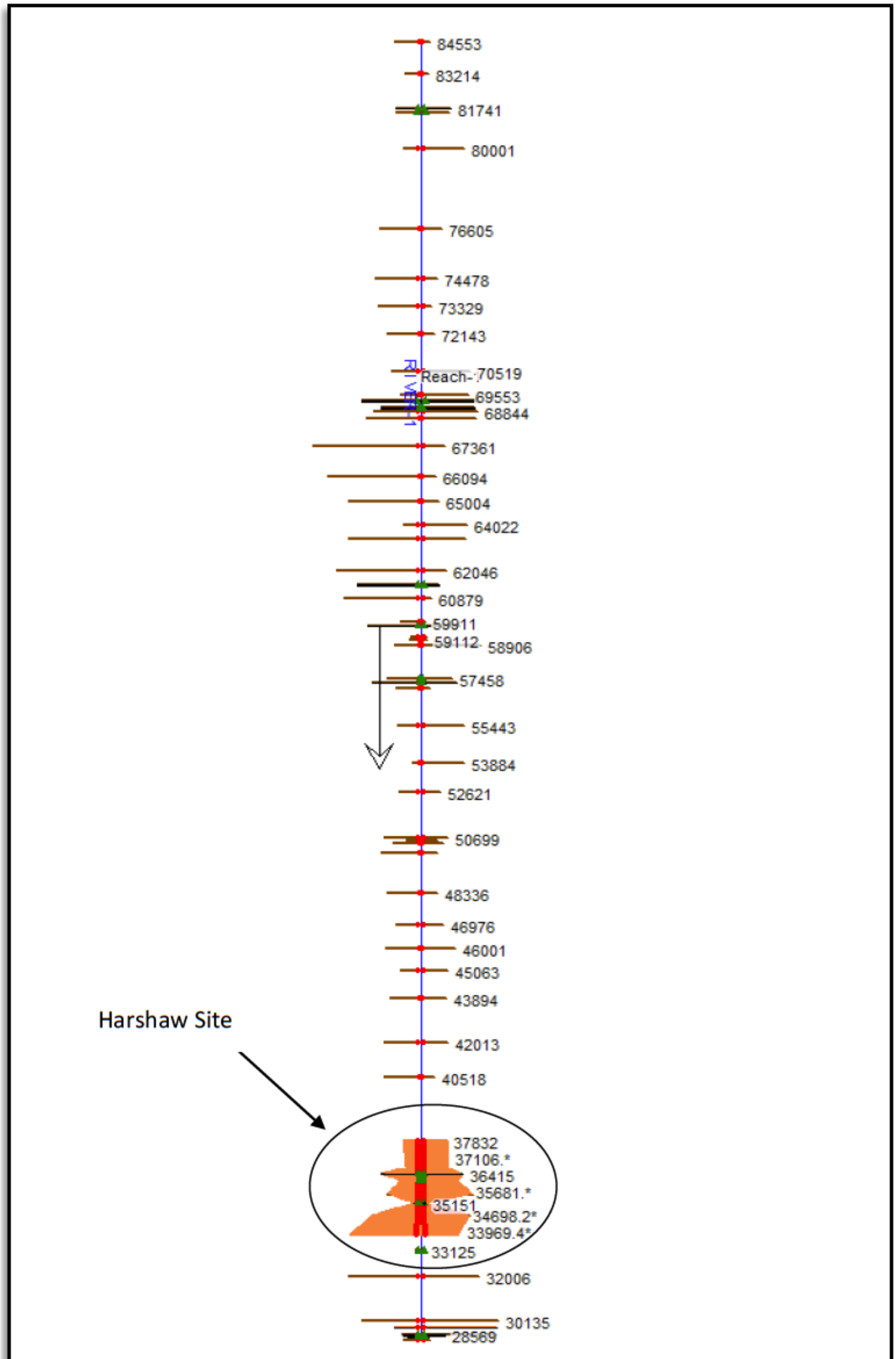

Figure C-1. Cuyahoga River HEC-2 Geometry

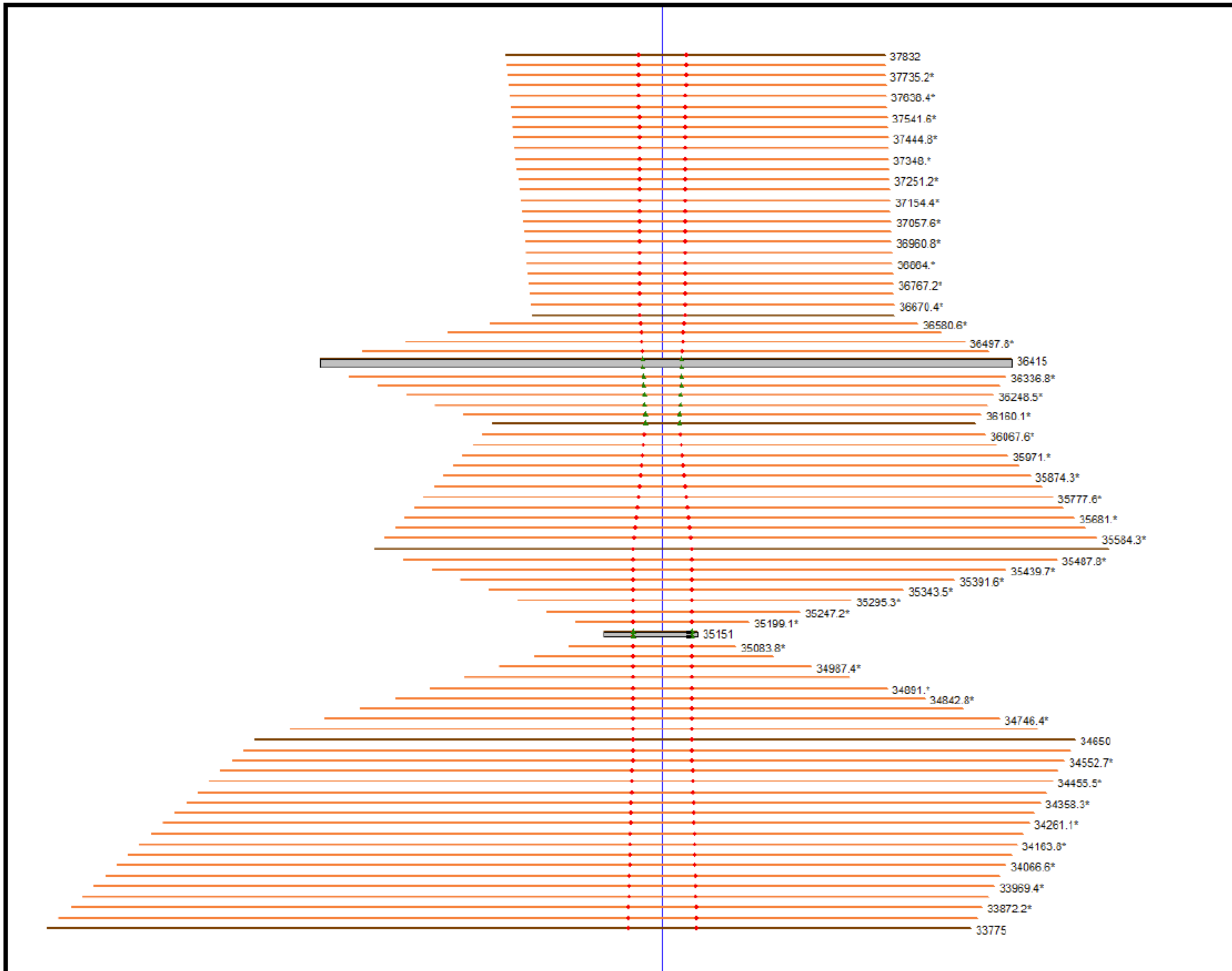

Figure C-2. River Stations Near the Harshaw Site

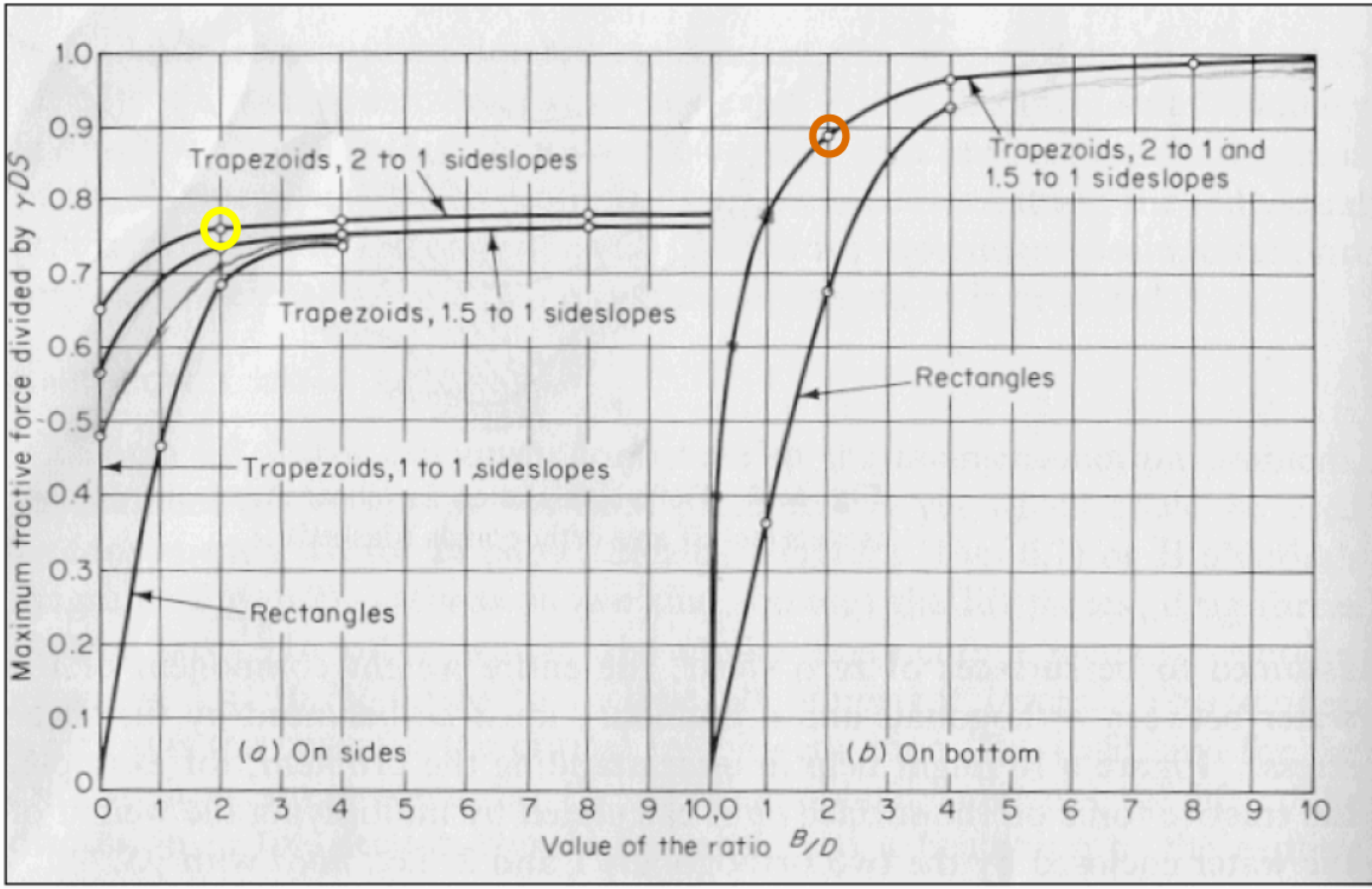

Figure C-3. Maximum Shear Stress in a Channel (Lane, 1953).

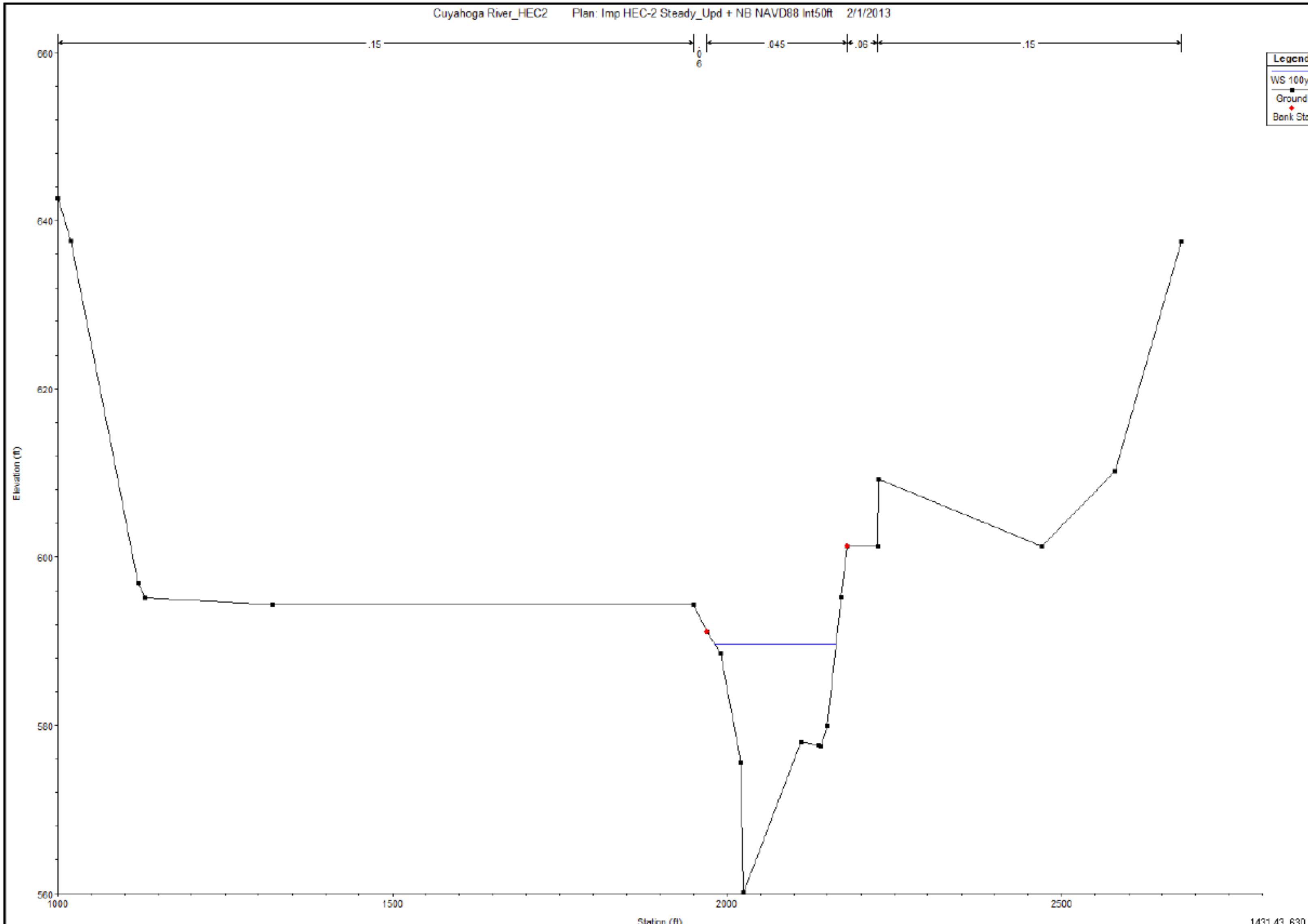

Figure C-4. Cross Section of River Station 36622.

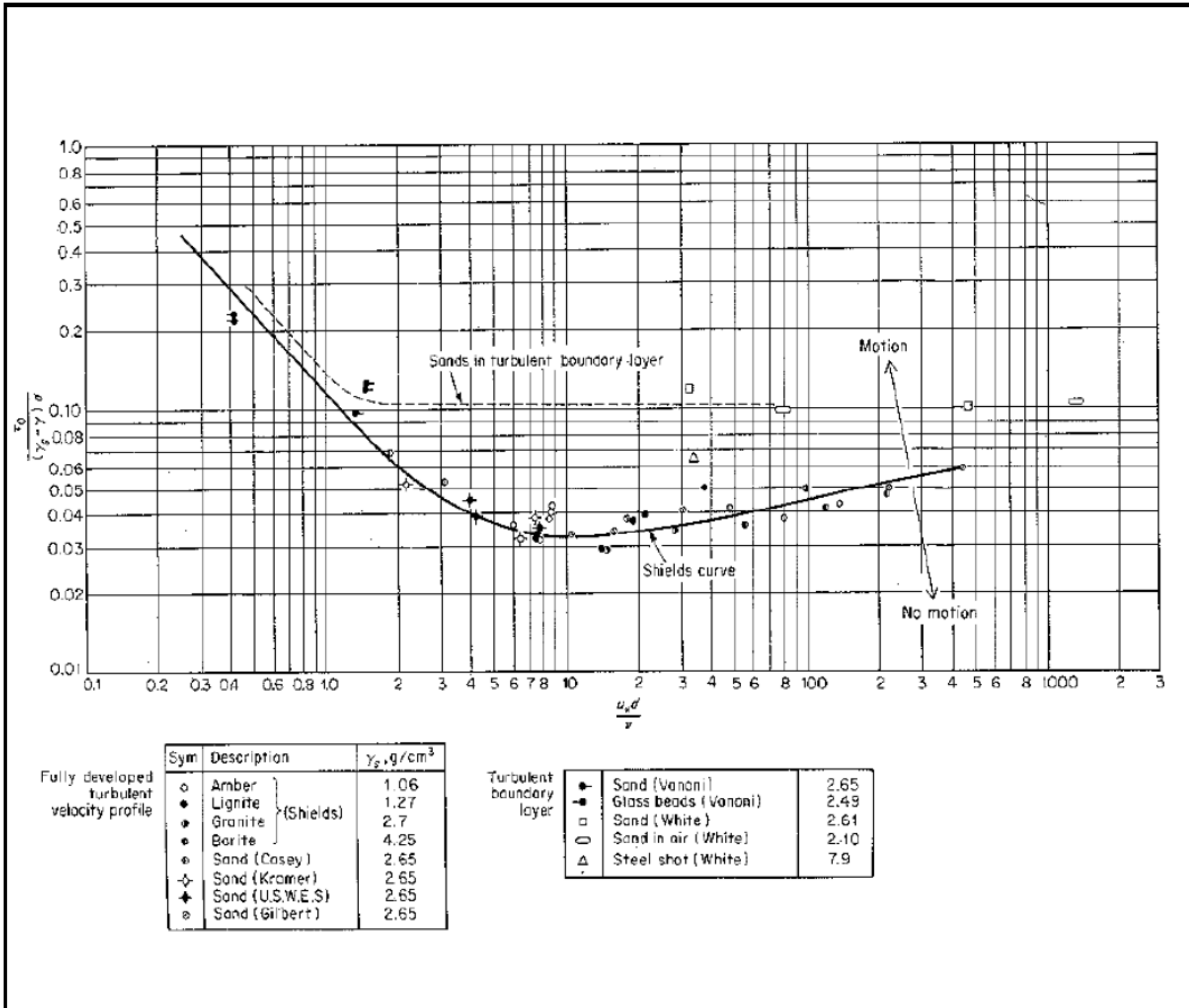

Figure C-5. Shield's Diagram (Gessler, 1971).

