Revised Draft

Remedial Investigation Report for Soil, Sediment, and Surface Water at RVAAP-45 Wet Storage Area

Former Ravenna Army Ammunition Plant
Portage and Trumbull Counties, Ohio

Contract No. W912QR-15-C-0046

Prepared for:

US Army Corps of Engineers®

U.S. Army Corps of Engineers
Louisville District

Prepared by:

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October 5, 2016

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14. ABSTRACT

This Remedial Investigation Report for Wet Storage Area presents physical characteristics, geology, and hydrogeology of Wet Storage Area; compiles historical and newly acquired environmental data; summarizes nature and extent of contamination in soil, sediment, and surface water; evaluates contaminant fate and transport; and provides human health and ecological risk assessments. These evaluations indicate there are no chemicals of concern (COCs) that pose unacceptable risk; and, therefore this report recommends No Further Action with respect to soil, sediment, and surface water at Wet Storage Area to attain Unrestricted (Residential) Land Use.

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Risk assessment, weight of evidence, nature and extent, fate and transport, no further action

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CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Leidos has completed the Revised Draft Remedial Investigation Report for Soil, Sediment, and Surface Water at RVAAP-45 Wet Storage Area at the Former Ravenna Army Ammunition Plant, Portage and Trumbull Counties, Ohio. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of data quality objectives; technical assumptions; methods, procedures, and materials to be used; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing U.S. Army Corps of Engineers (USACE) policy.

10/5/16

Jed Thomas, P.E.
Study/Design Team Leader, Main Author

Date

10/5/16

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Independent Technical Review Team Leader

Date

Significant concerns and the explanation of the resolution are as follows:

Internal Leidos Independent Technical Review comments are recorded on a Document Review Record per Leidos standard operating procedure ESE A3.1 Document Review. This Document Review Record is maintained in the project file. Changes to the report addressing the comments have been verified by the Study/Design Team Leader. As noted above, all concerns resulting from independent technical review of the project have been considered.

10/5/16

Lisa Jones-Bateman
Senior Program Manager

Date

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Documentation of Ohio EPA Approval of Final Document

(Documentation to be provided once approval is issued.)

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ARNG = Army National Guard.
CO = Central Office.
DERR = Division of Environmental Response and Revitalization.
ILE = Installation, Logistics, and Environment.
OHARNG = Ohio Army National Guard.
Ohio EPA = Ohio Environmental Protection Agency.
NEDO = Northeast Ohio District Office.
REIMS = Ravenna Environmental Information Management System.
USACE = U.S. Army Corps of Engineers.

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ACRONYMS AND ABBREVIATIONS

amsl	Above Mean Sea Level
AOC	Area of Concern
Army	U.S. Department of the Army
AT123D	Analytical Transient 1-,2-,3-Dimensional
BERA	Baseline Ecological Risk Assessment
bgs	Below Ground Surface
BHC	Hexachlorocyclohexane
btoc	below top of casing
Camp Ravenna	Camp Ravenna Joint Military Training Center
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMCOC	Contaminant Migration Chemical of Concern
CMCOPC	Contaminant Migration Chemical of Potential Concern
COC	Chemical of Concern
COPC	Chemical of Potential Concern
COPEC	Chemical of Potential Ecological Concern
CSM	Conceptual Site Model
DAF	Dilution Attenuation Factor
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DERR	Division of Environmental Response and Revitalization
DFFO	Directors Final Findings and Orders
DNT	Dinitrotoluene
DQO	Data Quality Objective
EcoSSL	Ecological Soil Screening Level
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ERS	Ecological Risk Screening
ESL	Ecological Screening Level
ESV	Ecological Screening Value
EU	Exposure Unit
f_{oc}	Mass Fraction of the Organic Carbon Soil Content
FS	Feasibility Study
FWCUG	Facility-wide Cleanup Goal
FWERWP	Facility-wide Ecological Risk Work Plan
FWGWMP	Facility-wide Groundwater Monitoring Program
FWHHRAM	Facility-wide Human Health Risk Assessor Manual
FWSAP	Facility-wide Sampling and Analysis Plan
gpm	Gallons Per Minute
GSSL	Generic Soil Screening Level
HELP	Hydrologic Evaluation of Landfill Performance