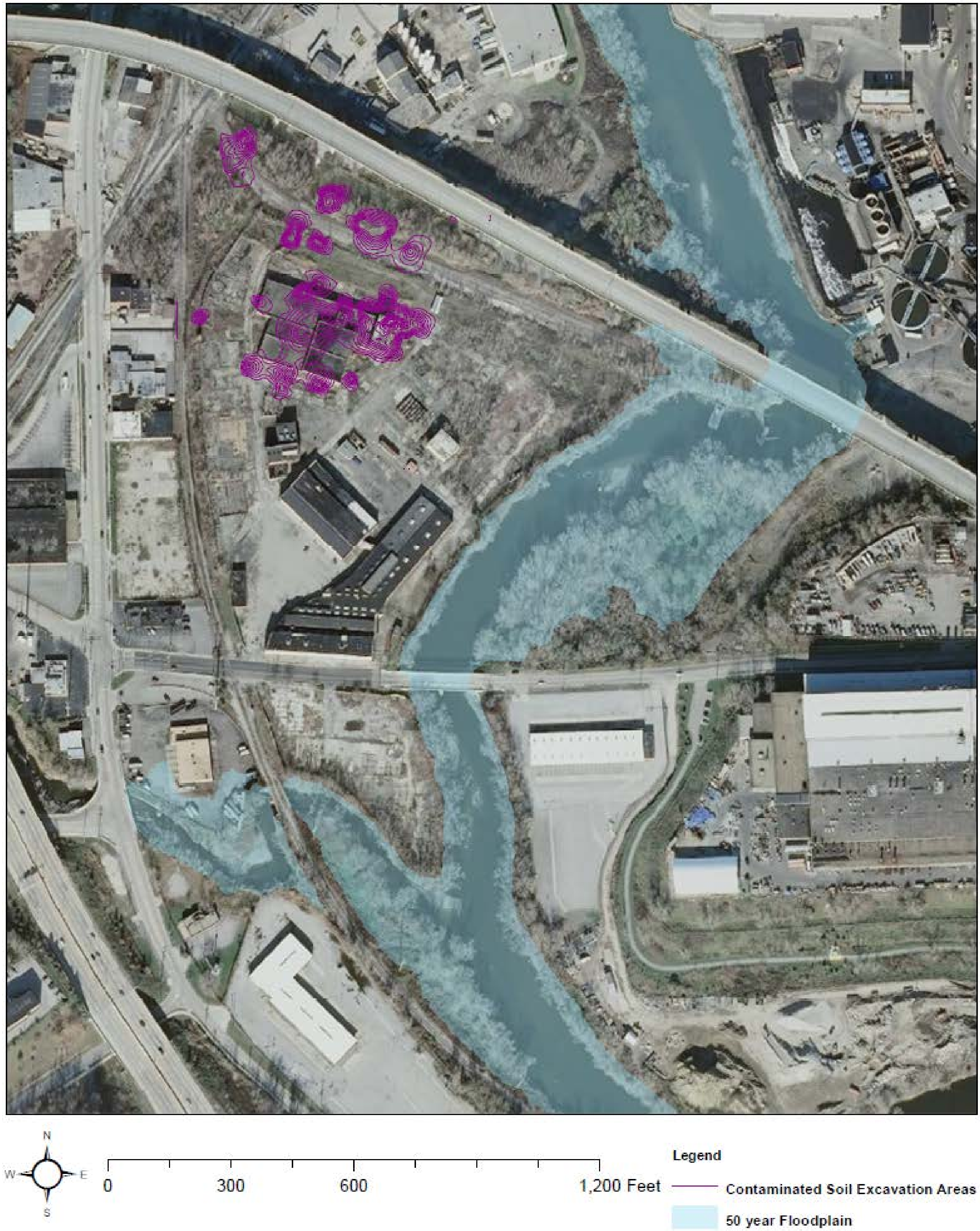

Figure C-6. 50-year Flood Plain.

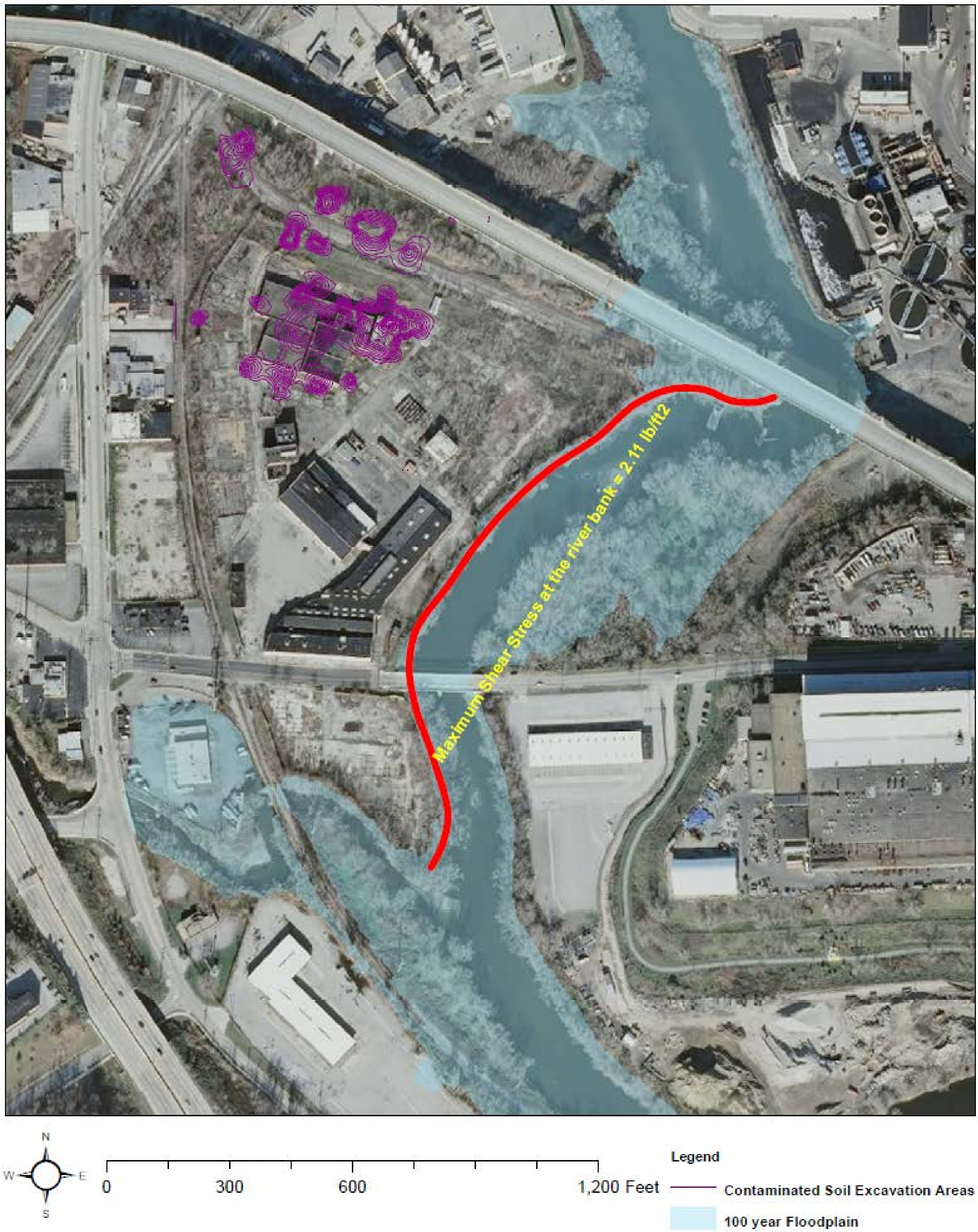

Figure C-7. 100-year Flood Plain.

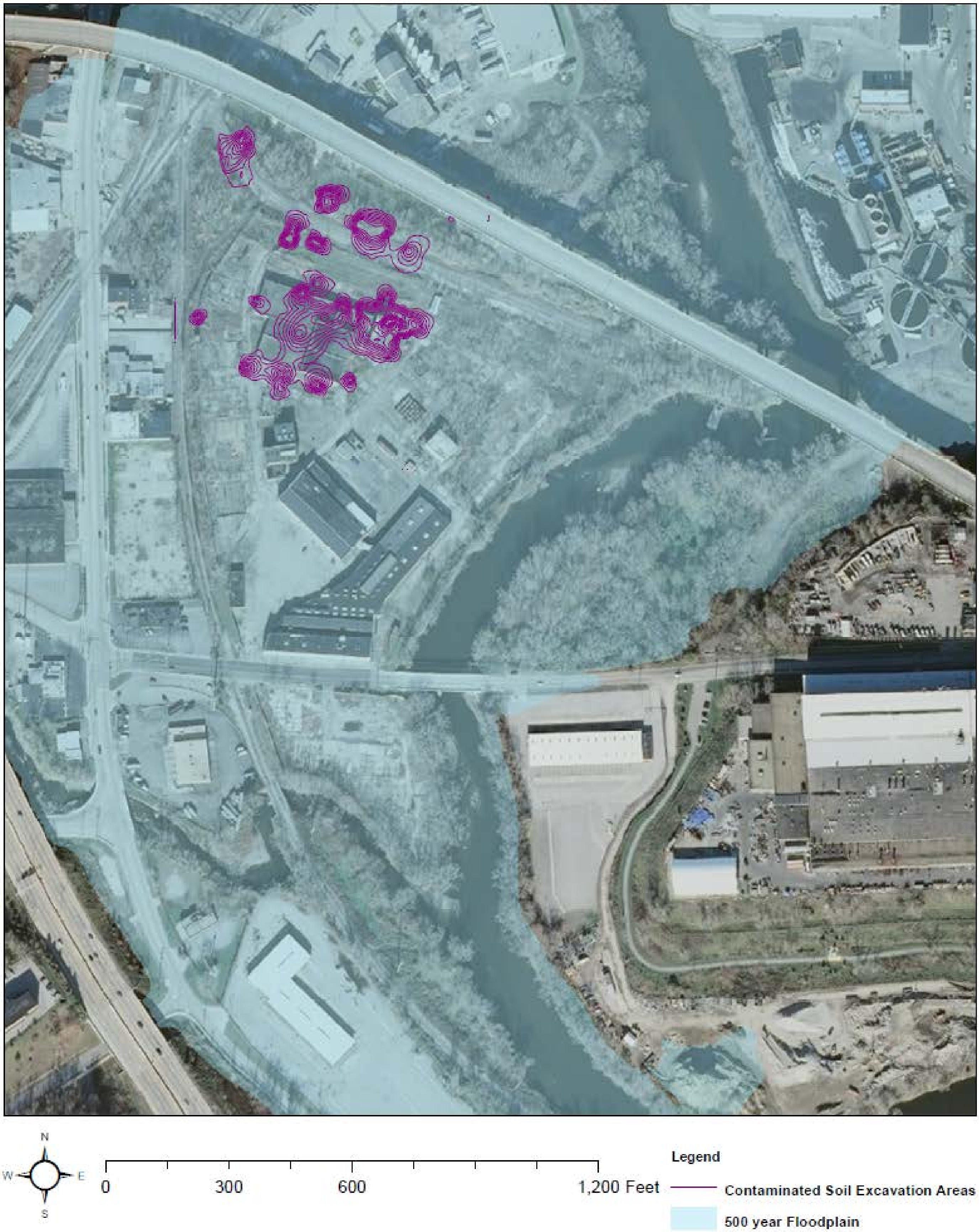

Figure C-8. 500-year Flood Plain.

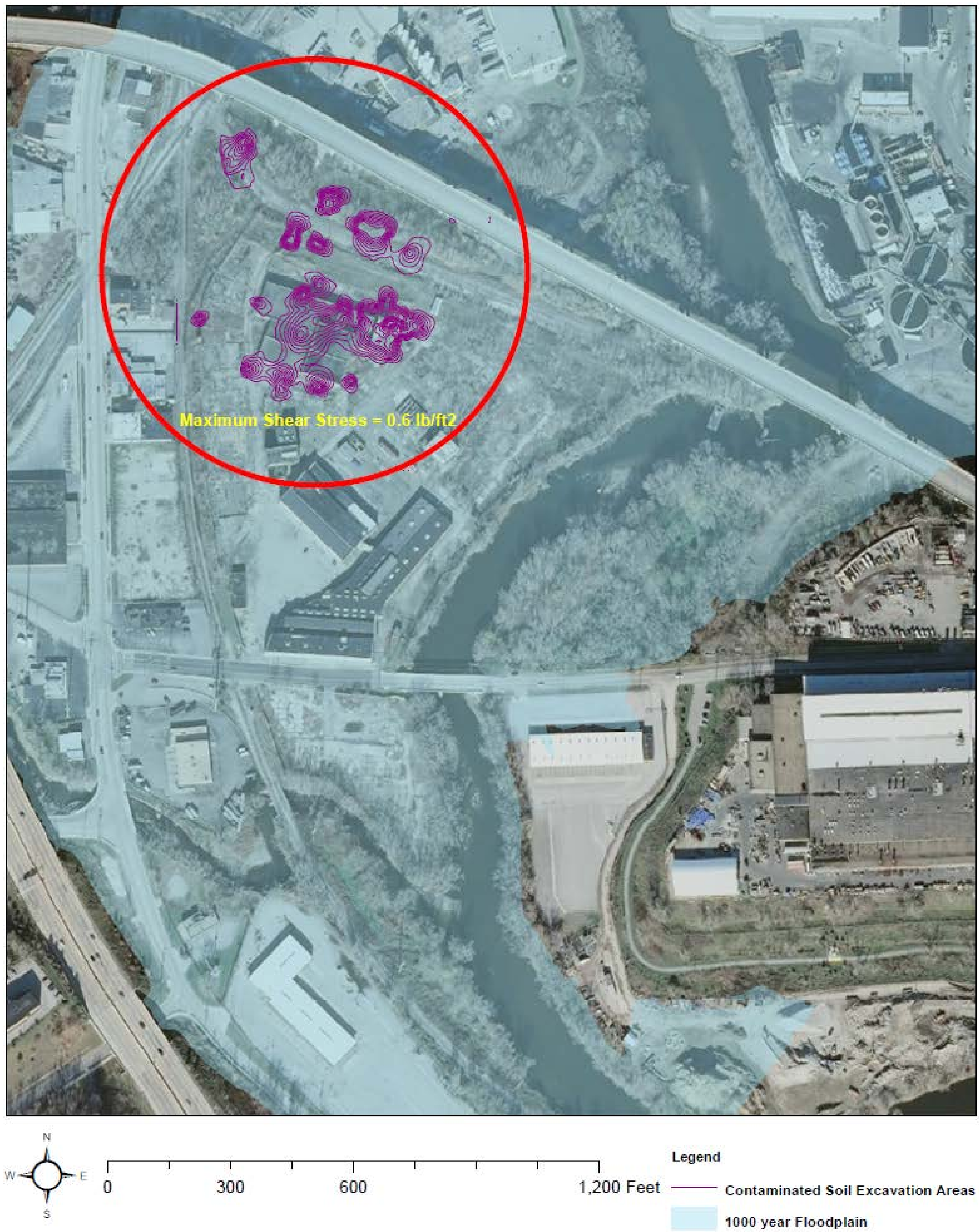

Figure C-9. 1,000-year Flood Plain.

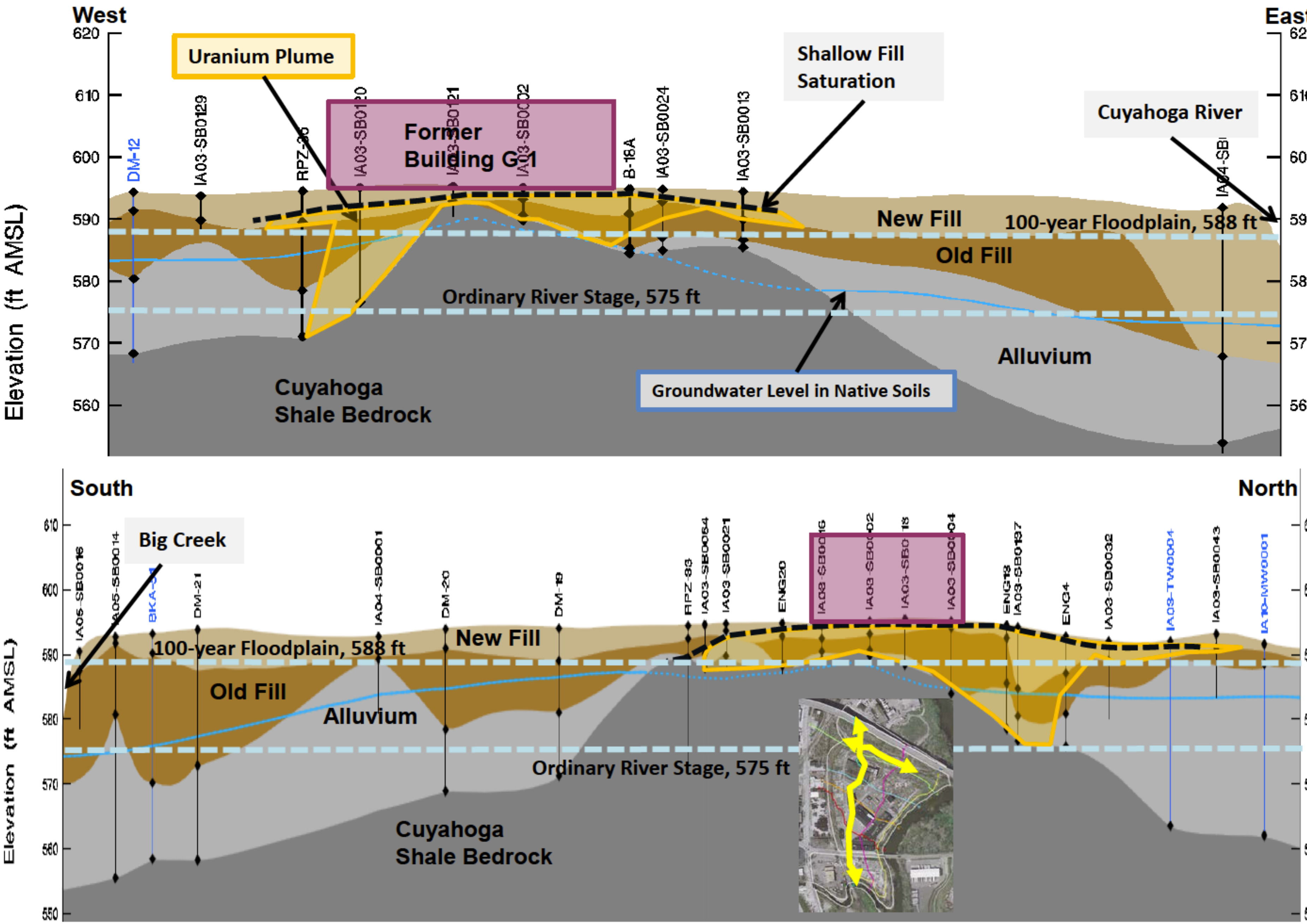

Figure C-10. Geologic Cross Sections Through G-1 Area and Cuyahoga River

APPENDIX D

CUYAHOGA RIVERBANK ASSESSMENT

Harshaw Chemical Site Visit

Cuyahoga River Bank Assessment

November 13, 2014

1.0 Introduction

The USACE - Buffalo District sent several environmental, hydraulic and geotechnical professionals to investigate bank stability of the Cuyahoga River and Big Creek adjacent to the former Harshaw Chemical Company property on 13 November 2014. This FUSRAP site is located northeast of Jennings Rd and Harvard Ave; south of Cleveland, Ohio. The Cuyahoga River flows north and borders the eastern portion of the property while Big Creek borders the south and empties into the Cuyahoga. The inspection team investigated the left river banks by walking along the crest in and outside the property's fence line and by viewing the bank from adjacent bridges, opposite banks and from a small boat on the river and creek. The objectives of this site visit was to 1) identify bank erosion or sloughing that may compromise the stability of the banks supporting the Harshaw FUSRAP site and 2) identify surface runoff points or seepage that may lead to bank erosion in the future.