HHRA	Human Health Risk Assessment
HHRS	Human Health Risk Screening
HLC	Henry’s Law Constant
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HQ	Hazard Quotient
IBI	Index of Biotic Integrity
ILCR	Incremental Lifetime Cancer Risk
INRMP	Integrated Natural Resources Management Plan
IRA	Interim Removal Action
IRIS	Integrated Risk Information System
ISM	Incremental Sampling Methodology
K_d	Sediment/Water Partitioning Coefficient
K_ds	Distribution Coefficients
K_{oc}	Water/Organic Carbon Partition Coefficient
K_{ow}	Octanol-Water Partition Coefficient
MCL	Maximum Contaminant Level
MDC	Maximum Detected Concentration
MDL	Maximum Detection Limit
MI	Multi-increment
MRS	Munitions Response Site
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
OAC	Ohio Administrative Code
ODA2	Open Demolition Area #2
OHARNG	Ohio Army National Guard
Ohio EPA	Ohio Environmental Protection Agency
OMZA	Outside Mixing Zone Average
OMZM	Outside Mixing Zone Maximum
ORAM	Ohio Rapid Assessment Method
PAH	Polycyclic Aromatic Hydrocarbon
PBA08 RI	Performance-Based Acquisition 2008 Remedial Investigation
PBA08 SAP	Performance-based Acquisition 2008 Supplemental Investigation Sampling and Analysis Plan Addendum No. 1
PBT	Persistent, Bioaccumulative, and Toxic
PCB	Polychlorinated Biphenyl
PP	Proposed Plan
PRG	Preliminary Remediation Goal
QA	Quality Assurance
QC	Quality Control
QHEI	Qualitative Habitat Evaluation Index
R	Retardation Factor
RDA	Recommended Daily Allowance
RDI	Recommended Daily Intake
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine

REIMS	Ravenna Environmental Information Management System
RfD	Reference Dose
RI	Remedial Investigation
RM	River Mile
ROD	Record of Decision
RRSE	Relative Risk Site Evaluation
RSL	Regional Screening Level
RVAAP	Ravenna Army Ammunition Plant
SAIC	Science Applications International Corporation
SESOIL	Seasonal Soil Compartment
SL	Screening Level
SOR	Sum-of-Ratio
SRC	Site-related Contaminant
SRV	Sediment Reference Value
SSL	Soil Screening Level
SSSL	Site-specific Soil Screening Level
SVOC	Semi-Volatile Organic Compound
TAL	Target Analyte List
TEC	Threshold Effects Concentration
TNT	2,4,6-Trinitrotoluene
TR	Target Risk
UCL	Upper Confidence Limit
URF	Unit Risk Factor
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USP&FO	U.S. Property and Fiscal Officer
VOC	Volatile Organic Compound
WOE	Weight-of-Evidence
WQS	Water Quality Standards

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EXECUTIVE SUMMARY

ES.1 INTRODUCTION AND SCOPE

This document has been revised by Leidos under U.S. Army Corps of Engineers Louisville District Contract Number W912QR-15-C-0046. This Remedial Investigation (RI) Report addresses soil, sediment, and surface water at Wet Storage Area within the former Ravenna Army Ammunition Plant (RVAAP) [now known as Camp Ravenna Joint Military Training Center (Camp Ravenna)] in Portage and Trumbull counties, Ohio.

This report has been prepared in accordance with the requirements of the Ohio Environmental Protection Agency (Ohio EPA) *Director's Final Findings and Orders* (DFFO) for RVAAP, dated June 10, 2004 (Ohio EPA 2004). The DFFO requires conformance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and National Contingency Plan to implement an RI to characterize the area of concern (AOC); develop a Feasibility Study (FS) Report (if remediation is necessary); and evaluate remedial alternatives to address contamination presenting unacceptable risk to human health and the environment, present a preferred alternative in a proposed plan (PP), and document stakeholder selection and acceptance of the preferred final remedy in a record of decision (ROD). The following sections present the site history, scope of this report, and an explanation of the evaluation of future use.