The Site Map included as Appendix A indicates areas A through H to better convey the findings of the field inspection. Some of the areas identified are linear and encompass stretches of bank that are relatively consistent, whereas others are point specific locations of concerns. The site inspection started from the northeast corner of the former Harshaw Chemical Company property, follows the Cuyahoga River upstream on the left bank and turns at the confluence with Big Creek to follow the left bank of Big Creek, which is the Southern edge of the Harshaw property. The inspection ended at the existing Rail Road tracks in southwest corner of the area of interest. Areas A through H are also labeled to reflect the photos included in Appendix B.

2.0 Geotechnical

Area A was a significant concern during the field visit due to the large localized area of sloughing due to river erosion. Pictures of this sloughing can be observed in Figures 1 through 4 in Appendix B. Close up inspection of the area showed that the bank material is most likely silty sand FILL with embedded pipes and wooden beams protruding through the eroded, shear, side slope, and miscellaneous brick and stone with embedded wire scattered within the vicinity. There was also a large concrete cylinder (as a bulk fill item) that had fallen into the river after the bank had eroded. A sinkhole was also present at the crest in this area (Figure 5) which hints that some subsurface piping has occurred and could be the result of differential settlement within the FILL subsurface stratum. At this time the rate of erosion does not seem to be alarming, but the area should be monitored to note further erosion.

Area B was very difficult to inspect due to the shallowness of the river and the lack of entry to walk along the crest. From the boat it was visible that large riprap had been placed at the toe to combat erosion and stabilize toe movement (Figures 9 through 11). The top of the bank also had indications of ground movement. Sinkholes on the Harshaw Chemical property (Figure 12 and 14) and a tilting fence line leaning towards the river (Figure 13) indicate the possibility of subsurface movement due to groundwater seepage through the FILL material. No major sloughing was identified in Area B, however there was limited access and high vegetation which made close up inspection difficult.

Area C was inspected to evaluate observed subsurface movement that caused a monitoring well to shear in 2007. Shown in Figures 17 through 22, Area C encompasses an "S-type" curve in the property's fence line. This area had an underground pipe that connected to a concrete outfall box which eventually overflowed and drained into the Cuyahoga River. The concrete outfall box was left in place at the toe of the "S-curve" when the aforementioned pipe was disconnected. The broken monitoring well is also in the vicinity, at the crest of the slope on the Harshaw Chemical property. Both of these entities are indicated on the site map. The monitoring well, seen in Figure 21, sheared off 15.18 feet below ground surface (17.61 feet below top of riser). The environmental team suspects that the disconnected outfall pipe had been leaking and created a slip surface plane within the FILL subsurface material. However, a subsurface cross section PDF provided in the HCC_FSA_Modeling_Figures_D1 document by the environmental department also depicts the natural water table at approximately 15 feet below the ground surface on the east side of the property. It is unknown if the area currently experiences ground movement, but riprap was placed just around the corner from the concrete outfall box prior to the Army Corps involvement with the site (pre 2003). The riprap is directly adjacent to the monitoring well (Figures 23 and 24) so an assumption can be made that the site has had seepage issues with this area in the past. It is recommended that continued observations be made in Area C since it has a history of movement.

Area D shows fill material dominates the bank in this reach. Make-shift riprap from old bridge parts and random blocks of stone secure the left bank's toe (Figure 30 and 31). Minor sloughing was also visible and can be seen in Figures 27 and 28. From the top of the river bank, the northern section of the reach had a double fence (Figure 33). The new fence was erected about 10 years ago and was to replace the original, rusted fence that had started to tilt towards the river. Since the northern area is directly adjacent to the Area C, it may have incurred some of its subsurface movement. The southern region of Area D still has the original fence and major subsurface movement does not seem to be an issue.

Area E was identified during the boat inspection. This area showed significant paths where runoff was extremely evident based on eroded areas. Refer to Figure 34 to see the extent of erosion due to water coming out of the outfall on the river bank. Upon further inspection, it looks like the erosion was from an old outfall pipe (outfall #6) which has since been sealed (see Figure 35). Although the pipe's runoff may not affect this area anymore, the bank slope still consists of debris and FILL, and may need to be dressed with structural FILL in order to prevent further erosion. Also, major sloughing was identified at the crest (Figure 37 and 38). There is only one fence and it is not currently failing, however continued sloughing due to erosion in this area may affect the structural stability of the fence.

Area F was fairly intact. This area along the southern tip of Harshaw Chemical seemed to have less random debris and FILL along the bank, and has no toe stability measures once you get south of the

Harvard Ave bridge abutment. The major issues would be toe erosion (figures 41 and 46) and some sloughing at the crest where old rail-tie stairs occurred (Figures 48 and 49). There is little room between the crest and Harshaw's property fence line, however major signs of erosion were not found.

Area G had an extremely steep left bank slope along Big Creek. Ground material was also very soft and there was little room when walking on the exterior Harshaw fence line and the crest of the bank. No major issues or concerns to be monitored were identified in this region. Refer to Figures 52 and 53 for this area.

Area H shows some sloughing along the mid to upper section of the left bank (figure 56), but toe erosion seemed to be the bigger factor. Some debris seems to be used as toe stability closest to the railroad abutment. However, directly adjacent to the area, significant toe erosion is present. Refer to Figures 54, 56 and 57 for photos of the area. It appears that the toe is eroding and will soon be undercutting a portion of the slope.

3.0 Hydraulic &Hydrology

The former Harshaw Chemical Company site is very flat consisting of mostly paved or previously paved surfaces with little to no areas of ponding observed and few signs of overland flow. The left bank has an established vegetative cover, which contributes to stability. The left bank (supporting bank to the Harshaw property) is on the outside of a bend and located between two bridges therefore shear stresses on this bank are likely to be higher. From the Harvard Avenue Bridge looking downstream, the bank appears to be relatively stable with some minor erosion 1-2 feet above the water surface, which is derived from scour during high-water events. The left bank of both Big Creek and Cuyahoga River are very steep, so erosion caused by high water events is expected.

Area A was of specific concern due to the close proximity to known soil contamination. Observations from inside the Harshaw property show few signs of overland flow from the site itself. An adjacent access road along the Northeast border of the site was very wet during the time of inspection and erosion from overland flow was evident under the Denison Ave Bridge north of Area A. Also, as can be seen from the site map and figure 1.1, where there is a large obstruction in the Cuyahoga River adjacent to the northeast corner of the property; this obstruction will cause a backwater effect during storm events raising water elevations allowing banks to become saturated increasing their potential to erode.

The riffles observed in Area B (Figures 9 and 10) indicate there is a change in streambed slope and an increase in water velocities, the higher velocities will cause higher friction forces to act on the stream banks which could lead to an increase in erosion potential. The banks have been reinforced with riprap along Area B, although where the riffles end, the riprap protection has been washed out and some minor undercutting is present (figure 10).

Area C is a designed outfall from the Harshaw Property (figures 18-19); the underground pipe directing flow to this outfall box has been disconnected, however there are still obvious signs of use. This area has a well established vegetative cover so the erosion is relatively minimal and the outfall pipe is surrounded by a reinforced sheetpile wall to support the bank around the outfall. Although this area is an obvious point of use directing flow from the property, it does not appear to be in extreme disrepair or threatening to the integrity of the banks.

Area D has some signs of undercutting that could have been caused by high water events or by sloughing. The bank still has well established trees, which will help stabilize the bank. This area also has improvised riprap and thus is known for erosion.

Area E is the section of bank that will absorb and redirect the energy from the river to create the meander under the Denison Ave Bridge. This area is susceptible to erosion as it absorbs that energy, as can be seen from figure 34. This area is also the location of a second designed outfall from the Harshaw Property, which has been disconnected from any pipes directing flow from the site, but still provides an obvious point of runoff from the property.

Area F has some obvious signs of erosion along the banks caused by high water-surface elevations along the Cuyahoga. This is likely primarily due the impedance caused by the Harvard Ave Bridge as well as the additional flow from Big Creek. There are minimal to no signs of overland flow from the Harshaw property in this area, however several pipes exists that indicate storm water may have historically been directed through the bank via the pipes (figures 40-41).

Area G continues to have minimal signs of overland flow however there were several more pipes protruding from the banks similar to figure 41 of Area F.

Area H has notable signs of toe erosion likely caused by the impedance of the railroad bridge. As water contracts to flow under the bridge the velocities will increase, as it then expands on the downstream end of the bridge (Area H) the energy will be absorbed by the banks likely causing the toe erosion present.

4.0 Conclusions

After a full investigation of the river banks adjacent to Harshaw Chemical property, there do not seem to be any immediate concerns. It is recommended the entire site be monitored occasionally, with closer monitoring to Areas A and C. Area A is of greatest concern due to close proximity of the eroded bank to on-site subsurface contamination. This location will be monitored on a routine basis (when staff are performing tasks at the site) to ensure the bank loss does not encroach on the contaminated area.

Appendix A:

Site Map

Figure 1: Site Map of the former Harshaw Chemical Company property with areas identified during the 13 November 2014 site visit

Appendix B:

Pictures

(Nov. 13, 2014 site visit)


Figure 1: Area A viewed from opposite bank


Figure 1.1: Obstruction Impeding Cuyahoga River Downstream of Area A

Figure 2: Area A looking upstream from the left bank

Figure 3: Area A looking upstream; zoomed in on the eroded area

Figure 4: Area A with [redacted]

Figure 5: Possible sinkhole near the crest of the left bank in Area A; outside of property line

Figure 6: Area A crown width from the Property fence line to the slope; approximately 5 ft

Figure 7: Area A looking downstream

Figure 8: Area B looking at the northern end form the opposite bank.


Figure 9: Area B viewed from the opposite bank


Figure 10: Area B from the boat; looking downstream at the bank

Figure 11: Area B, viewed from the boat

Figure 12: Area B; one of a few sinkholes in the Northeast area in Harshaw Chemical property

Figure 13: Area B; property fence line tilting to the river along the crest

Figure 14: Area B; sinkhole/depression adjacent to the property fenceline

Figure 15: Area B; anomaly in the river bank. Possibly old boat launch

Figure 16: View of the southern end of Area B from the boat

Figure 17: Area C viewed from the opposite river bank

Figure 18: Area C viewed from the boat; view of sheet pile and concrete outfall box

Figure 19: View of the outfall box and runoff path from the boat for Area C

Figure 20: Area C viewed from the boat


Figure 21: View of Area C from Harshaw Chemical property; looking north at the old monitoring well


Figure 22: View of the runoff area from outfall box in Area C; viewed from Harshaw Chemical property

Figure 23: Northern area of Area D viewed from the boat

Figure 24: Northern area of Area D viewed from the boat; misc riprap prior to 2003

Figure 25: Area D viewed from the boat; looking upstream

Figure 26: Area D viewed from the boat

Figure 27: Area D; signs of sloughing and a steep slope

Figure 28: View of Area D from the Harvard Ave Bridge

Figure 29: Area D viewed from the boat

Figure 30: Southern end of Area D viewed from the Harvard Ave Bridge

Figure 31: Whole view of Area D from the Harvard Ave Bridge; looking downstream

Figure 32: Area D; view of crest from the Harshaw Chemical Property to show how close fence line is to the slope

Figure 33: Area D; view of the double fence line at the crest of the slope due to the old fence tilting towards the river


Figure 34: Area E; Old outfall 6 which is currently sealed; viewed from the boat

Figure 35: View of sealed outfall 6 in Area E

Figure 36: Area E viewed on the slope; depicts the debris and rubble on the left bank slope around the outfall

Figure 37: Area E; sloughing at the crest of the river bank

Figure 38: Area E; minimal distance between Harshaw Chemical Property fence line and slope.

Figure 39: Northern End of Area F under the Harvard Ave Bridge; looking downstream

Figure 40: Viewing outfall 5 from the boat in Area F

Figure 40.1: Outfall pipe

Figure 41: Northern end of Area F showing erosion at the toe


Figure 42: View of Area F from the boat


Figure 43: Area F; toe erosion and some mid-bank sloughing

Figure 44: Area F viewed from the boat

Figure 45: Area F; Erosion at the toe viewed from the boat


Figure 46: View of Area F; looking upstream


Figure 47: View of Area F from the boat; looking upstream


Figure 48: Area F; at the crest, failing stairs and tilting fence line due to soil sloughing

Figure 49: Soil sloughing at the crest of the river bank at the Harshaw Chemical fence line

Figure 50: Area F; picture showing the crest width between the Harshaw Chemical fence line and the top of slope

Figure 51: Area G; looking upstream of the Cuyahoga River from the Southern point of the Harshaw Chemical property at the convergence with Big Creek


Figure 52: Area G along Big Creek; depicting the steep slope and the small width at the crest along the Harshaw Chemical fence line.


Figure 53: Area G looking downstream on Big Creek; slope view

Figure 54: Viewing Area H (left bank) from the rail road track bridge; looking downstream on Big Creek

Figure 55: View of left bank slope in Area H closest to the rail road bridge abutment

Figure 56: Area H from the rail road bridge; showing toe erosion

Figure 57: Area H; Toe erosion

Figure 58: Area H; shows toe erosion and bank sloughing

APPENDIX E

TABLES

Table 1. Changes to Existing Soil Sample Points for Contaminated Soil Volume Estimation

Location ID	Issue between Previous and Current Volume	Max SOR	Feasibility Study Hit Value	Proposed Hit Value	Rational
All	**Nondetect values are set to 0 for SOR calculations**	**--**			
IA03-SB0152	Previous volume did not use 09/06/07 data, which had SOR >1		0	1	Sample Hierarchy
IA03-SB0018	Was set to Hit 1 due to proximity to NBH22 (SOR>1), data was complete	0.104	1	0	Consistency with rational provided in feasibility study section 2.2.1.2
IA03-SB0016	Was set to Hit 1 due to proximity to NBH107 (SOR>1), data was complete	0.135	1	0	Consistency with rational provided in feasibility study section 2.2.1.2
IA03-SB0037	Was set to Hit 1 due to proximity to NBH37 (SOR>1), data was complete	0.043	1	0	Consistency with rational provided in feasibility study section 2.2.1.2
IA03-SB0006	Previous SOR < 1 due to not including TH-230 129.7509 pCi/g @ 0-2 below ground surface	4.485	0	1	Consistency with rational provided in feasibility study section 2.2.1.2
BEGE-SB0017	Was set to Hit 1 due to proximity to ABH224 (SOR>1), data was complete	0.297	1	0	Consistency with rational provided in feasibility study section 2.2.1.2
BEGE-SB0018	Was set to Hit 1 due to proximity to ABH224 (SOR>1), data was complete	0.151	1	0	Consistency with rational provided in feasibility study section 2.2.1.2
BEGE-SB0013	Was set to Hit 1 due to proximity to BEGE-SB0011 & IA03-SB0038 (SOR>1), data was complete	0.299	1	0	Consistency with rational provided in feasibility study section 2.2.1.2
BEGE-SB0014	Was set to Hit 1 due to proximity to BEGE-SB0011 & IA03-SB0038 (SOR>1), data was complete	0.182	1	0	Consistency with rational provided in feasibility study section 2.2.1.2
IA03-SB0153	SOR 0.51 was not included as 0.75 Hit	0.51	0	0.75	Consistency with rational provided in feasibility study section 2.2.1.2
IA05-SB0032	SOR 0.549 was not included as 0.75 Hit	0.549	0	0.75	Consistency with rational provided in feasibility study section 2.2.1.2
IA05-SB0035	SOR 0.611 was not included as 0.75 Hit	0.611	0	0.75	Consistency with rational provided in feasibility study section 2.2.1.2
IA03-SB0125	SOR 0.086 was not included as 0.75 Hit	0.86	0	0.75	Consistency with rational provided in feasibility study section 2.2.1.2

SOR = Sum of Ratios

Table 2. Estimated Contaminated Soil Volume Summary

Parameter	Cubic Yards		
	OU-1	OU-2	Total
excavation volumes			
in situ soil	6,962	647	7,608
in situ soil with swell (25 percent)	8,702	808	9,510
cutback	1,195	-	1,195
cutback soil with swell (25 percent)	1,493	-	1,493
Total Soil Excavation	10,195	808	11,004
Debris	1,654	269	1,922
off-site disposal volumes			
rad disposal	3,263	364	3,627
mixed waste disposal	1,088	40	1,128
off-site debris	827	134	961
Debris—rad disposal	620	121	741
mixed waste—debris disposal	207	13	220
Total off-site disposal (all types)	5,178	538	5,716
backfill volumes			
in situ used as backfill	2,175	202	2,378
cutback used as backfill	1,493	-	1,493
debris used as backfill	413	67	481
Total on-site backfill	3,669	202	3,871
soil remains on-site (not backfill)	2,175	202	2,378
debris remains on-site (not backfill)	413	67	481

Table 3. 2015 Soil Sampling Results

Parameter			RADIUM-226	RADIUM-228	THORIUM-228	THORIUM-230	THORIUM-232	URANIUM-234	URANIUM-235	URANIUM-238
Units			PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G
Analytical Method Code			E901.1	E901.1	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300
Location	Depth (ft)	Date								
G-1-01	1-2	4/27/2015	1.371	-	1.34	1.19	0.759	5.65	0.412	5.43
G-1-01	2-3	4/27/2015	1.634	-	0.914	1.23	0.995	3.88	0.171	3.88
G-1-01	7-8	4/27/2015	1.912	-	1.49	1.44	1.44	2.55	0.076	2.84
G-1-02	0-1	4/28/2015	1.16	-	0.753	1.75	0.654	3.26	0.161	3.44
G-1-02	6-7	4/28/2015	1.885	-	1.18	1.25	1.14	1.23	0.18	1.18
G-1-02	7-8	4/28/2015	2.046	-	1.23	1.23	1.27	1.29	0.082	1.28
G-1-03	0.5-2	4/21/2015	1.622	-	1.30	1.93	0.927	499	26	484
G-1-03	2.5-3.5	4/21/2015	1.526	-	1.12	1.24	1.03	26	2.00	26
G-1-03	4-5	4/21/2015	1.887	-	1.40	1.27	1.22	2.71	0.252	2.68
G-1-04	1-2	4/20/2015	1.17	-	0.644	0.72	0.409	16	0.99	16
G-1-04	3-4	4/20/2015	2.113	-	1.02	2.35	1.26	314	19	320
G-1-04	13-14	4/20/2015	1.881	-	1.70	2.00	1.19	4.56	0.223	4.17
G-1-05	0-1	2/10/2015	2.094	0.775	0.941	0.907	0.659	8.82	0.603	8.84
G-1-05	8-9	2/10/2015	2.06	2.354	1.65	1.59	1.87	2.37	0.351	1.73
G-1-05	12-13	2/10/2015	1.739	2.369	1.34	1.75	0.991	1.68	0.108	1.49
G-1-06	0.5-2	4/28/2015	1.586	-	0.885	1.76	0.975	9.57	0.44	8.76
G-1-06	2-3	4/28/2015	2.17	-	1.09	1.25	1.11	12	0.569	12
G-1-06	13-14	4/28/2015	1.786	-	1.10	1.43	1.04	1.31	0.111	0.988
G-1-07	0-1	2/5/2015	16	1.936	0.733	247	1.21	190	11	191
G-1-07	5-6	2/5/2015	2.393	1.526	1.46	3.42	1.53	4.94	0.384	4.64
G-1-07	11-12	2/5/2015	2.112	2.03	1.22	1.70	0.812	2.16	0.153	1.81
G-1-08	0-1	2/5/2015	1.505	0.902	1.03	1.05	0.726	3.17	0.181	3.54
G-1-08	4-4.5	2/5/2015	2.329	2.54	1.71	5.24	1.68	4.71	0.338	3.59

Notes:

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- = not analyzed
ft = feet

E901.1 = Gamma Emitting Radionuclides in Water
HSL-300 = Beta Emitting Radionuclides in Water
pci/g = picocuries per gram

Table 3. 2015 Soil Sampling Results (Continued)

Parameter			RADIUM-226	RADIUM-228	THORIUM-228	THORIUM-230	THORIUM-232	URANIUM-234	URANIUM-235	URANIUM-238
Units			PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G
Filter			No	No	No	No	No	No	No	No
Analytical Method Code			E901.1	E901.1	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300
Location	Depth (ft)	Date								
G-1-08	8-9	2/5/2015	1.557	1.756	0.971	2.10	1.13	2.28	0.173	2.28
G-1-09	0-1.5	2/5/2015	1.26	1.007	0.525	1.28	0.70	7.10	0.498	6.64
G-1-09	12-13	2/5/2015	1.889	1.759	1.05	1.16	0.856	2.12	0.281	1.95
G-1-09	2-3	2/5/2015	2.028	1.332	0.845	1.64	0.985	33	1.84	33
G-1-10	0.5-1.5	4/21/2015	1.429	-	1.06	1.22	0.839	3.55	0.137	3.17
G-1-10	12-13.5	4/21/2015	1.529	-	1.21	1.31	0.956	1.32	0.111	1.14
G-1-10	3-4	4/21/2015	2.018	-	1.15	1.40	1.14	8.32	0.588	8.42
G-1-11	0-1	2/9/2015	0.608	0.629 U	0.597 U	1.11	0.497 U	0.877	0.102	0.615
G-1-11	1-2	2/9/2015	2.014	1.492	1.14	1.81	1.37	1.94	0.095	2.01
G-1-11	3-4	2/9/2015	1.833	1.72	1.63	1.56	1.43	1.67	0.131	1.40
G-1-12	0.5-2	4/28/2015	4.473	-	0.428	21	0.497	180	10	188
G-1-12	13-14	4/28/2015	1.248	-	1.79	1.18	1.46	1.20	0.055	1.22
G-1-12	6-7	4/28/2015	1.926	-	1.15	6.22	1.12	14	0.736	14
G-1-13	0.5-1.5	4/21/2015	1.992	-	1.18	1.48	1.12	5.13	0.187	4.96
G-1-13	12-13	4/21/2015	1.88	-	1.38	1.36	1.10	1.69	0.189	1.55
G-1-13	2-3	4/21/2015	1.493	-	1.55	1.62	1.28	1.92	0.104 U	2.20
G-1-14	0.5-2	4/22/2015	1.891	-	0.897	2.43	0.793	13	0.802	13
G-1-14	4-5	4/22/2015	2.369	-	1.35	1.52	1.16	1.36	0.093	1.21
G-1-14	9-10	4/22/2015	1.913	-	1.62	1.72	1.28	6.68	0.376	5.40
G-1-15	1-2	2/9/2015	1.658	1.604	1.28	1.25	0.982	4.53	0.244	4.09
G-1-15	13-14	2/9/2015	1.969	1.476	1.54	2.02	1.26	2.00	0.309	1.67
G-1-15	9-10	2/9/2015	2.172	1.549	1.22	1.68	1.42	1.64	0.076	1.82
G-1-16	0-1.5	4/22/2015	1.459	-	0.821	1.11	0.722	3.03	0.146	3.26

Notes:

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ft = feet

E901.1 = Gamma Emitting Radionuclides in Water
HSL-300 = Beta Emitting Radionuclides in Water
pci/g = picocuries per gram

Table 3. 2015 Soil Sampling Results (Continued)

Parameter			RADIUM-226	RADIUM-228	THORIUM-228	THORIUM-230	THORIUM-232	URANIUM-234	URANIUM-235	URANIUM-238
Units			PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G
Filter			No	No	No	No	No	No	No	No
Analytical Method Code			E901.1	E901.1	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300
Location	Depth (ft)	Date								
G-1-16	10-11.5	4/22/2015	1.666	-	1.75	1.32	1.15	1.69	0.146	2.48
G-1-16	6-7	4/22/2015	1.797	-	1.29	1.53	1.17	1.90	0.113	1.27
G-1-17	11-12	4/27/2015	1.762	-	1.39	1.29	1.23	1.52	0.102	1.12
G-1-17	1-2.5	4/27/2015	2.31	-	0.87	8.54	0.966	35	1.76	33
G-1-17	7-8.5	4/27/2015	2.019	-	1.31	1.60	1.10	1.37	0.089	1.54
G-1-18	0-1	4/27/2015	0.676	-	0.577	0.875	0.437	2.00	0.13	1.68
G-1-18	13-14	4/27/2015	1.949	-	1.53	1.28	1.16	1.24	0.054	1.29
G-1-18	6-7	4/27/2015	1.602	-	1.25	1.43	1.03	1.21	0.098	1.44
IA03-TW0005R	0.5-1.5	5/12/2015	1.182	-	1.50	1.74	0.72	51	3.28	51
IA03-TW0005R	3-4.5	5/12/2015	1.776	-	1.45	1.42	1.26	5.39	0.453	5.46
IA03-TW0005R	5-6	5/12/2015	1.618	-	1.29	1.55	1.09	1.83	0.072	1.59
IA03-TW0006R	0.5-1.5	5/12/2015	2.581	-	1.53	5.10	1.22	134	8.23	141
IA03-TW0006R	10-11.5	5/12/2015	1.876	-	1.42	1.82	1.03	5.40	0.603	5.13
IA03-TW0006R	2-3	5/12/2015	1.987	-	1.30	18	0.551	404	20	411
RB-01	0-0	8/24/2015	1.656	-	0.901	1.21	1.06	0.935	0.084	0.953
RB-02	0-0	8/24/2015	1.627	-	0.915	1.15	0.918	1.13	0.032	1.16
RB-03	0-0	8/24/2015	1.573	-	1.01	1.45	0.978	1.03	0.073	0.955
RB-04	0-0	8/24/2015	1.182	-	0.953	0.904	0.708	9.14	0.448	8.79
RB-05	0-0	8/24/2015	1.347	-	0.475	0.855	0.484	3.23	0.131	3.08
RB-06	0-0	8/24/2015	1.677	-	0.752	1.36	0.217	3.08	0.174	3.22
RB-07	0-0	8/24/2015	1.184	-	0.947	0.905	0.93	2.08	0.131	2.01
RB-08	0-0	8/24/2015	1.492	-	0.798	0.928	0.598	7.48	0.459	7.68
RB-09	0-0	8/24/2015	1.325	-	1.27	1.60	1.01	4.34	0.249	4.94

Notes:

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E901.1 = Gamma Emitting Radionuclides in Water
HSL-300 = Beta Emitting Radionuclides in Water
pci/g = picocuries per gram

Table 3. 2015 Soil Sampling Results (continued)

Parameter			RADIUM-226	RADIUM-228	THORIUM-228	THORIUM-230	THORIUM-232	URANIUM-234	URANIUM-235	URANIUM-238
Units			PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G
Analytical Method Code			E901.1	E901.1	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300
Location	Depth (ft)	Date								
RB-10	0-0	8/24/2015	0.862	-	0.763	0.917	0.754	0.902	0.089	0.688
RB-11	0-0	8/24/2015	1.262	-	0.76	0.608	0.626	2.65	0.12	2.14
RB-12	0-0	8/24/2015	1.299	-	0.921	0.67	0.779	0.872	0.047	0.873
SB-01	2-3	5/8/2015	1.836	-	0.968	1.34	0.989	3.69	0.154	2.74
SB-02	1-2	5/7/2015	1.50	-	0.929	1.38	1.06	3.48	0.11	3.39
SB-03	5-6.5	5/7/2015	2.562	-	1.68	1.88	1.58	1.34	0.054	1.54
SB-04	0-1	5/7/2015	1.748	-	1.15	1.72	0.998	16	0.937	17
SB-05	0-1	5/8/2015	2.087	-	0.954	2.26	0.775	6.45	0.395	7.00
SB-05	20-21	5/8/2015	1.873	-	1.04	1.27	1.20	1.33	0.082	1.24
SB-05	4-5	5/8/2015	2.30	-	1.53	1.83	1.40	1.75	0.10	1.92
SB-06	0-1.5	5/8/2015	2.286	-	0.737	2.24	0.847	3.66	0.138	3.65
SB-06	10-11.5	5/8/2015	1.474	-	0.988	1.25	1.08	1.42	0.111	1.33
SB-06	5-6	5/8/2015	2.457	-	1.66	1.72	1.11	1.93	0.18	1.80
SB-07	5-6	5/7/2015	2.272	-	1.39	1.67	1.05	1.67	0.067	1.63
SB-08	0-1.5	5/7/2015	1.553	-	1.16	1.37	1.17	2.06	0.224	2.10
SB-09	0-1	5/7/2015	0.89	-	0.564	1.18	0.39	8.44	0.409	8.21
SB-10	0-1	5/7/2015	2.486	-	1.03	2.44	0.849	16	0.615	15
SB-11	0-1.5	5/7/2015	1.176	-	0.614	1.27	0.416	18	1.04	19
SB-11	13-14	5/7/2015	2.115	-	1.24	1.44	0.961	1.50	0.044	1.65
SB-11	4-5.5	5/7/2015	2.386	-	1.43	1.84	1.02	1.82	0.139	1.67
SB-12	0-1	5/20/2015	1.414	-	0.985	1.44	0.836	36	2.17	37
SB-12	4-5.5	5/20/2015	1.696	-	1.75	1.22	1.61	1.59	0.192	1.70
SB-12	5.5-6.5	5/20/2015	1.472	-	1.28	1.06	1.87	1.30	0.086	1.17

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ft = feet

E901.1 = Gamma Emitting Radionuclides in Water
HSL-300 = Beta Emitting Radionuclides in Water
pci/g = picocuries per gram

Table 3. 2015 Soil Sampling Results (Continued)

Parameter			RADIUM-226	RADIUM-228	THORIUM-228	THORIUM-230	THORIUM-232	URANIUM-234	URANIUM-235	URANIUM-238
Units			PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G
Analytical Method Code			E901.1	E901.1	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300
Location	Depth (ft)	Date								
SB-13	4-5	5/7/2015	2.331	-	1.13	1.40	1.15	1.51	0.034	1.40
SB-14	2-3	5/20/2015	2.089	-	1.54	5.88	0.899	50	3.18	50
SB-14	10-11	5/20/2015	2.773	-	1.12	1.49	1.06	3.52	0.312	3.14
SB-14	16-17	5/20/2015	2.098	-	0.867	1.55	1.03	1.33	0.168	1.05
SB-15	2-3	5/20/2015	2.282	-	1.01	1.74	0.907	44	2.11	44
SB-15	11-12	5/20/2015	1.918	-	1.37	1.15	1.10	1.47	0.143	1.79
SB-15	16-17	5/20/2015	1.957	-	1.48	1.19	1.08	1.60	0.075	1.66
SB-16	5-6	5/7/2015	2.427	-	1.44	2.44	1.39	126	8.82	124
SB-17	2-3	5/20/2015	1.763	-	1.20	1.46	1.13	6.57	0.439	5.87
SB-17	3-4	5/20/2015	2.71	-	1.05	31	1.10	125	6.29	118
SB-17	16-17.5	5/20/2015	2.261	-	1.16	1.38	1.10	2.68	0.274	2.49
SB-18	1-1.5	5/20/2015	2.016	-	1.29	1.32	1.17	2.16	0.19	2.21
SB-18	3-4.5	5/20/2015	2.023	-	1.44	1.09	0.992	1.40	0.087	1.45
SB-18	4.5-5.5	5/20/2015	1.568	-	1.19	1.19	1.48	1.11	0.096	0.984
SB-19	1-2	5/20/2015	1.842	-	1.20	1.45	1.15	6.16	0.513	6.26
SB-19	4-5	5/20/2015	1.889	-	1.23	1.29	1.01	2.79	0.258 U	3.49
SB-19	6-7.5	5/20/2015	1.932	-	1.48	1.25	1.01	1.09	0.123	1.63
SB-20	0-1	5/4/2015	2.313	-	1.01	2.17	0.769	11	0.564	11
SB-20	10-11	5/4/2015	2.321	-	1.59	1.84	1.42	1.31	0.075 U	1.10
SB-20	6-7.5	5/4/2015	1.954	-	1.21	1.18	1.17	1.50	0.035	1.39
SB-21	0.5-2	5/4/2015	1.945	-	1.02	1.32	0.914	3.84	0.184	3.65
SB-22	0-1	5/4/2015	2.379	-	1.25	2.37	1.01	4.03	0.19	3.74
SB-22	20-21	5/4/2015	1.734	-	1.12	1.49	1.01	2.16	0.158	2.48

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ft = feet

E901.1 = Gamma Emitting Radionuclides in Water
HSL-300 = Beta Emitting Radionuclides in Water
pci/g = picocuries per gram

Table 3. 2015 Soil Sampling Results (Continued)

Parameter			RADIUM-226	RADIUM-228	THORIUM-228	THORIUM-230	THORIUM-232	URANIUM-234	URANIUM-235	URANIUM-238
Units			PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G
Filter			No	No	No	No	No	No	No	No
Analytical Method Code			E901.1	E901.1	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300
Location	Depth (ft)	Date								
SB-22	9-10.5	5/4/2015	1.482	-	0.879	0.842	0.85	34	1.67	34
SB-23	0-1	5/4/2015	2.46	-	0.953	1.90	1.00	4.24	0.227	3.92
SB-23	12-13	5/4/2015	1.595	-	0.681	1.02	0.685	45	3.51	49
SB-23	23-24	5/4/2015	1.879	-	1.45	1.47	1.32	1.70	0.155	1.68
SB-24	7-8	5/6/2015	1.975	-	1.21	1.53	1.01	1.69	0.081	1.68
SB-25	5-6	5/4/2015	1.948	-	1.19	1.60	1.28	3.11	0.154	2.31
SB-26	4-5	5/5/2015	2.349	-	1.32	1.84	1.39	1.54	0.121	1.23
SB-27	6-7.5	5/5/2015	1.512	-	1.28	1.45	1.38	1.78	0.057	1.38
SB-28	6-7	5/5/2015	1.741	-	1.19	1.19	1.14	1.20	0.081	1.39
SB-29	5-6	5/5/2015	2.361	-	1.31	1.91	1.14	1.38	0.102	1.52
SB-30	5-6.5	5/5/2015	1.627	-	1.41	1.24	1.19	0.892	0.121	1.10
SB-31	0-1	5/28/2015	3.513	-	3.16	3.40	3.14	3.13	0.211	3.14
SB-32	6-7	5/5/2015	2.041	-	1.41	1.49	1.16	1.82	0.271 U	1.62
SB-33	0-1	5/5/2015	1.51	-	0.672	1.03	0.572	1.67	0.088	1.57
SB-34	0-1	5/15/2015	2.412	-	1.33	2.41	1.05	2.39	0.048	2.91
SB-34	12-13	5/15/2015	1.529	-	1.60	1.37	1.43	1.31	0.053	1.13
SB-34	29-30	5/15/2015	1.093	-	0.729	0.728	0.741	1.09	0.058	1.04
SB-35	4-5	5/5/2015	2.52	-	1.07	1.85	0.827	6.19	0.341	6.23
SB-36	0-1	5/8/2015	3.095	-	1.24	2.08	1.08	2.79	0.193	2.77
SB-36	2-3	5/8/2015	0.128	-	0.098	0.078 U	0.068 U	0.065	0.081 U	0.072
SB-36	25-26	5/8/2015	1.282	-	1.04	1.02	0.775	0.983	0.045	0.753
SB-37	0-1	5/14/2015	1.528	-	1.23	1.72	0.826	35	2.01	37
SB-37	19-20	5/14/2015	1.487	-	1.22	1.21	1.13	1.32	0.122	1.37

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E901.1 = Gamma Emitting Radionuclides in Water
HSL-300 = Beta Emitting Radionuclides in Water
pci/g = picocuries per gram

Table 3. 2015 Soil Sampling Results (Continued)

Parameter			RADIUM-226	RADIUM-228	THORIUM-228	THORIUM-230	THORIUM-232	URANIUM-234	URANIUM-235	URANIUM-238
Units			PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G
Analytical Method Code			E901.1	E901.1	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300
Location	Depth (ft)	Date								
SB-37	26-27	5/14/2015	1.271	-	1.11	0.974	0.907	1.50	0.119 U	1.13
SB-38	0-1	5/11/2015	1.568	-	0.515	1.09	0.46	4.92	0.207	4.93
SB-38	20-21.5	5/11/2015	1.068	-	1.20	1.07	0.936	2.01	0.21	1.95
SB-38	29-30	5/11/2015	0.869	-	0.578	0.76	0.461	0.482	0.12 U	0.357
SB-39	0-1	5/14/2015	1.426	-	0.764	1.35	0.751	9.94	0.66	9.76
SB-39	4-5	5/14/2015	1.08	-	0.565	1.86	0.109 U	1,039	50	1,069
SB-39	27-28	5/14/2015	0.929	-	0.813	0.867	0.633	4.32	0.223	4.06
SB-40	4-5	5/5/2015	1.838	-	1.12	1.67	1.15	1.75	0.089	1.39
SB-41	2-3	5/15/2015	0.76	-	0.385	2.62	0.327	47	2.22	48
SB-41	23-24	5/15/2015	1.527	-	1.28	0.979	1.07	1.23	0.03	0.964
SB-41	28-29	5/15/2015	1.143	-	1.19	0.894	0.779	0.768	0.111	1.31
SB-42	4-5.5	5/6/2015	1.981	-	1.21	1.61	0.953	2.98	0.236	2.49
SB-43	0-1	5/13/2015	2.097	-	1.12	1.67	1.12	1.69	0.154	1.92
SB-43	12-13	5/13/2015	1.494	-	1.41	1.38	0.942	1.85	0.125	1.76
SB-43	20-21	5/13/2015	0.268	-	0.264	0.192	0.152	7.70	0.468	7.43
SB-44	0-1	5/18/2015	1.709	-	1.39	1.45	1.24	3.43	0.298	3.03
SB-44	6-7.5	5/18/2015	1.802	-	0.724	1.31	0.546	53	3.68	50
SB-44	20-21	5/18/2015	1.112	-	0.761	0.746	0.837	0.932	0.071 U	0.899
SB-45	0-1	5/18/2015	1.585	-	0.871	1.44	0.745	3.05	0.114	3.09
SB-45	2-3	5/18/2015	1.775	-	0.723	4.60	0.768	32	1.67	31
SB-45	26-27	5/18/2015	1.453	-	1.02	0.989	0.808	1.30	0.086	1.15
SB-46	0-1	5/6/2015	2.834	-	0.816	2.11	0.964	3.78	0.187	3.47
SB-47	5-6	5/5/2015	1.278	-	1.02	1.02	0.722	1.90	0.191	1.67

Notes:

U = not detected
Detection limits shown are method detection limits.
- = not limits Analyzed
ft = feet

E901.1 = Gamma Emitting Radionuclides in Water
HSL-300 = Beta Emitting Radionuclides in Water
pci/g = picocuries per gram

Table 3. 2015 Soil Sampling Results (Continued)