ES.1.1 Site History

Wet Storage Area is a 36-acre fenced AOC located directly northwest of the intersection of George Road and Newton Falls Road. An unnamed tributary to Sand Creek is located in the western portion of the AOC, and Sand Creek is located outside of the AOC, north of the fence line. Six igloos within Wet Storage Area were earth-covered, and the floors, walls, and ceilings were constructed of reinforced concrete. The four westernmost igloos were constructed with a conductive lead floor liner in order to dissipate static electricity.

From 1941–1945, Wet Storage Area was used to store highly explosive, shock-sensitive primary explosives, including lead azide, mercury fulminate, and tetryl (USACHPPM 1998), and potentially nitroguanidine (USACE 2015). During storage activities, explosive material was containerized and covered with water within drums that were stored separately in six storage igloos at the AOC. There is no documentation indicating any spills occurred at the AOC. No historical information exists to indicate a fuel storage tank was present at Wet Storage Area; however, Building PS-7 was a generator house, which likely used diesel fuel.

During remedial action activities in 2011 at RVAAP-004-R-01 Open Demolition Area #2 (ODA2) munitions response site, a temporary staging area was established in Wet Storage Area. A total of 517 drums of soil and debris contaminated with white phosphorus were transported by Triad Transport, Inc. and disposed at an approved off-site disposal facility. After being demobilized from Wet Storage Area, an inspection was requested by the RVAAP Facility Manager and was conducted along with the Ohio

EPA on October 11, 2011. The area was deemed acceptable, and there were no further actions required. All project activities were completed with no spills, leaks, accidents, or incidents (Toltest 2012).

Four storage igloos (WS-1, WS-1A, WS-2, and WS-2A) (including slabs and foundations) were removed in 2003–2004. Remaining features at Wet Storage Area include storage igloos WS-3 and WS-3A and access roads that enter the AOC from the south. The Wet Storage Area perimeter fence is still in place, but it is not currently maintained. Small construction drainage ditches border the access roads near the igloo locations.

ES.1.2 Scope

The scope of this RI Report is to perform a CERCLA evaluation of soil, sediment, and surface water at Wet Storage Area using available RI data to evaluate the nature and extent of contamination; fate and transport of contaminants in the environment; and risk assessments for surface and subsurface soil, sediment, and surface water. This report includes sample results and information from the Building T-5301 Interim Removal Action (IRA), ODA2 Phase II RI, Characterization of 14 AOCs, and also provides a summary of the Performance-based Acquisition 2008 Remedial Investigation (PBA08 RI) at Wet Storage Area that was performed to supplement data from previous sampling events.

The media of concern associated with Wet Storage Area are surface soil [0–1 ft below ground surface (bgs)], subsurface soil (1–13 ft bgs), sediment, and surface water. This report does not include a full evaluation of groundwater, as it will be evaluated as an individual AOC for the entire facility. However, the potential for soil contaminants to leach to and migrate in groundwater is evaluated in this RI Report to determine whether additional soil remedial actions to protect groundwater may be necessary.

ES.1.3 Evaluation of Future Use

In February 2014, the U.S. Department of the Army and Ohio EPA amended the risk assessment process to address changes in the RVAAP restoration program. The *Final Technical Memorandum: Land Uses and Revised Risk Assessment Process for the RVAAP Installation Restoration Program* (ARNG 2014) (herein referred to as the Technical Memorandum) identified three Categorical Land Uses and Representative Receptors to be considered during the RI phase of the CERCLA process. These three Land Uses and Representative Receptors are presented below.

1. Unrestricted (Residential) Land Use – Resident Receptor (Adult and Child) (formerly called Resident Farmer).
2. Military Training Land Use – National Guard Trainee.
3. Commercial/Industrial Land Use – Industrial Receptor [U.S. Environmental Protection Agency's (USEPA) Composite Worker].

Unrestricted (Residential) Land Use is considered protective for all three Land Uses at Camp Ravenna. Therefore, if an AOC meets the requirements for Unrestricted (Residential) Land Use, then the AOC is also considered to have met the requirements of the other Land Uses (i.e., Industrial and Military Training), and those other Land Uses do not require evaluation.

As stated in Paragraph 6.d of the Technical Memorandum, if an AOC fails to meet Unrestricted (Residential) Land Use, then an FS will be completed that evaluates cleanup options for all three Land Uses [i.e., Unrestricted (Residential) Land Use, Military Training Land Use, and Commercial/Industrial Land Use]. Remedial alternatives for meeting each Land Use are to be evaluated per the current guidelines for selecting a remedy for the AOC. The preferred remedy is one that would meet Unrestricted (Residential) Land Use. RI/FS Reports in progress at the time of the Technical Memorandum's approval on February 11, 2014 will not be revised to include an evaluation of Commercial/Industrial Land Use as an Alternative if it achieves no further action for Unrestricted (Residential) Land Use.

ES.2 FINDINGS AND RECOMMENDATIONS OF THE REMEDIAL INVESTIGATION

This section presents a summary of data used in this RI, contaminant nature and extent, fate and transport, human health risk assessment (HHRA), and environmental risk assessment (ERA), followed by the conclusions of the RI.

ES.2.1 Data Use and Sample Selection Process

Quality-assured sample data from the Building T-5301 IRA, ODA2 Phase II RI, Characterization of 14 AOCs report (MKM 2007), and 2010 PBA08 RI were used to evaluate nature and extent of contamination at Wet Storage Area. These investigations used discrete and incremental sampling methodology (ISM) sampling methods.

All available sample data collected at the locations were evaluated to determine suitability for use in various key RI data screens and evaluations (i.e., nature and extent, fate and transport, and risk assessment). Evaluation of the data's suitability for use in the PBA08 RI involved two primary considerations: whether the data represented current AOC conditions and sample collection methods (e.g., discrete vs. ISM).

Surface water and sediment samples outside the AOC from the 2002 ODA2 Phase II RI and the 2000 Building T-5301 IRA were considered with respect to contaminant migration but were not used in the Wet Storage Area data screening process. Samples from the Characterization of 14 AOCs data set were evaluated to determine if conditions had changed substantively between earlier characterization efforts and the 2010 PBA08 RI. The samples collected in 2004–2005 were collected within ditch lines adjacent to former buildings and in areas encompassing, but also extending substantially beyond the footprint of the former buildings. Therefore, both data sets were considered representative of current conditions within and surrounding the footprints of the former buildings/igloos at Wet Storage Area.

Data collected in 2010 as part of the PBA08 RI focused on delineating the extent of contaminants identified in surface soil (0–1 ft bgs), subsurface soil (1–13 ft bgs), sediment, and surface water. The PBA08 RI sampled locations with the greatest likelihood of contamination (e.g., adjacent to production buildings or within sediment accumulation areas, such as ditches) and analyzed for chemicals identified in historical investigations. Additionally, sediment and surface water samples were collected from drainage ditches and streams exiting the AOC.