Parameter			RADIUM-226	RADIUM-228	THORIUM-228	THORIUM-230	THORIUM-232	URANIUM-234	URANIUM-235	URANIUM-238
Units			PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G	PCI/G
Analytical Method Code			E901.1	E901.1	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300	HSL-300
location	Depth (ft)	Date								
SB-48	0-1	5/19/2015	1.364	-	1.05	1.74	1.14	3.08	0.186	2.24
SB-48	9-10	5/19/2015	1.908	-	1.68	1.45	1.32	1.10	0.079	1.50
SB-48	21-22	5/19/2015	2.053	-	1.21	1.20	1.05	1.49	0.135	1.23
SB-49	0-1	5/19/2015	1.716	-	1.31	1.81	1.27	2.37	0.187 U	2.35
SB-49	4-5	5/19/2015	2.023	-	0.776	3.94	0.595	34	1.89	33
SB-49	24-25	5/19/2015	1.562	-	0.913	1.10	0.871	0.976	0.079	1.48
SB-50	0-1	5/5/2015	1.656	-	0.934	1.57	0.594	1.30	0.142	1.50
SB-50	6-7.5	5/5/2015	1.55	-	1.62	1.58	1.25	1.47	0.131	1.10
SB-50	16-17	5/5/2015	1.503	-	0.889	1.43	1.15	1.06	0.048	0.956
SB-51	0-1	5/6/2015	3.122	-	1.12	2.61	1.03	3.17	0.281	3.14
SB-51	13-14	5/6/2015	1.198	-	1.07	1.17	0.803	0.851	0.107 U	0.882
SB-51	19-20	5/6/2015	1.235	-	0.668	0.713	0.613	0.657	0.059	0.62
SB-52	4-5	5/6/2015	1.884	-	1.19	1.47	1.40	1.19	0.105	1.34
SB-53	0-1	5/6/2015	2.837	-	0.833	2.28	0.77	3.26	0.109	2.48
SB-53	1-2	5/6/2015	2.694	-	1.10	2.65	0.897	2.17	0.104	2.98
SB-53	5-6	5/6/2015	2.668	-	0.939	2.55	0.755	2.34	0.249	2.70
SB-54	5-6	5/5/2015	1.718	-	1.43	1.32	1.17	1.66	0.03	1.28
SB-55	6-7	5/6/2015	0.981	-	0.834	0.831	0.965	1.13	0.056	0.911
SB-56	5-6.5	5/6/2015	1.444	-	1.25	1.16	0.924	2.15	0.201	2.15
SB-57	0-1	5/6/2015	1.635	-	1.04	1.85	1.06	1.37	0.143	1.63

Notes:

U = not detected
Detection limits shown are method detection limits.
- = not analyzed
ft = feet

E901.1 = Gamma Emitting Radionuclides in Water
HSL-300 = Beta Emitting Radionuclides in Water
pci/g = picocuries per gram

Table 4. Total Uranium Analytical Results for Groundwater

Parameter		TOTAL URANIUM	TOTAL URANIUM	TOTAL URANIUM	TOTAL URANIUM
Units		µG/L	µG/L	µG/L	µG/L
Filter		No	No	Yes	Yes
Analytical Method Code		D5174	SW6020	D5174	SW6020
Location	Date				
G-1-01	6/8/2015	-	16	-	17
G-1-01	8/3/2015	-	13	-	13
G-1-01	9/23/2015	-	14	-	14
G-1-02	6/9/2015	-	22	-	16
G-1-02	8/3/2015	-	11	-	12
G-1-02	9/22/2015	-	11	-	11
G-1-03	6/9/2015	-	12,000	-	12,000
G-1-03	8/4/2015	-	11,000	-	11,000
G-1-03	9/22/2015	-	13,000	-	13,000
G-1-04	6/8/2015	-	490	-	470
G-1-04	8/4/2015	-	360	-	330
G-1-04	9/21/2015	-	300	-	310
G-1-05	6/11/2015	-	11	-	11
G-1-05	8/3/2015	-	8.70	-	65
G-1-05	9/21/2015	-	490	-	190
G-1-06	9/24/2015	0.638	-	0.609	-
G-1-06	6/11/2015	-	0.29	-	0.51
G-1-06	8/6/2015	-	0.56	-	0.36
G-1-07	9/24/2015	3.86	-	3.71	-
G-1-07	6/2/2015	-	13	-	-
G-1-07	8/6/2015	-	12	-	11
G-1-08	6/1/2015	-	51	-	48
G-1-08	8/5/2015	-	48	-	46
G-1-08	9/23/2015	-	46	-	46
G-1-09	9/24/2015	2.35	-	2.35	-
G-1-09	6/2/2015	-	5.20	-	13
G-1-09	8/5/2015	-	4.70	-	4.70
G-1-10	9/23/2015	0.436	-	0.448	-
G-1-10	6/8/2015	-	0.90	-	3.80
G-1-10	8/4/2015	-	0.84	-	0.90
G-1-11	9/23/2015	1.02	-	1.12	-
G-1-11	6/9/2015	-	3.60	-	3.10
G-1-11	8/4/2015	-	14	-	1.40
G-1-12	6/12/2015	-	120	-	73
G-1-12	8/3/2015	-	44	-	44
G-1-12	9/21/2015	-	45	-	46
G-1-13	9/23/2015	0.325	-	0.293	-
G-1-13	6/9/2015	-	0.82	-	0.89
G-1-13	8/4/2015	-	0.22	-	0.046 U
G-1-14	6/8/2015	-	210	-	190
G-1-14	8/4/2015	-	220	-	210
G-1-14	9/21/2015	-	120	-	160

Parameter		TOTAL URANIUM	TOTAL URANIUM	TOTAL URANIUM	TOTAL URANIUM
Units		µG/L	µG/L	µG/L	µG/L
Filter		No	No	Yes	Yes
Analytical Method Code		D5174	SW6020	D5174	SW6020
Location	Date				
G-1-15	9/23/2015	0.145	-	0.107	-
G-1-15	6/10/2015	-	0.20	-	0.20
G-1-15	8/3/2015	-	0.18	-	1.00
G-1-16	9/23/2015	13	-	12	-
G-1-16	6/10/2015	-	11	-	11
G-1-16	8/3/2015	-	12	-	12
G-1-17	6/9/2015	-	12	-	11
G-1-17	8/3/2015	-	330	-	420
G-1-17	9/23/2015	-	6.60	-	6.00
G-1-18	6/10/2015	-	7.00	-	15
G-1-18	8/3/2015	-	16	-	16
G-1-18	9/23/2015	-	10.00	-	10.00
IA03-TW0002R	6/10/2015	-	6.40	-	6.10
IA03-TW0002R	8/5/2015	-	9.00	-	29
IA03-TW0002R	9/23/2015	-	5.30	-	5.40
IA03-TW0005R	6/8/2015	-	3,400	-	3,500
IA03-TW0005R	8/5/2015	-	5,300	-	5,100
IA03-TW0005R	9/22/2015	-	6,600	-	6,800
IA03-TW0006R	6/12/2015	-	2.20E+05	-	2.40E+05
IA03-TW0006R	8/3/2015	-	2.40E+05	-	2.50E+05
IA03-TW0006R	9/21/2015	-	1.40E+05	-	1.60E+05
TWP01	1/26/2015	0.354	-	0.144	-
TWP02	1/29/2015	0.171	-	0.136	-
TWP03	1/26/2015	0.504	-	0.332	-
TWP04	1/29/2015	0.569	-	0.158	-
TWP05	1/29/2015	0.674	-	0.223	-
TWP06	1/29/2015	0.367	-	0.163	-
TWP07	1/29/2015	0.21	-	0.173	-
TWP08	1/26/2016	0.832	-	0.303	-
TWP09	1/26/2016	0.608	-	0.379	-
TWP10	1/26/2016	1.21	-	1.28	-
TWP11	1/26/2016	6.68	-	4.28	-
TWP12	1/26/2016	2.52	-	0.25	-
TWP13	1/26/2016	0.22	-	0.128	-

Notes:

D5174 = ASTM Method for Total Uranium in Water and Soil by Pulsed Laser Phosphorimetry
SW6020 = Inductively Coupled Plasma Mass Spectrometry
- = not analyzed
µG/L = micrograms per liter

Table 5. Temporary Well Point Water Quality Results

Station	Date Sampled	Temperature (Degrees Celsius)	Spec. Cond. (mS/cm)	pH (Std Unit)	Turbidity (NTU)	Dissolved O2 (mg/L)	eH (mV)	Water Level (ft bgs)	Boring TD (ft)	Screen Length (ft)	Total Uranium (µg/L)
TWP1	1/26/15	6.1	2.02	7.02	157	4.47	5	7.30	29.0	15.0	0.4
TWP2	1/29/15	8.5	1.93	6.93	7	3.15	–17	7.01	29.5	15.0	0.2
TWP3	1/26/15	6.6	2.26	7.68	120	4.26	–31	7.30	30.0	15.0	0.5
TWP4	1/29/15	9.7	1.80	6.68	812	3.04	–14	6.95	30.0	15.0	0.6
TWP5	1/29/15	8.5	3.48	6.64	398	3.81	–1	7.70	30.0	15.0	0.7
TWP6	1/29/15	10.1	2.38	6.60	11	3.95	0	9.30	28.0	15.0	0.4
TWP7	1/29/15	7.4	2.16	6.48	30	5.97	8	8.95	20.0	10.0	0.2
TWP8	1/26/15	9.9	1.66	7.01	72	4.54	5	6.40	28.5	15.0	0.8
TWP9	1/26/15	9.3	1.03	6.50	77	4.80	34	6.10	27.5	15.0	0.6
TWP10	1/26/15	11.1	1.12	6.23	94	6.02	49	6.21	25.0	15.0	1.2
TWP11	1/26/15	12.4	1.71	7.54	150	5.42	–24	6.30	21.5	10.0	7.0
TWP12	1/26/15	11.4	1.68	6.17	999	5.84	53	6.29	20.0	10.0	2.5
TWP13	1/26/15	11.3	0.56	5.38	70	6.31	97	8.64	19.0	10.0	0.2

mV = millivolts
* Water levels measure before pumping/sampling
** All borings terminated at refusal (shale bedrock assumed)
*** Sand filter pack installed to approximately 1-2 ft above top of screen in all TWPs

Table 6. Radiological Cancer Risk Assessment Summary

Receptor	Year	OU 1	OU 2
		FS Operable Units	
		Surface Soil (0-2 feet below ground surface)	
Residential Adult	0	NA	NA
Residential Adult	185	NA	NA
Residential Adult	1000	NA	NA
Industrial worker	0	**3.E-04**	**6.E-04**
Industrial worker	1000	**5.E-04**	**5.E-04**
Maintenance worker	0	**5.E-04**	**1.E-03**
Maintenance worker	1000	**9.E-04**	**1.E-03**
Construction worker	0	NA	NA
Construction worker	1000	NA	NA
Recreational Adult	0	3.E-05	8.E-05
Recreational Adult	1000	6.E-05	6.E-05
Recreational Adolescent	0	1.E-05	3.E-05
Recreational Adolescent	1000	2.E-05	2.E-05
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 feet below ground surface)	
Residential Adult	0	**9.E-04**	**2.E-03**
Residential Adult	185	**1.E-03**	**2.E-03**
Residential Adult	1000	**2.E-03**	**2.E-03**
Industrial worker	0	NA	NA
Industrial worker	1000	NA	NA
Maintenance worker	0	NA	NA
Maintenance worker	1000	NA	NA
Construction worker	0	2.E-05	3.E-05
Construction worker	1000	3.E-05	3.E-05
Recreational Adult	0	NA	NA
Recreational Adult	1000	NA	NA
Recreational Adolescent	0	NA	NA
Recreational Adolescent	1000	NA	NA
Subsistence Farmer Adult	0	**2.E-03**	**5.E-03**
Subsistence Farmer Adult	185	**1.E-02**	**2.E-02**
Subsistence Farmer Adult	335	**4.E-03**	**5.E-03**
Subsistence Farmer Adult	1000	**5.E-03**	**4.E-03**

Cancer risks greater than 1E-04 are indicated in bold.

Notes:

NA: Medium is not evaluated for that receptor

Table 7. Radiological Dose Summary for Baseline, RME (mrem/year)

Receptor	Year	FS Operable Units OU 1	OU 2
		Surface Soil (0-2 feet below ground surface)	
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 feet below ground surface)	
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**

Doses greater than 25mrem/year are indicated in bold.

NA: Medium is not evaluated for that receptor

Table 8. Non-Cancer Risks by Operable Unit - Hazard Quotient

Receptor	OU1	OU2
Surface Soil (0-2 feet below ground surface)		
Residential Adult	NA	NA
Residential Child	NA	NA
Industrial worker	4.E-02	1.E-02
Maintenance worker	4.E-02	1.E-02
Construction worker	NA	NA
Trespasser Adult	2.E-02	5.E-03
Trespasser Adolescent	3.E-02	8.E-03
Subsistence Farmer Adult	NA	NA
Subsistence Farmer Child	NA	NA
Total Soil (0-13 feet below ground surface)		
Residential Adult	1.E-01	5.E-02
Residential Child	6.E-01	2.E-01
Industrial worker	NA	NA
Maintenance worker	NA	NA
Construction worker	2.E-01	6.E-02
Trespasser Adult	NA	NA
Trespasser Adolescent	NA	NA
Subsistence Farmer Adult	5.E-01	2.E-01
Subsistence Farmer Child	**2.E+00**	4.E-01

NA: Medium is not evaluated for that receptor

	A–E	F	G–K	L	M	N	O
1	Table 9. UCL Statistics for Data Sets with Non-Detects						
2							
3	User Selected Options						
4	Date/Time of Computation	5/11/2017 2:58:44 PM					
5	From File	WorkSheet.xls					
6	Full Precision	OFF					
7	Confidence Coefficient	95%					
8	r of Bootstrap Operations	2000					
9							
10	U238 OU1						
11							
12	**General Statistics**						
13	Total Number of Observations	1772	Number of Distinct Observations	1026			
14	Number of Detects	1134	Number of Non-Detects	638			
15	Number of Distinct Detects	706	Number of Distinct Non-Detects	389			
16	Minimum Detect	0.072	Minimum Non-Detect	0			
17	Maximum Detect	88.7	Maximum Non-Detect	10.8			
18	Variance Detects	211.3	Percent Non-Detects	36%			
19	Mean Detects	11.02	SD Detects	14.53			
20	Median Detects	5.3	CV Detects	1.318			
21	Skewness Detects	2.609	Kurtosis Detects	7.194			
22							
23	**Normal GOF Test on Detects Only**						
24	Shapiro Wilk Test Statistic	0.643	**Normal GOF Test on Detected Observations Only**				
25	5% Shapiro Wilk P Value	0	Detected Data Not Normal at 5% Significance Level				
26	Lilliefors Test Statistic	0.254	**Lilliefors GOF Test**				
27	5% Lilliefors Critical Value	0.026	Detected Data Not Normal at 5% Significance Level				
28	**Detected Data Not Normal at 5% Significance Level**						
29							
30	**Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs**						
31	Mean	7.305	Standard Error of Mean	0.301			
32	SD	12.65	95% KM (BCA) UCL	7.755			
33	95% KM (t) UCL	7.8	95% KM (Percentile Bootstrap) UCL	7.793			
34	95% KM (z) UCL	7.8	95% KM Bootstrap t UCL	7.815			
35	90% KM Chebyshev UCL	8.208	95% KM Chebyshev UCL	8.617			
36	97.5% KM Chebyshev UCL	9.185	99% KM Chebyshev UCL	10.3			
37							
38	**Gamma GOF Tests on Detected Observations Only**						
39	A-D Test Statistic	38.78	**Anderson-Darling GOF Test**				
40	5% A-D Critical Value	0.785	cted Data Not Gamma Distributed at 5% Significance L				
41	K-S Test Statistic	0.142	**Kolmogrov-Smirnoff GOF**				
42	5% K-S Critical Value	0.028	cted Data Not Gamma Distributed at 5% Significance L				
43	**Detected Data Not Gamma Distributed at 5% Significance Level**						
44							
45	**Gamma Statistics on Detected Data Only**						
46	k hat (MLE)	0.991	k star (bias corrected MLE)	0.989			
47	Theta hat (MLE)	11.12	Theta star (bias corrected MLE)	11.15			
48	nu hat (MLE)	2248	nu star (bias corrected)	2243			
49	MLE Mean (bias corrected)	11.02	MLE Sd (bias corrected)	11.09			
50							
51	**Gamma Kaplan-Meier (KM) Statistics**						
52	k hat (KM)	0.334	nu hat (KM)	1182			
53			Adjusted Level of Significance (β)	0.0499			
54	Approximate Chi Square Value (N/A, α)	1103	Adjusted Chi Square Value (N/A, β)	1103			
55	nma Approximate KM-UCL (use when n>=50)	7.827	% Gamma Adjusted KM-UCL (use when n<50)	7.827			
56							
57	**DL/2 Statistics**						
58	Mean in Original Scale	7.453	SD in Original Scale	12.57			
59	95% t UCL (Assumes normality)	7.944					
60	**DL/2 is not a recommended method, provided for comparisons and historical reasons**						
61							
62	**Nonparametric Distribution Free UCL Statistics**						
63	**Data do not follow a Discernible Distribution at 5% Significance Level**						
64							
65	**Suggested UCL to Use**						
66	97.5% KM (Chebyshev) UCL	9.185				27.6	
67							
68	uggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95						
69	Recommendations are based upon data size, data distribution, and skewness.						
70	recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee						
71	simulations results will not cover all Real World data sets; for additional insight the user may want to consult a s						
72							