ES.2.2 Summary of Nature and Extent of Contamination

Nature and extent of contamination in surface soil (0–1 ft bgs), subsurface soil (greater than 1 ft bgs), sediment, and surface water was evaluated in the RI. Data from the RIs (Building T-5301 IRA, ODA2 Phase II RI, 2004 Characterization of 14 AOCs, and 2010 PBA08 RI) effectively characterize the nature and extent of the contamination at the AOC. Surface water and sediment samples outside the AOC from the 2002 ODA2 Phase II RI and the 2000 Building T-5301 IRA were considered with respect to contaminant migration but were not used in the Wet Storage Area data screening process. Figure ES-1 shows the sample locations used to conduct this RI. To support the evaluation of nature and extent of contamination, site-related contaminant (SRC) concentrations were compared to screening levels (SLs) corresponding to the lowest facility-wide cleanup goal (FWCUG) for the Resident Receptor (Adult and Child) and National Guard Trainee at a target hazard quotient (HQ) of 0.1 or target risk (TR) of 1E-06, as presented in the *Facility-wide Human Health Cleanup Goals for the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2010a) (herein referred to as the FWCUG Report). It can be concluded that the vertical and horizontal extent of contamination is defined, and no further sampling is needed to evaluate Wet Storage Area.

ES.2.2.1 Surface Soil

The predominant SRCs in surface soil at Wet Storage Area were inorganic chemicals and semi-volatile organic compounds (SVOCs), the majority of which were polycyclic aromatic hydrocarbons (PAHs). Fourteen inorganic chemicals were identified as SRCs in surface soil. The maximum concentrations for inorganic SRCs were not concentrated in any one location, and two ISM samples with the most maximum detections for surface soil were WSAss-002M and WSAss-033M. The highest density of samples with inorganic chemicals above background concentrations was located in the vicinity of the former igloos in the northwestern portion of Wet Storage Area. Aluminum, arsenic, and cobalt concentrations exceeded their respective SLs and were considered chemicals of potential concern (COPCs); however, only arsenic concentrations at nine ISM locations exceeded the respective Resident Receptor (Adult and Child) at a TR of 1E-05, HQ of 1. The arsenic exceedance does not appear to be concentrated in any particular area of the AOC.

All 21 SVOC SRCs were detected at 2004 ISM sample location WSAss-004M, located adjacent to one of the southwestern igloos, with maximum detections for all 21 of the SVOC SRCs observed in this sample. Thirteen SVOCs were detected at WSAss-036M, which delineates the area containing WSAss-004M, at concentrations typically two orders of magnitude lower than those observed at WSAss-004M. Although SVOC detections in surface soil occur throughout the AOC, the samples with the highest concentrations generally occur adjacent to the former and extant igloo locations and are effectively delineated by the PBA08 RI data. Five of the six PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] that exceeded their SLs at WSAss-004M were detected at concentrations greater than their respective Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. Benzo(a)pyrene also exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1 at discrete PBA08 RI sample locations WSAsb-022, WSAsb-024, WSAsb-027, and WSAsb-028. Benz(a)anthracene, benzo(b)fluoranthene, and dibenz(a,h)anthracene also exceeded the Resident Receptor (Adult and Child) FWCUG at a TR1E-05, HQ of 1 at discrete PBA08 RI sample locations WSAsb-024 and WSAsb-028.

An explosive (3-nitrotoluene), propellant (nitrocellulose), and five pesticides (4,4'-dichlorodiphenyldichloroethylene; endosulfan sulfate; endrin; alpha-chlordane; and beta-hexachlorocyclohexane) were identified as SRCs in the surface soil at Wet Storage Area. None of the detected concentrations exceeded their respective SLs. Volatile organic compounds (VOCs) and polychlorinated biphenyls (PCBs) were not detected in the surface soil.

ES.2.2.2 Subsurface Soil

Four inorganic chemicals (arsenic, cadmium, cobalt, and silver) were identified as SRCs, although no spatial or vertical trend is apparent for the distribution of inorganic chemicals in subsurface soil, and concentrations only marginally exceeded their applicable background concentrations. Seventeen SVOCs were identified as SRCs, with soil boring location WSAsb-024 (located adjacent to one of the former igloos in the northwest portion of the AOC) containing the greatest number and highest concentrations of SVOCs. Benzo(a)pyrene was detected in the 1–4 ft bgs interval at WSAsb-024 at a concentration that exceeded its respective SL of 0.022 mg/kg; thus, benzo(a)pyrene was identified as a COPC. The benzo(a)pyrene concentration was detected below the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. No SVOCs were detected from the 4–7 or 7–13 ft bgs intervals at WSAsb-024. The majority of SVOC SRCs were PAHs which were identified as SRCs in surface soil as well.