	A–E	F	G–K	L	M	N	O
73	U238 OU2						
74							
75	**General Statistics**						
76	Total Number of Observations	107	Number of Distinct Observations	102			
77	Number of Detects	47	Number of Non-Detects	60			
78	Number of Distinct Detects	44	Number of Distinct Non-Detects	59			
79	Minimum Detect	0.41	Minimum Non-Detect	0.229			
80	Maximum Detect	60.5	Maximum Non-Detect	4.195			
81	Variance Detects	81.28	Percent Non-Detects	56.07%			
82	Mean Detects	4.086	SD Detects	9.016			
83	Median Detects	1.84	CV Detects	2.206			
84	Skewness Detects	5.68	Kurtosis Detects	35.02			
85	Mean of Logged Detects	0.784	SD of Logged Detects	0.9			
86							
87	**Normal GOF Test on Detects Only**						
88	Shapiro Wilk Test Statistic	0.355	**Shapiro Wilk GOF Test**				
89	5% Shapiro Wilk Critical Value	0.946	Detected Data Not Normal at 5% Significance Level				
90	Lilliefors Test Statistic	0.355	**Lilliefors GOF Test**				
91	5% Lilliefors Critical Value	0.129	Detected Data Not Normal at 5% Significance Level				
92	**Detected Data Not Normal at 5% Significance Level**						
93							
94	**Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs**						
95	Mean	2.201	Standard Error of Mean	0.603			
96	SD	6.153	95% KM (BCA) UCL	3.349			
97	95% KM (t) UCL	3.202	95% KM (Percentile Bootstrap) UCL	3.336			
98	95% KM (z) UCL	3.194	95% KM Bootstrap t UCL	5.182			
99	90% KM Chebyshev UCL	4.011	95% KM Chebyshev UCL	4.831			
100	97.5% KM Chebyshev UCL	5.969	99% KM Chebyshev UCL	8.204			
101							
102	**Gamma GOF Tests on Detected Observations Only**						
103	A-D Test Statistic	3.94	**Anderson-Darling GOF Test**				
104	5% A-D Critical Value	0.782	cted Data Not Gamma Distributed at 5% Significance L				
105	K-S Test Statistic	0.224	**Kolmogrov-Smirnoff GOF**				
106	5% K-S Critical Value	0.133	cted Data Not Gamma Distributed at 5% Significance L				
107	**Detected Data Not Gamma Distributed at 5% Significance Level**						
108							
109	**Gamma Statistics on Detected Data Only**						
110	k hat (MLE)	0.934	k star (bias corrected MLE)	0.888			
111	Theta hat (MLE)	4.376	Theta star (bias corrected MLE)	4.599			
112	nu hat (MLE)	87.78	nu star (bias corrected)	83.51			
113	MLE Mean (bias corrected)	4.086	MLE Sd (bias corrected)	4.335			
114							
115	**Gamma Kaplan-Meier (KM) Statistics**						
116	k hat (KM)	0.128	nu hat (KM)	27.39			
117	Approximate Chi Square Value (27.39, α)	16.45	Adjusted Chi Square Value (27.39, β)	16.34			
118	nma Approximate KM-UCL (use when n>=50)	3.665	% Gamma Adjusted KM-UCL (use when n<50)	3.69			
119							
120	**Gamma ROS Statistics using Imputed Non-Detects**						
121	GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs						
122	GROS may not be used when kstar of detected data is small such as < 0.1						
123	For such situations, GROS method tends to yield inflated values of UCLs and BTVs						
124	r gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimat						
125	Minimum	0.01	Mean	1.8			
126	Maximum	60.5	Median	0.01			
127	SD	6.277	CV	3.487			
128	k hat (MLE)	0.251	k star (bias corrected MLE)	0.25			
129	Theta hat (MLE)	7.168	Theta star (bias corrected MLE)	7.191			
130	nu hat (MLE)	53.75	nu star (bias corrected)	53.58			
131	MLE Mean (bias corrected)	1.8	MLE Sd (bias corrected)	3.598			
132			Adjusted Level of Significance (β)	0.0478			
133	Approximate Chi Square Value (53.58, α)	37.76	Adjusted Chi Square Value (53.58, β)	37.58			
134	Gamma Approximate UCL (use when n>=50)	2.555	95% Gamma Adjusted UCL (use when n<50)	2.567			
135							
136	**Lognormal GOF Test on Detected Observations Only**						
137	Shapiro Wilk Test Statistic	0.915	**Shapiro Wilk GOF Test**				
138	5% Shapiro Wilk Critical Value	0.946	Detected Data Not Lognormal at 5% Significance Leve				
139	Lilliefors Test Statistic	0.117	**Lilliefors GOF Test**				
140	5% Lilliefors Critical Value	0.129	etected Data appear Lognormal at 5% Significance Lev				
141	**Detected Data appear Approximate Lognormal at 5% Significance Level**						
142							
143	**Lognormal ROS Statistics Using Imputed Non-Detects**						
144	Mean in Original Scale	2.118	Mean in Log Scale	0.00582			
145	SD in Original Scale	6.193	SD in Log Scale	0.95			
146	95% t UCL (assumes normality of ROS data)	3.112	95% Percentile Bootstrap UCL	3.192			
147	95% BCA Bootstrap UCL	3.777	95% Bootstrap t UCL	5.317			
148	95% H-UCL (Log ROS)	1.929					
149							
150	**UCLs using Lognormal Distribution and KM Estimates when Detected data are Lognormally Distributed**						
151	KM Mean (logged)	0.020	95% H-UCL (KM -Log)	2.247			
152	KM SD (logged)	1.055	95% Critical H Value (KM-Log)	2.262			
153	KM Standard Error of Mean (logged)	0.134					
154							
155	**DL/2 Statistics**						
156	**DL/2 Normal**		**DL/2 Log-Transformed**				
157	Mean in Original Scale	2.259	Mean in Log Scale	0.168			
158	SD in Original Scale	6.164	SD in Log Scale	0.911			
159	95% t UCL (Assumes normality)	3.248	95% H-Stat UCL	2.162			
160	**DL/2 is not a recommended method, provided for comparisons and historical reasons**						
161							
162	**Nonparametric Distribution Free UCL Statistics**						
163	**Detected Data appear Approximate Lognormal Distributed at 5% Significance Level**						
164							
165	**Suggested UCL to Use**						
166	95% KM (t) UCL	3.202	95% KM (% Bootstrap) UCL	3.336			9.9
167							
168	uggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95						
169	Recommendations are based upon data size, data distribution, and skewness.						
170	recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee						
171	simulations results will not cover all Real World data sets; for additional insight the user may want to consult a s						

Table 10. Remedial Alternative Cost Summary

Remedial Alternative		Construction Duration	Total Duration*	Capital Cost	Non-Discounted O&M Cost	Discounted O&M Cost (3.26%)	Non-Discounted Total	Discounted Total	Average Annual Maintenance Cost
1	No- Action (OU-1)	0	0	$ -	$ -	$ -	$ -	$ -	$ -
2	Limited Action and Land-Use Controls (OU-1)	0.5 yr	1000 yr	$ 4,545,926	$ 58,649,922	$ 1,640,332	$ 63,195,848	$ 6,186,258	$ 58,650
3	Complete Removal with Off-Site Disposal (OU-1)	2.5 yr	1000 yr	$ 32,551,854	$ 8,077,821	$ 232,148	$ 40,629,675	$ 32,784,001	$ 8,078
5	No- Action (OU-2)	0	0	$ -	$ -	$ -	$ -	$ -	$ -
6	Limited Action and Land-Use Controls (OU-2)	0	1000 yr	$ 2,420,176	$ 40,396,171	$ 1,230,031	$ 42,816,347	$ 3,650,207	$ 40,396
7	Complete Removal with Off-Site Disposal (OU-2)	1.5 yr	3.5 yr	$ 5,909,693	$ -	$ -	$ 5,909,693	$ 5,909,693	$ -

Notes:
* - Total Duration includes construction, turnover to DOE and O&M
yr = year

Table 11. Alternative Component Costs and Contingency

Remedial Alternative	Alternative 2 Limited Action and Land-Use Controls (OU-1)			Alternative 3 Complete Removal with Off-Site Disposal (OU-1)			Alternative 6 Limited Action and Land-Use Controls (OU-2)			Alternative 7 Complete Removal with Off-Site Disposal (OU-2)		
Category	Percent	Cost	Contingency	Percent	Cost	Contingency	Percent	Cost	Contingency	Percent	Cost	Contingency
Mob/Demob & Site Preparation	-	-	-	26%	$ 1,420,682	$ 375,706	-	-	-	26%	$ 525,364	$ 138,935
Excavation	-	-	-	46%	$ 10,011,158	$ 4,620,976	-	-	-	46%	$ 613,766	$ 283,304
Off-Site Transport & Disposal	-	-	-	78%	$ 5,314,492	$ 4,165,931	-	-	-	78%	$ 507,979	$ 398,195
Contractor Design	-	-	-	13%	$ 1,674,633	$ 218,275	-	-	-	17%	$ 164,711	$ 27,437.68
Land Use Controls	27%	$ 2,209,554	$ 586,372	-	-	-	19%	$ 1,104,058	$ 205,713	-	-	-
O&M	67%	$ 35,217,134	$ 23,432,788	72%	$ 4,708,905	$ 3,368,915.76	59%	$ 22,940,835	$ 13,450,768	-	-	-

Notes:
80% Contingency Level
Alternatives 1 and 5 have no costs

APPENDIX F

LABORATORY DATA FILES

(SUBMITTED AS A SEPARATE FILE)

APPENDIX G

DETAILED COST ESTIMATES

Alternative 2 ·Limited Action and Land Use Controls (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update %	3Q17	815 20	1 063
	4Q12	766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Capital Cost						
Administrative Land Use Controls						
Administrative Land Use Controls	lot	$702,000 00	$746,533 78	$918,236 55	1	Includes planning documents, planning meetings, omplementation, and monitoring and enforcement for first year Estimates are based on the RACER Administrative Land Use Control Modell Assumed moderate/high level of complexity to implememnt these controls
Monitoring Plan						
Monitoring Plan	ea	$30,000 00	$31,903 15	$39,240 88	1	Includes monitoring plan for surface soil, sediment, and air monitoring Estimates are based on the RACER Monitoring Model
Mobilization/Demobilization						
Equipment Mob/Demob						Bank Stabilization
Medium Equipment	ea	$251 00	$266 92	$328 32	2	Mob/demob dozer, loader, backhoe or excavator, 70-150 H P, up to 50 miles RSM 01543 650 0020 Assume 2 pieces
Large Equipment	ea	$470 00	$499 82	$614 77	2	Mob/demob, dozer, loader, backhoe or excavator, above 150 H P , up to 50 miles RSM 01543 650 0100 Assume 2 pieces
Small Equipment	ea	$70 50	$74 97	$92 22	5	Mob/demob, delivery charge for small equipment, placed in rear of, or towed by pickup RSM 01543 650 1100 Assume 5 pieces
Bank Stabilization						
Install Gabion Baskets	lf	$1,070 00	$1,137 88	$1,399 59	200	Gabion retaining wall, sloped backfill, 1 5:1, stepped face, 9' base, 15'high, sandy soil RSMG20402703300
Geotextile	sf	$0 22	$0 23	$0 29	60000	Stabilization fabric, polypropylene, 6 oz/SY RSM 32112 323 6000
Riprap (24") Layer	cy	$56 00	$59 55	$73 25	4444	Rip-Rap random, broken stone, machine placed for slpe protection RSM 31371 310 0100
Crusehed Stone (6") Choke Course	cy	$60 60	$64 44	$79 27	1111	Base course drainage layers, aggregate base course, spread and compacted 3/4" crushed stone, to 6" deep RSM 32112 323 010
Land Use Controls						
Establish Control Areas	day	$1,750 00	$1,861 02	$2,289 05	2	Boundary and Survey markers, crew for building lot layout, 3 person crew RSM 01712 313 1200
Develop Drawings	hr	$80 00	$85 08	$104 64	40	Develop Control Drawings

Alternative 2 ·Limited Action and Land Use Controls (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update %	3Q17	815 20	1 063
	4Q12	766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Signs	sf	$29 50	$31 37	$38 59	44	Assume signs on fence every 100 lf Project signs, high intensity reflectorized, buy excl posts RSM 01581 350 0020
Fence	lf	$63 00	$67 00	$82 41	2000	Fence, chain link industrial, aluminized steel, 6 ga Wire 2 1/2" posts @ 10'oc, 8 ft high, includes excavation, in concrete, excludes barbed wire RSM 32311 320 0940
Gate	ea	$1,750 00	$1,861 02	$2,289 05	2	Fence, chain link industrial, double swing gates, 6 ft high, 20' opening, includes excavation, posts & hardware in concrete RSM 32311 320 5070
Mobilization and Demobilization						
Submittals/Implementation Plans						
Submittals	ea	$15,000 00	$15,951 58	$19,620 44	5	Assume 5 plans and/or appendices to work plan Based on Engineering Judgment
Sampling Radioactive Contaminated Media						
Rad Monitoring						
Labor	hr	$55 55	$59 07	$72 66	400	This element covers IH/HP technicians for the following areas: 2 to support installation of riprap 1 month The IH/HP technicians and equipment would be required for a total of 1 months duration at 200 hr/month The total Hours are 2 monthsx 200 hr/mo

Alternative 2 ·Limited Action and Land Use Controls (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update %	3Q17	815 20	1 063
	4Q12	766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Equipment	mo	$3,500 00	$3,722 03	$4,578 10	2	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 (2 @ 325/mo =
						$650/mo)
						3 Micro R Meter, Mode! 19 (2 @ $185/mo = $380/mo)
						4 Ludlum - M3 - 44-2 - 44·9 Meler 3, Na! Gamma Scintillator, G·M Pancake Detector (2 @ $125/mo = $250/mo)
						5 Personal air sampling pumps (2 @ $100/mo = $200/mo)
						6 Personal air sampling pump charger (2 @ $70/mo = $140/mo)
						7 High volume air samplers (5 @ $180/mo = $900/mo) 8 Sources (2 @ $50/mo = $100)
						9 Dosimetry (5 @ $10/mo = $50)
						Total= $3,270/month Use $3,500/mo direct cost ($4505 with OH&P)to account for other miscellaneous equipment, shipping, *or* supplies Assume technicians are local and no per diem or travel is required
Bioassays	ea	$147 32	$156 67	$192 70	5	Bioassays (1 fyr x 1yr x 5 people)
<u>PPE Allowance</u>	set	$8 09	$8 60	$10 58	1980	PPE Estimate Assume average of 30 sets/day for 1 month Includes Disposable Boot Covers, Coverall, gloves, and Ear Plugs ECHO 33010421, 23, 25, and 29
<u>Operation and Maintenance</u>						
<u>Administrative Land Use Controls</u>						
Administrative Land Use Controls	total	$17,000 00	$18,078 45	$22,236 50	1000	Includes moitoring and enforcement of administrative land use controls Includes annual site inspection visits and peridoc notice letters and status reports every 2 years Estimates are based on the RACER Administrative Land Use Controls Model
<u>Bank Stabilization</u>	total					
Riprap 24" layer (cy)	cy	$56 00	$59 55	$73 25	4444	Assume Riprap and crushed stone is completey replaced every 50 years or 2% annually

Alternative 2 ·Limited Action and Land Use Controls (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update %	3Q17	815 20	1 063
	4Q12	766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Crushed Stone (6") choke Course	cy	$60 60	$64 44	$79 27	1111	Base course draiinage layers, aggregate base course, spread and compacted 3/4" crushed stone to 6" deep RSM 32112323010
Five Year Reviews						
Five Year Reviews	ea	$18,000 00	$19,141 89	$23,544 53	200	Includes CERCLA five year reviews, Estimates are based on the RACER Five Year Review Model for a moderately complex site

Alternative 2 ·Limited Action and Land Use Controls (OU-1)
Updated Cost Estimate

Item	CSRA Category	Percent	Cost
CAPITAL COSTS			
Administrative Land Use Controls	Land Use Controls		
Administrative Land Use Controls	Land Use Controls		$918,237
Monitoring Plan	Land Use Controls		
Monitoring Plan	Land Use Controls		$39,241
Equipment Mob/Demob.	Land Use Controls		
Medium Equipment (ea)	Land Use Controls		$657
Large Equipment (ea)	Land Use Controls		$1,230
Small Equipment (ea)	Land Use Controls		$461
Bank Stabilization	Land Use Controls		
Install Gabion Baskets	Land Use Controls		$279,918
Geotextile	Land Use Controls		$17,266
Riprap (24") Layer	Land Use Controls		$325,521
Crushed Stone (6") Choke stone	Land Use Controls		$88,065
Land Use Controls	Land Use Controls		
Establish Control Areas (Surveys)	Land Use Controls		$4,578
Develop Drawings	Land Use Controls		$4,186
Signs	Land Use Controls		$1,698
Fence	Land Use Controls		$164,812
Gate	Land Use Controls		$4,578
Submittals/Implementation Plans	Land Use Controls		
Submittals	Land Use Controls		$98,102
Rad Monitoring	Land Use Controls		
Labor	Land Use Controls		$29,064
Equipment	Land Use Controls		$9,156
Bioassays	Land Use Controls		$963
PPE Allowance	Land Use Controls		$20,952
Captial Costs Sum			**$2,008,685**
Design		**10%**	**$200,869**
Subtotal			**$2,209,554.04**
Contingency			**$586,372.14**
Total with Contingency			**$2,795,926.17**
USACE Construction Oversite			**$750,000**
USACE Turnover to DOE			**$1,000,000**
Total Capital Cost			**$4,545,926**

Alternative 2 ·Limited Action and Land Use Controls (OU-1)
Updated Cost Estimate

Item	CSRA Category	Percent	Cost
OPERATIONS AND MAINTENANCE COSTS			
Administrative Land Use Controls			
Administrative Land Use Controls			
Non-discounted (Total)	O&M		$22,236,498
Non-discounted (Annually)	O&M		$22,236 50
Discounted (Total)	O&M		$682,101
Bank Stabilization			
Riprap (24") Layer (every 50 years @ $325,521 ea)			
Crushed Stone (6") Choke stone (every 50 years @$88,065 ea)			
Non-discounted (Total)	O&M		$8,271,731
Non-discounted (Annually)	O&M		$8,271 73
Discounted (Total)	O&M		$104,104
Five Year Reviews			
Five Year Reviews			
Non-discounted (Total)	O&M		$4,708,905
Non-discounted (Annually)	O&M		$4,708 91
Discounted (Total)	O&M		$135,329
O&M Costs Sum (Non-discounted total)			**$35,217,134**
Contingency (Total)			**$23,432,788**
Contingency (Discounted)			**$718,797**
Total Operation and Maintenance (Non-Discounted)			**$58,649,922**
Total Operation and Maintenance (Discounted)			**$1,640,332**
TOTAL (Non Discounted Cost)			**$63,195,848**
TOTAL (Discounted Cost)			**$6,186,258**

Alternative 3 Complete Removal with Off-Site Disposal (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Capital Cost						
Mobilization/Demobilization						
Equipment Mob/Demob						
Medium Equipment	ea	$251 00	**$266.92**	$328 32	16	Mob/demob dozer, loader, backhoe or excavator, 70-150 H P, up to 50 miles RSM 01543 650 0020 Assume 8 pieces per year (2 year construction)
Large Equipment	ea	$470 00	**$499.82**	$614 77	16	Mob/demob, dozer, loader, backhoe or excavator, above 150 H P , up to 50 miles RSM 01543 650 0100 Assume 8 pieces per year (2 year construction)
Small Equipment	ea	$70 50	**$74.97**	$92 22	50	Mob/demob, delivery charge for small equipment, placed in rear of, or towed by pickup RSM 01543 650 1100 Assume 25 pieces per year (2 year construction)
Submittals/Implementation Plans						
Submittals	ea	$15,000 00	**$15,951.58**	$19,620 44	15	Includes submitla!s such as Alr 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
Permitting						
Permitting	ea	$20,000 00	**$21,268.77**	$26,160 59	1	Local and state permitting not required, but assume work in/adjacent to river will require permitting Based on Engineering Judgment
Temporary Structures and facilities						
Haul Roads	sf	$1 29	**$1.37**	$1 69	5000	Base course drainage layers, aggregate base course, spread & compacted, 3/4" crushed stone, to 6" deep RSM 32112 323 0110
Temporary Fencing	lf	$7 55	**$8.03**	$9 88	375	Temporary Fencing, chain link, rented up to 12 months, 6' high, 11 ga, to 1000' RSM 01562 650 0200
Office Trailers	mo	$440 00	**$467.91**	$575 53	24	Assume 2 trailers Office Trailer, furnished, rent per month, 50' x 12', excl hookups with air conditioning RSM 01521 320 0550 and 0700
Storage Trailers	ea	$102 00	**$108.47**	$133 42	48	Assume 4 storage boxes Storage Boxes, rent per month, 40' x 8' RSM 01521 320 1350
Signs	sf	$29 50	**$31.37**	$38 59	40	Project signs, high intensity refleclorized, buy, excl posts RSM 01581 350 0020
Decon Facility	ea	$28,751 00	**$30,574.92**	$37,607 15	1	Based on RACER Decontamination Pad Model for Equipment Decontamination

Alternative 3 Complete Removal with Off-Site Disposal (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Electric Generator	mo	$1,871 00	**$1,989.69**	$2,447 32	12	Assume 1 electric generator gas engine 10 kW RSM 01543 340 2300
Portable Toilets	mo	$253 44	**$269.52**	$331 51	24	Assume 2 each Rent portable toilet chemical, recycle, flush type RSM 01543 340 6420
Waste Volume Reduction Process Staging Area						
Pre-Engineered Building	sf	$17 55	**$18.66**	$22 96	20000	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
Laydown Area	sf	$1 29	**$1.37**	$1 69	20000	Base course for roadways, crushed stone base, compacted, crushed 1-1/2" stone base, to 8" deep RSM 32112 323 0308
Liner	sf	$1 16	**$1.23**	$1 52	20000	Liners, membrane llning systems HDPE, 100,000 S F or more, 30 mil thick RSM 33471 353 1100
Temporary Utilities and Equipment						
Extend Electric Service	ea	$7,450 00	**$7,922.62**	$9,744 82	1	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
Temporary Water Connection	ea	$2,500 00	**$2,658.60**	$3,270 07	1	Assume temporary hydrant or \'later line connection Based on Engineering Judgment
Monthly Utility and Office expenses	mo	$346 50	**$368.48**	$453 23	24	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	$3,062 00	**$3,256.25**	$4,005 19	36	Assume 3 trucks Rent truck pickup 3/4 ton 4 wheel drive RSM 01543 340 7200
Security						
Security Guard	hr	$27 50	**$29.24**	$35 97	7795	Assume 16 hrs/day for 16 months (2 construction seasons) x 30 45 days per months Watchman, security service, uniformed person, monthly basis, min RSM 01563 250 0020
Sampling Radioactive Contaminated Media						
Rad Monitoring						