One VOC (toluene) and one pesticide (4,4'-dichlorodiphenyltrichloroethane) were identified as SRCs, although they occurred at low, estimated concentrations in different depth intervals of soil boring WSAsb-028. Explosives, propellants, and PCBs were not detected in the subsurface soil.

ES.2.2.3 Sediment and Surface Water

The greatest number and highest magnitude of identified SRCs in sediment samples were detected in the most upstream location within the unnamed tributary to the west of Wet Storage Area. The predominant SRCs in sediment were inorganic chemicals and PAHs. SRC concentrations generally followed a clear longitudinal trend, exhibiting decreasing numbers and concentrations with downstream distance. However, location WSAsd-037, which exhibits the highest and most PAH and inorganic detections, is in a location that is upstream relative to potential surface water contributions from Wet Storage Area; therefore, it is not influenced by runoff from the AOC. Two of the inorganic chemicals (antimony and manganese) were not identified as SRCs in surface soil at Wet Storage Area and occurred in sediment at upstream location WSAsd-037 at concentrations twice or more of the maximum concentrations observed in surface soil at the AOC. Manganese concentrations at WSAsd-037 exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. One VOC (2-butanone) was detected in sediment sample WSAsd-037 upstream of the AOC. Chloromethane and the pesticide dieldrin were detected in sediment in one historical sample in Sand Creek, downstream of the AOC. Explosives, propellants, pesticides, and PCBs were not detected in sediment samples at Wet Storage Area.

Surface water at Wet Storage Area is present within the unnamed tributary on the west side of the AOC, which then enters into Sand Creek to the north. Within the former operational area at Wet Storage Area, surface water only occurs as storm water runoff either overland or within discontinuous ditch lines immediately adjacent to intra-AOC access roads. While five inorganic SRCs were identified in surface water, these inorganic chemicals did not have established background concentrations, and all detections were at concentrations below laboratory screening criteria. Explosives, propellants, SVOCs, pesticides, and PCBs were not detected in surface water samples at Wet Storage Area. Nitrocellulose, bis(2-ethylhexyl)phthalate, acetone, carbon disulfide, and chloroform were each detected once at locations outside the AOC.

ES.2.3 Summary of Contaminant Fate and Transport

All SRCs identified in surface soil, subsurface soil, and sediment at Wet Storage Area were evaluated through the stepwise contaminant fate and transport evaluation. The evaluation included analyzing leaching and migration from soil and sediment to groundwater and determining whether contamination present in soil and sediment may potentially impact groundwater quality at the site.

Maximum concentrations of SRCs identified in surface and subsurface soil were evaluated using a series of generic screening steps to identify initial contaminant migration chemicals of potential concern (CMCOPCs). Initial CMCOPCs for soil were further evaluated using the Seasonal Soil Compartment Model to predict leaching concentrations and identify final CMCOPCs based on RVAAP facility-wide background concentrations and the lowest risk-based screening criteria among USEPA maximum contaminant levels, USEPA tap water regional screening levels, or RVAAP groundwater FWCUGs for the Resident Receptor Adult. A sediment screening analysis was performed for sediment samples at the AOC. The sediment screening analysis for this AOC assumed that the sediment concentration and the recharging groundwater concentration were in equilibrium and that there was no dilution in groundwater. The resulting groundwater concentrations were compared against RVAAP facility-wide background concentrations and the lowest risk-based screening criteria to identify the final CMCOPCs. These final CMCOPCs were evaluated using the analytical transient 1-, 2-, 3-dimensional model to predict groundwater concentrations beneath source areas and at the nearest downgradient groundwater receptor to the AOC (e.g., stream).