Alternative 3 Complete Removal with Off-Site Disposal (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Labor	hr	$55 55	**$59.07**	$72 66	9200	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, 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 46 months duration at 200 hrslmonth Total hours are 46 months x 200 hrs/mo = 9200 hrs
Equipment	mo	$5,500 00	**$5,848.91**	$7,194 16	16	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, Mode! 2360 with 43·89 (5 @ 325/mo =
						$1,625/mo)
						3 Micro R Meter, Mode! 19 (2 @ $185/mo = $380/mo)
						4 Ludlum - M3 - 44-2 - 44·9 Meler 3, Na! 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 samp!ers (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	$147 32	**$156.67**	$192 70	100	Bioassays (2yr x 1yr x 50 people)
PPE Allowance	set	$8 09	**$8.60**	$10 58	10080	PPE Estimate Assume 30 sets per dayfor 16 mo Includes disposal Boot covers, coveralls, gloves & EarPlugs ECHO 3301421, 23,25, and 29
Rad Soils Sampling/Handling/Packaging						
Rad Off site Lab Soils Analysis						Confirmatory Sampling

Alternative 3 Complete Removal with Off-Site Disposal (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
						Since a MARSSIM analysis has not been performed, assume confirmation samples are obtained every 1,000 sf The total area is 195,000 sf Tota! samples collected are 195 Add 100o/o 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 11,000 cy Total samples collected = 220 Samples will be analyzed for radionuclide's Assume 5% of rad samples will also have TCLP Test = 11 ea)
Ttiorium Isotopic	ea	$140 38	**$149.29**	$183 62	727	Testing, rad analytical vegetationlsedimenVsoil, alpha spectroscopy, thorium isotopic ECHOS 33022334
Lead -210	ea	$174 13	**$185.18**	$227 77	727	Testing, rad analytical vegetationlsedimenVsoil, gamma spectroscopy, lead-210 ECHOS 33022344
Radium 226 and 228	ea	$142 50	**$151.54**	$186 39	727	Testing, rad analytical vegetatlontsedirnenVsoil, gamma spectroscopy, radium-226, 228 ECHOS 33022346
Uranium	ea	$142 50	**$151.54**	$186 39	727	Testing; rad analytical vegetation/sedimenVsoil, alpha spectroscopy, uranium isotopic ECHOS 33022335
TCLP	ea	$559 74	**$595.25**	$732 16	62	Targeted TCLP (Metals, Volatiles, Semi-Volatiles only), Soil Analysis ECHOS 33021705
Site Work						
Clearing and Grubbing	acre	$6,100 00	**$6,486.97**	$7,978 98	10	Clearing & grubbing, medium trees, to 12" diameter, cut and cilip RSM 31111 010 0200 Assume wood chip used as mulcil onsite
Surveying			**$2,500,000.00**			
Establish Site Control/layout	day	$1,750 00	**$1,861.02**	$2,289 05	3	Boundary & survey markers, crew for building layout, 3 person crew RSM 01712 313 1200
Reestablish Site Control/Layout	day	$1,750 00	**$1,861.02**	$2,289 05	3	Boundary & survey markers, crew for building layout, 3 person crew RSM 01712 313 1200
Volume Surveys	day	$1,750 00	**$1,861.02**	$2,289 05	3	Boundary & survey markers, crew for building layout, 3 person crew RSM 01712 313 1200
Post Restoration Survey	day	$1,750 00	**$1,861.02**	$2,289 05	3	Boundary & survey markers, crew for building layout, 3 person crew RSM 01712 313 1200
Cofferdam						

Alternative 3 Complete Removal with Off-Site Disposal (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
cofferdam	ls			$300,000 00	1	Assume 400 ft Price quote from Aquadam - www aquadam com Price quote includes purchase and delivery Additional costs included in the price shown include installation & removal using cranes and laborers
Additional Installations (if needed)	ls			$20,000 00	0	
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	$850 00	**$903.92**	$322,289 05	16	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	$2 37	**$2.52**	$3 10	600	Dewatering, sump hole construction, includes excavation and gravel pit RSM 31231 920 1600 Assume 20 each @ 30 cf
Storage Tank Delivery	ea	$500 00	**$531.72**	$654 01	8	Mobilize and demobilize 20,000 gal storage tanks Based on Engineering Judgement
Storage Tank Rental	mo	$1,200 00	**$1,276.13**	$1,569 64	32	Storage tank rental, 20,000 gal Based on Engineering Judgment Assume an average of 4 for 8 months each
Water Filtration	ea	$12,400 00	**$13,186.64**	$16,219 56	1	Water filter, commercial, fully automatic or push button automatic, taste and odor removal, 57 GPM, 2" pipe size RSM 22321 910 9320
Filters	ea	$39 00	**$41.47**	$51 01	192	
						Water filter, cartridge style, dirt and rust type, replacement cartridge RSM 22321 910 1200
Solids Collect And Containment						
Erosion and Sediment Control						
Silt Fence and Straw Bales	lf	$8 31	**$8.84**	$10 87	1,900	Erosion control, silt fence, polypropylene, 3' high and hay bales, staked RSM 31251 310 1100 and 1250
Check Dams	*cy*	*$58.00*	**$61.68**	$75 87	40	Rip rap and rock lining, random, broken stone, machine placed for slope protection RSM 31371 310 0100
	cy	*$47.50*	**$50.51**	$62 13	40	Base course roadways, crushed stone, compacted, 1-1/2", 8" deep RSM 32112 3231522
Truck Entrance						

Alternative 3 Complete Removal with Off-Site Disposal (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Dust Control						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 RSMeans Crew B12-S RSM 31 23 16 13 1320 @ 765 cy day/ Reducing productivity by 33% as stated above = 765 cy x 66=505 cy/day Total estimated qty = 808 cy / 505 cy/day = 2 days This appears to be overly optimistic Use 15 days excavation
Water Trucks	mo	$2,584 00	**$2,747.92**	$3,379 95	6	Rent water tank trailer w/pumped discharge, 5000 gallon capacity RSM 01543 340 6900
Concrete Demolition and Size Reduction						
Concrete Demolition	cy	$153 00	**$162.71**	$200 13	1532	Demolish, remove pavement & curb, concrete, rod reinforced, 7" to 24" thick, remove with backhoe, excludes hauling RSM 02411 317 5500
Asphaltic Concrete Demolition	sy	$8 80	**$9.36**	$11 51	730	Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees RSM 02411 317 5050
Soll Excavation and Waste Volume Reduction Process						
Excavate Soils	day	$7,590 00	**$8,071.50**	$9,927 94	18	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 RSMeans Crew B12-S RSM 31 23 16 13 1320 @ 765 cy day/ Reducing productivity by 33% as stated above = 765 cy x 66=505 cy/day Total estimated qty = 8702 cy / 505 cy/day = 18 days
Waste Volume Reduction Process						
Waste Volume Reduction Operation	tons	$35 00	**$37.22**	$45 78	11,922	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 8702 cy x 1 37 t/cy = 11,922 tons
Waste Volume Reduction Support Crew	day	$3,476 00	**$3,696.51**	$4,546 71	12	Includes 3 cy loader, 1 O E , and 1 LS as spotters and support to waste volume reduction process, and 1 Sample Tech RSMeans Crew B12-S Assumes 1,000 tons/day

Alternative 3 Complete Removal with Off-Site Disposal (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Waste Volume Reduction Support Equipment	mo	$30,000 00	**$31,903.15**	$39,240 88	1 5	Includes feed and discharge conveyors, screening plan, and trammel Based on Painesville Site cost 'Nith quotes from screen machine
Diesel Generator	mo	$15,195 00	**$16,158.95**	$19,875 50	1 5	Rent electric generator gas engine 250 kW RSM 01543 340 2800
Load/Package Contaminated Waste	day	$4,152 00	**$4,415.40**	$5,430 94	17	Includes 3 cy loader, 1 O E , 1TD, and 2 LS 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	$350 00	**$372.20**	$457 81	50	Assume mixed waste is placed in 10 cy bags and left onsite Assume bags are filled to 85% capacity

Alternative 3 Complete Removal with Off-Site Disposal (OU-1)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Offsite Transport and Disposal						$4,708,905 38
Transport and Disposal (Soils)	cy	$593 01	**$630.63**	$775 67	3263	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 intermoda!s per railcar
Transport and Disposal (Standard Debris)	cy	$945 42	**$1,005.40**	$1,236 64	620	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 (Mixed Waste)	cy	$600 00	**$638.06**	$1,550 67	1,294	Assume 25% mixed·waste (25% of Transport & Disposal Soils) and add $775/cy mixed waste disposal premium for treatment and disposal
Transport construction and Demolition Debris	cy			$30 00	306	Say any concrete or footer below 2 ft
Restoration						
Backfill Onsite Soils	cy	$10 80	**$11.49**	$14 13	3,669	Includes loading soils from stockpile and transporting to backfill Includes spreading and compacting in 8-in lifts Includes testing Qty from Environmental Engineering Team
Off-Site Backfill for Balance of Site	cy	$47 50	**$50.51**	$62 13	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
Seeding, Vegetative Cover	MSF	$88 00	**$93.58**	$115 11	90	3368915 765
Fence and Other Miscellaneous Repairs	lot	$25,000 00	**$26,585.96**	$32,700 73	1	
Plans and Reports						
Corrective Action Completion Report Technical Labor	hrs	$80 00	**$85.08**	$104 64	1000	Includes Construction QC data and preparing report
Operation and Maintenance						
Five Year Review						
Five Year Review	ea	$18,000 00	**$19,141.89**	$23,544 53	200	Includes CERCLA five year review Estimates are based on the RACER Five Year Review Model for a moderately complex site

Alternative 3 ·Complete Removal with Off-Site Disposal (OU-1)
Updated Cost Estimate

Item	Percent	CSRA Category	Cost
CAPITAL COSTS			
Mobilization/Demobilization		Mob/Demob & Site Preparation	
Equipment Mob/Demob.		Mob/Demob & Site Preparation	
Medium Equipment		Mob/Demob & Site Preparation	$5,253
Large Equipment		Mob/Demob & Site Preparation	$9,836
Small Equipment		Mob/Demob & Site Preparation	$4,611
Submittals/Implementation Plans		Mob/Demob & Site Preparation	
Submittals		Mob/Demob & Site Preparation	$294,307
Permitting		Mob/Demob & Site Preparation	
Permitting		Mob/Demob & Site Preparation	$26,161
Temporary Structures and Facilities		Mob/Demob & Site Preparation	
Haul Roads		Mob/Demob & Site Preparation	$8,437
Temporary Fencing		Mob/Demob & Site Preparation	$3,703
Office Trailers		Mob/Demob & Site Preparation	$13,813
Storage Trailers		Mob/Demob & Site Preparation	$6,404
Signs		Mob/Demob & Site Preparation	$1,543
Decon Facility		Mob/Demob & Site Preparation	$37,607
Electric Generator		Mob/Demob & Site Preparation	$29,368
Portable Toilets		Mob/Demob & Site Preparation	$7,956
Waste Volume Reduction Process Staging Area		Mob/Demob & Site Preparation	
Pre-engineered Building		Mob/Demob & Site Preparation	$459,118
Laydown Area		Mob/Demob & Site Preparation	$33,747
Liner		Mob/Demob & Site Preparation	$30,346
Temporary Utilities and Equipment		Mob/Demob & Site Preparation	
Extend Electric Service		Mob/Demob & Site Preparation	$9,745
Temporary Water Connection		Mob/Demob & Site Preparation	$3,270
Monthly Utility and Office Expenses		Mob/Demob & Site Preparation	$10,878
Trucks		Mob/Demob & Site Preparation	$144,187
Security		Mob/Demob & Site Preparation	
Security Guard		Mob/Demob & Site Preparation	$280,392
Sampling Radioactive Contaminated Media		Excavation	
Rad Monitoring		Excavation	
Labor		Excavation	$668,481
Equipment		Excavation	$115,107
Bioassays		Excavation	$19,270
PPE Allowance		Excavation	$106,666
Rad Offsite Lab Soils Analysis		Excavation	
Thorium Isotopic		Excavation	$133,493
Lead-21O		Excavation	$165,587
Radium 226 and 228		Excavation	$135,509
Uranium		Excavation	$135,509
TCLP		Excavation	$45,394
Site Work		Excavation	
Clearing and Grubbing		Excavation	$79,790
Surveying		Excavation	

Alternative 3 ·Complete Removal with Off-Site Disposal (OU-1)
Updated Cost Estimate

Item	Percent	CSRA Category	Cost
Establish Site Control/Layout		Excavation	$6,867
Reestablish Site Control Layout		Excavation	$6,867
Volume Surveys		Excavation	$6,867
Post Restoration Survey		Excavation	$6,867
Cofferdam		Excavation	
Cofferdam		Excavation	$300,000
Additional installations if needed		Excavation	$0
Surface Water Collect & Control Including Dewatering		Excavation	
Excavation Dewatering		Excavation	
Site Work		Excavation	$5,156,625
Sump Holes		Excavation	$1,860
Storage Tank Delivery		Excavation	$5,232
Storage Tank Rental		Excavation	$50,228
Water Filtration		Excavation	$16,220
Water Filters		Excavation	$9,795
Solids Collect And Containment		Excavation	
Erosion and Sediment Control		Excavation	
Silt Fence and Straw Bales		Excavation	$20,652
Check Dams		Excavation	$3,035
Truck Entrance		Excavation	$2,485
Dust Control		Excavation	
Water Trucks		Excavation	$20,280
Concrete Demolition and Size Reduction		Excavation	
Concrete Demolition		Excavation	$306,597
Asphaltic Concrete Demolition		Excavation	$8,403
Soil Excavation and Waste Volume Reduction Process		Excavation	
Excavate Soils		Excavation	$178,703
Waste Volume Reduction Operation		Excavation	$545,801
Waste Volume Reduction Support Crew		Excavation	$54,561
Waste Volume Reduction Support Equipment		Excavation	$58,861
Diesel Generator (mo)		Excavation	$29,813
Load/Package Contaminated Waste		Excavation	$92,326
Bags for Mixed Waste (10 cy)		Excavation	$22,891
Offsite Transport and Disposal		Off-Site Transport & Disposal	
Transport and Disposal (Soils)		Off-Site Transport & Disposal	$2,531,183
Transport and Disposal (Standard Debris)		Off-Site Transport & Disposal	$766,870
Transport and Disposal (Mixed Waste)		Off-Site Transport & Disposal	$2,007,259
Transport construction and Demolition Debris		Off-Site Transport & Disposal	$9,180
Restoration		Excavation	
Backfill Onsite Soils		Excavation	$51,831
Off-Site Backfill for Balance of Site		Excavation	$1,327,686
Seeding, Vegetative Cover		Excavation	$10,360
Fence and Other Miscellaneous Repairs		Excavation	Includes 2 5 cy
Closure Reports		Excavation	
Corrective Action Completion Report		Excavation	$104,642

Alternative 3 ·Complete Removal with Off-Site Disposal (OU-1)
Updated Cost Estimate

Item	Percent	CSRA Category	Cost
Subtotal			**$16,746,332**
Design	**10%**		**$1,674,633**
Subtotal with Design			**$18,420,966**
Contingencies			**$9,380,888**
Total with Contingencies			**$27,801,854**
USACE Oversite (Construction)			**$3,750,000**
USACE Turnover to DOE			**$1,000,000**
Total Captal Cost			**$32,551,854**
Operation and Maintenance			
Five Year Reviews			
Five Year Reviews			
Non-discounted (Total)		O&M	$4,708,905
Non-discounted (Annually)		O&M	$4,708 91
Discounted (Total)		O&M	$135,329
Subtotal (Non-discounted Total)			**$4,708,905**
Contingencies			**$3,368,916**
Total O&M (Non-Discounted)			**$8,077,821**
Total O&M (Discounted)			**$232,148**
TOTAL (Non-Discounted Cost)			**$40,629,675**
TOTAL (Discounted Cost)			**$32,784,001**

Alternative 6 ·Limited Action and Land Use Controls (OU-2)
Updated Cost Estimate

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Capital Cost						
Administrative Land Use Controls						
Administrative Land Use Controls	lot	$702,000 00	$746,533 78	$918,236 55	1	Includes planning documents, planning meetings, omplementation, and monitoring and enforcement for first year Estimates are based on the RACER Administrative Land Use Control Modell Assumed moderate/high level of complexity to implememnt these controls
Monitoring Plan						
Monitoring Plan	ea	$30,000 00	**$31,903.15**	$39,240 88	1	Includes monitoring plan for surface soil, sediment, and air monitoring Estimates are based on the RACER Monitoring Model
Land Use Controls						
Establish Control Areas	day	$1,750 00	**$1,861.02**	$2,289 05	2	Boundary and Survey markers, crew for building lot layout, 3 person crew RSM 01712 313 1200
Develop Drawings	hr	$80 00	**$85.08**	$104 64	40	Develop Control Drawings
Signs	sf	$29 50	**$31.37**	$38 59	36	Assume signs on fence every 100 lf Project signs, high intensity reflectorized, buy excl posts RSM 01581 350 0020
Fence	lf	$63 00	**$67.00**	$82 41	1600	Fence, chain link industrial, aluminized steel, 6 ga Wire 2 1/2" posts @ 10'oc, 8 ft high, includes excavation, in concrete, excludes barbed wire RSM 32311 320 0940
Gate	ea	$1,750 00	**$1,861.02**	$2,289 05	2	Fence, chain link industrial, double swing gates, 6 ft high, 20' opening, includes excavation, posts & hardware in concrete RSM 32311 320 5070
Operation and Maintenance						
Administrative Land Use Controls						
Administrative Land Use Controls	annual	$17,000 00	$18,078 45	$22,236 50	1000	Includes moitoring and enforcement of administrative land use controls Includes annual site inspection visits and peridoc notice letters and status reports every 2 years Estimates are based on the RACER Administrative Land Use Controls Model
Five Year Reviews						
Five Year Reviews	ea	$18,000 00	$19,141 89	$23,544 53	200	Includes CERCLA five year reviews, Estimates are based on the RACER Five Year Review Model for a moderately complex site

Alternative 6 ·Limited Action and Land Use Controls (OU-2)
Updated Cost Estimate

Item	Percent	CSRA Category	Cost
CAPITAL COST			
Administrative Land Use Controls		Land Use Controls	
Administrative Land Use Controls		Land Use Controls	$918,237
Monitoring Plan		Land Use Controls	
Monitoring Plan		Land Use Controls	$39,241
Land Use Controls		Land Use Controls	
Establish Control Areas		Land Use Controls	$4,578
Develop Drawings		Land Use Controls	$4,186
Signs		Land Use Controls	$1,389
Fence		Land Use Controls	$131,849
Gate		Land Use Controls	$4,578
Subtotal			**$1,104,058**
Design	**10%**		**$110,406**
Subtotal with Design			**$1,214,464**
Contingencies			**$205,713**
Total with contingencies			**$1,420,176**
USACE Turnover to DOE			**$1,000,000**
Total Capital Costs			**$2,420,176**
OPERATIONS AND MAINTENANCE			
Administrative Land Use Controls			
Administrative Land Use Controls			
Non-discounted (Total)		O&M	$22,236,498
Non-discounted (Annually)		O&M	$22,236 50
Discounted (Total)		O&M	$682,101
Five Year Reviews			
Five Year Reviews			
Non-discounted (Total)		O&M	$4,708,905
Non-discounted (Annually)		O&M	$4,708 91
Discounted (Total)		O&M	$135,329
Subtotal O&M (Non-discounted Total)			**$26,945,403**
Contingencies (Non-discounted)			**$13,450,768**
Contingencies (Discounted)			**$412,600**
TOTAL O&M (Non-Discounted Cost)			**$40,396,171**
TOTAL O&M (Discounted Cost)			**$1,230,031**
TOTAL (Non-Discounted Cost)			**$42,816,347**
TOTAL (Discounted Cost)			**$3,650,207**

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Capital Cost						
Mobilization/Demobilization						
Equipment Mob/Demob						
Medium Equipment	ea	$251 00	**$266.92**	$328 32	10	Mob/demob dozer, loader, backhoe or excavator, 70-150 H P, up to 50 miles RSM 01543 650 0020 Assume 10 pieces
Large Equipment	ea	$470 00	**$499.82**	$614 77	10	Mob/demob, dozer, loader, backhoe or excavator, above 150 H P , up to 50 miles RSM 01543 650 0100 Assume 10 pieces
Small Equipment	ea	$70 50	**$74.97**	$92 22	20	Mob/demob, delivery charge for small equipment, placed in rear of, or towed by pickup RSM 01543 650 1100 Assume 20 pieces
Submittals/Implementation Plans						
Submittals	ea	$15,000 00	**$15,951.58**	$19,620 44	15	Includes submitla!s such as Alr 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
Permitting						
Permitting	ea	$20,000 00	**$21,268.77**	$26,160 59	0	Local and state permitting not required, but assume work in/adjacent to river will require permitting Based on Engineering Judgment
Temporary Structures and facilities						
Haul Roads	sf	$1 29	**$1.37**	$1 69	2000	Base course drainage layers, aggregate base course, spread & compacted, 3/4" crushed stone, to 6" deep RSM 32112 323 0110
Temporary Fencing	lf	$7 55	**$8.03**	$9 88	375	Temporary Fencing, chain link, rented up to 12 months, 6' high, 11 ga, to 1000' RSM 01562 650 0200
Office Trailers	mo	$440 00	**$467.91**	$575 53	16	Assume 2 trailers for1 construction season of 8 months Total 16 months rentals Office Trailer, furnished, rent per month, 50' x 12', excl hookups with air conditioning RSM 01521 320 0550 and 0700
Storage Trailers	ea	$102 00	**$108.47**	$133 42	16	Assume 4 storage boxes Storage Boxes, rent per month, 40' x 8' RSM 01521 320 1350

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Key Paramaters and Assumptions

This worksheet contains updated unit costs

Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)

Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code

Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Signs	sf	$29 50	**$31.37**	$38 59	40	Project signs, high intensity refleclorized, buy, excl posts RSM 01581 350 0020
Decon Facility	ea	$28,751 00	**$30,574.92**	$37,607 15	1	Based on RACER Decontamination Pad Model for Equipment Decontamination
Electric Generator	mo	$1,871 00	**$1,989.69**	$2,447 32	4	Assume 1 electric generator gas engine 10 kW RSM 01543 340 2300
Portable Toilets	mo	$253 44	**$269.52**	$331 51	8	Assume 2 each Rent portable toilet chemical, recycle, flush type RSM 01543 340 6420
<u>Waste Volume Reduction Process Staging Area</u>						
Pre-Engineered Building	sf	$17 55	**$18.66**	$22 96	2500	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
Laydown Area	sf	$1 29	**$1.37**	$1 69	2500	Base course for roadways, crushed stone base, compacted, crushed 1-1/2" stone base, to 8" deep RSM 32112 323 0308
Liner	sf	$1 16	**$1.23**	$1 52	2500	Liners, membrane llning systems HDPE, 100,000 S F or more, 30 mil thick RSM 33471 353 1100
<u>Temporary Utilities and Equipment</u>						
Extend Electric Service	ea	$7,450 00	**$7,922.62**	$9,744 82	1	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
Monthly Utility and Office Expenses	mo	$346 75	**$368.75**	$453 56	8	
Temporary Water Connection	ea	$2,500 00	**$2,658.60**	$3,270 07	1	Assume temporary hydrant or \\later line connection Based on Engineering Judgment
Trucks	mo	$3,062 00	**$3,256.25**	$4,005 19	8	Assume 3 trucks Rent truck pickup 3/4 ton 4 wheel drive RSM 01543 340 7200
Security						

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Key Paramaters and Assumptions

This worksheet contains updated unit costs

Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)

Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code

Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Security Guard	hr	$27 50	**$29.24**	$35 97	992	Assume 16 hrs/day for 2 months (during excavation and loading operations Watchman, security service, uniformed person, monthly basis, min RSM 01563 250 0020
Sampling Radioactive Contaminated Media						
<u>Rad Monitoring</u>						
Labor	hr	$55 55	**$58.15**	$71 52	800	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 an anticipated total of 4 months duration at 200 hrs/month Total hours are 4 months x 200 hrs/mo =800 hrs
Equipment	mo	$5,500 00	**$5,848.91**	$7,194 16	4	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, Mode! 2360 with 43·89 (5 @ 325/mo =
						$1,625/mo)
						3 Micro R Meter, Mode! 19 (2 @ $185/mo = $380/mo)
						4 Ludlum - M3 - 44-2 - 44·9 Meler 3, Na! 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)
						9 Dosimetry (20 @ $10/mo = $200)
						Tola!= $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	$147 32	**$156.67**	$192 70	60	Bioassays (2/yr x 1yr x 30 people)

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Key Paramaters and Assumptions

This worksheet contains updated unit costs

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Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code

Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
PPE Allowance	set	$3 00	**$3.19**	$3 92	1320	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
Rad Soils Sampling/Handling/Packaging						
Rad Off site 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 77,000 sf Total samples collected are 77 Add 100% additional samples for sidewall samples Add 30% additional samples for hotspots and QA/QC samples Total samples = 200 ea Samples will be analyzed for radionuclide's Assume 10% of rad samples will also have TCLP Test = 20 ea)
Thorium Isotopic (ea)	ea	$147 00	**$156.33**	$192 28	20	Testing, rad, analytical vegetation/sedoment/soil, alpha spectroscopy, thorium isotopic ECHOS 33022334
Lead-21O (ea)	ea	$182 25	**$193.81**	$238 39	20	Testing, rad, analytical vegetation/sedoment/soil, gamma spectroscopy, lead-210 ECHOS 33022334
Radium 226 and 228 (ea)	ea	$149 15	**$158.61**	$195 09	20	Testing, rad, analytical vegetation/sedoment/soil, gamma spectroscopy, radium 226, 228 ECHOS 33022346
Uranium (ea)	ea	$149 15	**$158.61**	$195 09	20	Testing, rad, analytical vegetation/sedoment/soil, alpha spectroscopy, uranium isotopic ECHOS 33022335
TCLP (ea)	ea	$586 00	**$623.17**	$766 51	2	Targeted TCLP (Metals, Voltiles, Semi-Voltiles only), Soil Analysis ECHOS 33021705
Clearing and Grubbing	acre	2	$6,400 00	$7,872 00	2	
Surveying						Boundary & survey markers, crew for building layout, 3 person crew RSM 01712 313 1200
Establish Site Control/layout	day	$1,750 00	**$1,861.02**	$2,289 05	1	Boundary & survey markers, crew for building layout, 3 person crew RSM 01712 313 1200
Reestablish Site Control/Layout	day	$1,750 00	**$1,861.02**	$2,289 05	1	Boundary & survey markers, crew for building layout, 3 person crew RSM 01712 313 1200

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)
Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Volume Surveys	day	$1,750 00	**$1,861.02**	$2,289 05	1	Boundary & survey markers, crew for building layout, 3 person crew RSM 01712 313 1200
Post Restoration Survey	day	$1,750 00	**$1,861.02**	$2,289 05	1	Assume 100% of water is filtered and used for dust control of soils or discharged according to local regulations
Surface Water Collect & Control Including Dewatering						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
Excavation Dewatering	day	$850 00	**$903.92**	$1,111 82	2	
						Dewatering, sump hole construction, includes excavation and gravel pit RSM 31231 920 1600 Assume 20 each @ 30 cf
Sump Holes	cf	$2 37	**$2.52**	$3 10	100	
						Mobilize and demobilize 20,000 gal storage tanks Based on Engineering Judgement
Storage Tank Delivery	ea	$500 00	**$531.72**	$654 01	1	Storage tank rental, 20,000 gal Based on Engineering Judgment Assume an average of 4 for 8 months each
Storage Tank Rental	mo	$1,200 00	**$1,276.13**	$1,569 64	1	Water filter, commercial, fully automatic or push button automatic, taste and odor removal, 57 GPM, 2" pipe size RSM 22321 910 9320
Water Filtration	ea	$12,400 00	**$13,186.64**	$16,219 56	1	
Filters	ea	$39 00	**$41.47**	$51 01	24	Water filter, cartridge style, dirt and rust type, replacement cartridge RSM
						22321 910 1200
<u>Solids Collect And Containment</u>						
<u>Erosion and Sediment Control</u>						Erosion control, silt fence, polypropylene, 3' high and hay bales, staked RSM 31251 310 1100 and 1250
Silt Fence and Straw Bales	lf	$8 31	**$8.84**	$10 87	240	Rip rap and rock lining, random, broken stone, machine placed for slope protection RSM 31371 310 0100
Check Dams	*cy*	*$58.00*	**$61.68**	$75 87	10	Base course roadways, crushed stone, compacted, 1-1/2", 8" deep RSM 32112 3231522
Truck Entrance	*cy*	*$47.50*	**$50.51**	$62 13	20	

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Key Paramaters and Assumptions

This worksheet contains updated unit costs
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Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code
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Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Dust Control						Rent water tank trailer w/pumped discharge, 5000 gallon capacity RSM
Water Trucks	mo	$2,584 00	**$2,747.92**	$3,379 95	2	01543 340 6900
Demolition						Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees RSM 02411 317 5050
Asphaltic Concrete Demolition	sy	$8 80	**$9.36**	$11 51	1611	
Soll Excavation and Waste Volume Reduction Process						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 RSMeans Crew B12-S RSM 31 23 16 13 1320 @ 765 cy day/ Reducing productivity by 33% as stated above = 765 cy x 66=505 cy/day Total estimated qty = 808 cy / 505 cy/day = 2 days This appears to be overly optimistic Use 15 days excavation
Excavate Soils	day	$7,590 00	**$8,071.50**	$9,927 94	15	
Waste Volume Reduction Process						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 808 cy x 1 3 tons per cy = 1050 tons
Waste Volume Reduction Operation	tons	$35 00	**$37.22**	$45 78	1,050	Includes 3 cy loader, 1 O E , and 1 LS as spotters and support to waste volume reduction process, and 1 Sample Tech RSMeans Crew B12-S Assumes 1,000 tons/day 1 day appears overly optimistic Use 5 days
Waste Volume Reduction Support Crew	day	$3,476 00	**$3,696.51**	$4,546 71	5	Includes feed and discharge conveyors, screening plan, and trammel Based on Painesville Site cost 'Nith quotes from screen machine
Waste Volume Reduction Support Equipment	mo	$30,000 00	**$31,903.15**	$39,240 88	0 5	Rent electric generator gas engine 250 kW RSM 01543 340 2800

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Key Paramaters and Assumptions

This worksheet contains updated unit costs

Unit Prices Escalated per EM1110-2-1304 (CWCCIS Amendment #9, Tables Revised as of 30 Sept 2016) from Aug 2012 (4Q12) to Jun 2017 (3Q17)

Use Indices for CWBS Feature Code 19 Buildings, Grounds & Utilities since there is no HTRW Feature Code

Home office overhead, field office overhead, and profit are estimated at 23%

Update Ratio	2Q16			815 20	1 063
	4Q12			766 57	

Item	Unit	Unit Price From SAIC	Updated Unit Prices	Updated Unit Cost with Overhead and Profit	Estimated Quantity	Notes
Diesel Generator	mo	$15,195 00	**$16,158.95**	$19,875 50	0 5	Includes 3 cy loader, 1 O E , 1TD, and 2 LS as spotters and handling intermodals Reduced productivity by 50% for loading intermodals and security/S&H requirements RSMeans Crew B12·S
Load/Package Contaminated Waste	day	$4,152 00	**$4,415.40**	$5,430 94	10	Assume mixed waste is placed in 10 cy bags and left onsite Assume bags are fill to 85 % capacity
Bags for Mixed Waste (10 cy)	ea	$350 00	**$372.20**	$457 81	35	
<u>Offsite Transport and Disposal</u>						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 (Soils)	cy	$593 01	**$630.63**	$763 40	364	
Transport and Disposal (Standard Debris)	cy			$1,217 08	121	Assume 10% mixed·waste and add $600/cy mixed waste disposal premium for treatment and disposal
Transport and Disposal (Mixed Waste)	cy			$1,538 40	54	
Transport construction and Demolition Debris	cy			$30 00	13	
<u>Restoration</u>						4708905 384
Backfill Onsite Soils	cy	$10 80	**$11.49**	$14 13	202	spreading and compacting in 8-in lifts Includes testing 1000 cytotal - 650 transport offsite = 350 cy
						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
Off-Site Backfill for Balance of Site	cy	$47 50	**$50.51**	$62 13	202	Seeding with mulch and fertilizer Assume 2 acres are restored in disturbed areas including equipment damage RSMeans 329219142200
Seeding, Vegetative Cover	MSF	$88 00	**$93.58**	$115 11	45	Assume fencing, utility poles, lights, and other structures are removed during remediation and will be replaced
Fence and Other Miscellaneous Repairs	lot	$10,000 00	**$10,634.38**	$13,080 29	1	
<u>Plans and Reports</u>						Includes Construction QC data and preparing report
Corrective Action Completion	hrs	$80 00	**$85.08**	$104 64	600	

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Updated Cost Estimate

Item	Percent	CSRA Category	Cost
CAPITAL COST			
Mobilization/Demobilization		Mob/Demob & Site Preparation	
Equipment Mob/Demob		Mob/Demob & Site Preparation	
Medium Equipment		Mob/Demob & Site Preparation	$3,283
Large Equipment		Mob/Demob & Site Preparation	$6,148
Small Equipment		Mob/Demob & Site Preparation	$1,844
Submittals/Implementation Plans		Mob/Demob & Site Preparation	
Submittals		Mob/Demob & Site Preparation	$294,307
Permitting		Mob/Demob & Site Preparation	
Permitting		Mob/Demob & Site Preparation	$0
Temporary Structures and Facilities		Mob/Demob & Site Preparation	
Haul Roads		Mob/Demob & Site Preparation	$3,375
Temporary Fencing		Mob/Demob & Site Preparation	$3,703
Office Trailers		Mob/Demob & Site Preparation	$9,209
Storage Trailers		Mob/Demob & Site Preparation	$2,135
Signs		Mob/Demob & Site Preparation	$1,543
Decon Facility		Mob/Demob & Site Preparation	$37,607
Electric Generator		Mob/Demob & Site Preparation	$9,789
Portable Toilets		Mob/Demob & Site Preparation	$2,652
Waste Volume Reduction Process Staging Area		Mob/Demob & Site Preparation	
Pre-engineered Building		Mob/Demob & Site Preparation	$57,390
Laydown Area		Mob/Demob & Site Preparation	$4,218
Liner		Mob/Demob & Site Preparation	$3,793
Temporary Utilities and Equipment		Mob/Demob & Site Preparation	
Extend Electric service		Mob/Demob & Site Preparation	$9,745
Monthly Utility and Office Expenses		Mob/Demob & Site Preparation	$3,628
Temporary Water Connection		Mob/Demob & Site Preparation	$3,270
Trucks		Mob/Demob & Site Preparation	$32,041
Security		Mob/Demob & Site Preparation	
Security Guard		Mob/Demob & Site Preparation	$35,683
Sampling Radioactive Contaminated Media		Excavation	
Rad Monitoring		Excavation	
Labor		Excavation	$57,220
Equipment		Excavation	$28,777
Bioassays		Excavation	$11,562
PPE Allowance		Excavation	$5,180
Rad Offsite Lab Soils Analysis		Excavation	
Thorium Isotopic		Excavation	$3,846
Lead-21O		Excavation	$4,768
Radium 226 and 228		Excavation	$3,902
Uranium		Excavation	$3,902
TCLP		Excavation	$1,533
Site Work		Excavation	
Clearing and Grubbing		Excavation	$15,744
Surveying		Excavation	
Establish Site Control/Layout		Excavation	$2,289

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Updated Cost Estimate

Item	Percent	CSRA Category	Cost
Reestablish Site Control Layout		Excavation	$2,289
Volume Surveys		Excavation	$2,289
Post Restoration Survey		Excavation	$2,289
Surface Water Collect & Control Including Dewatering		Excavation	
Excavation Dewatering		Excavation	
Site Work		Excavation	$2,224
Sump Holes		Excavation	$310
Storage Tank Delivery		Excavation	$654
Storage Tank Rental		Excavation	$1,570
Water Filtration		Excavation	$16,220
Water Filters		Excavation	$1,224
Solids Collect And Containment		Excavation	
Erosion and Sediment Control		Excavation	
Silt Fence and Straw Bales		Excavation	$2,609
Check Dams		Excavation	$759
Truck Entrance		Excavation	$1,243
Dust Control		Excavation	
Water Trucks		Excavation	$6,760
Demolition		Excavation	
Asphaltic Concrete Demolition		Excavation	$18,544
Soil Excavation and Waste Volume Reduction Process		Excavation	
Excavate Soils		Excavation	$148,919
Waste Volume Reduction Operation		Excavation	$48,070
Waste Volume Reduction Support Crew		Excavation	$22,734
Waste Volume Reduction Support Equipment		Excavation	$19,620
Diesel Generator		Excavation	$9,938
Load/Package Contaminated Waste		Excavation	$54,309
Bags for Mixed Waste (10 cy)		Excavation	$16,023
Offsite Transport and Disposal		Off-Site Transport & Disposal	
Transport and Disposal (Soils)		Off-Site Transport & Disposal	$277,703
Transport and Disposal (Standard Debris)		Off-Site Transport & Disposal	$147,053
Transport and Disposal (Mixed Waste)		Off-Site Transport & Disposal	$82,833
Transport construction and Demolition Debris		Off-Site Transport & Disposal	$390
Restoration		Excavation	
Backfill Onsite Soils		Excavation	$2,854
Off-Site Backfill for Balance of Site		Excavation	$12,551
Seeding, Vegetative Cover		Excavation	$5,180
Fence and Other Miscellaneous Repairs		Excavation	$13,080
Closure Reports		Excavation	
Corrective Action Completion Report		Excavation	$62,785
Subtotal			**$1,647,110**
Design	**10%**		**$164,711**
Subtotal with Design			**$1,811,821**
Contingencies			**$847,872**
USACE Oversite Construction			**$2,250,000**
USACE Turnover to DOE			**$1,000,000**

Alternative 7 ·Complete Removal with Off-Site Disposal (OU-2)
Updated Cost Estimate

Item	Percent	CSRA Category	Cost
TOTAL			$5,909,693

Site to be free release after remediation No O&M costs