The evaluation of modeling results with respect to current AOC groundwater data and model limitations identified the following CMCOPCs for soil and sediment:

- Arsenic and naphthalene in soil were predicted to exceed the screening criteria in groundwater beneath the source area; however, none of these constituents were predicted to exceed screening criteria at the downgradient receptor location.
- Manganese, benz(a)anthracene benzo(b)fluoranthene, and naphthalene in sediment were predicted to exceed the screening criteria in groundwater beneath the source area; however, none of these constituents were predicted to exceed screening criteria at the downgradient receptor location.

A qualitative assessment of the sample results and considerations of the limitations and assumptions of the models were performed to identify if any contaminant migration chemicals of concern (CMCOCs) are present in soil and sediment at Wet Storage Area that may impact the groundwater beneath the source or at the downstream receptor location. This qualitative assessment concluded that there were no CMCOCs present in soil and sediment that may impact the groundwater beneath the source or at the downstream receptor location. No further action is required of soil and sediment at Wet Storage Area for the protection of groundwater.

ES.2.4 Summary of the Human Health Risk Assessment

The HHRA identified chemicals of concern (COCs) and conducted risk management analysis to determine if COCs pose unacceptable risk to the Resident Receptor (Adult and Child). Since the risk management analysis determined there were no unacceptable risks to the Resident Receptor (Adult and Child), it can be concluded that there is no unacceptable risk to the National Guard Trainee and Industrial Receptor.

Media of concern at Wet Storage Area are surface soil, subsurface soil, surface water, and sediment. Soil data associated with Wet Storage Area were aggregated into surface and subsurface soil. Sediment and surface water were evaluated from the unnamed tributary at the ingress of the tributary onto Wet Storage Area and approximately 100 ft upstream of the confluence with Sand Creek.

No COCs were identified for the Resident Receptor (Adult and Child) in subsurface soil, sediment, or surface water. Arsenic and five PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were identified as COCs for the Resident Receptor (Adult and Child) in surface soil.

Arsenic (21 mg/kg) exceeded the FWCUG (4.25 mg/kg) and surface (15.4 mg/kg) and subsurface (19.8 mg/kg) background criteria in surface soil ISM sample WSAss-020M, collected near igloo WS-1A. The reported arsenic concentration in the larger ISM sample (WSAss-036M) collected in 2010 to delineate the southwest portion of Wet Storage Area (which surrounds the approximate location of WSAss-020M) was 14.8 mg/kg. Regional studies indicate arsenic may be naturally occurring in Ohio soils at greater than 20 mg/kg. Arsenic appears to be present at Wet Storage Area at naturally occurring concentrations and there is no known operational source of arsenic. Based on this evaluation, arsenic does not represent a hot spot and was not identified as a COC for potential remediation in surface soil.

Five PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were identified as surface soil COCs exceeding their FWCUGs and contributing to a sum-of-ratios greater than one in Wet Storage Area surface soil at ISM sample location WSAss-004M. Since ISM samples represent an average concentration across the area sampled, no statistical analysis of ISM data was conducted (i.e., the detected concentration in each ISM sample was compared directly to FWCUGs). WSAss-004M is 0.02 acres and represents the parking area at the end of the driveway in front of former igloo WS-1. The acreage of WSAss-004M alone is too small to represent a residential exposure unit (EU). ISM sample WSAss-036M was collected in March 2010 to define the lateral extent of contamination around igloos WS-1 and WS-1A, including the area of sample

WSAss-004M. The PAH concentrations reported in WSAss-036M (ranging from not detected to 0.033 mg/kg) are more representative of the larger EU area and are below FWCUGs for the Resident (Adult and Child). Due to the low concentrations of PAHs reported in surrounding sample WSAss-036M and absence of an identified source of PAHs other than roads, vehicle exhaust, and building debris, PAHs were not identified as COCs for potential remediation in surface soil at Wet Storage Area.

Based on the risk management analysis, no COCs were identified to be carried forth in an FS for the Resident Receptor (Adult and Child) in any of the media of concern; therefore, no other receptors were evaluated and no further action is necessary to be protective of human health receptors.

ES.2.5 Summary of the Ecological Risk Assessment

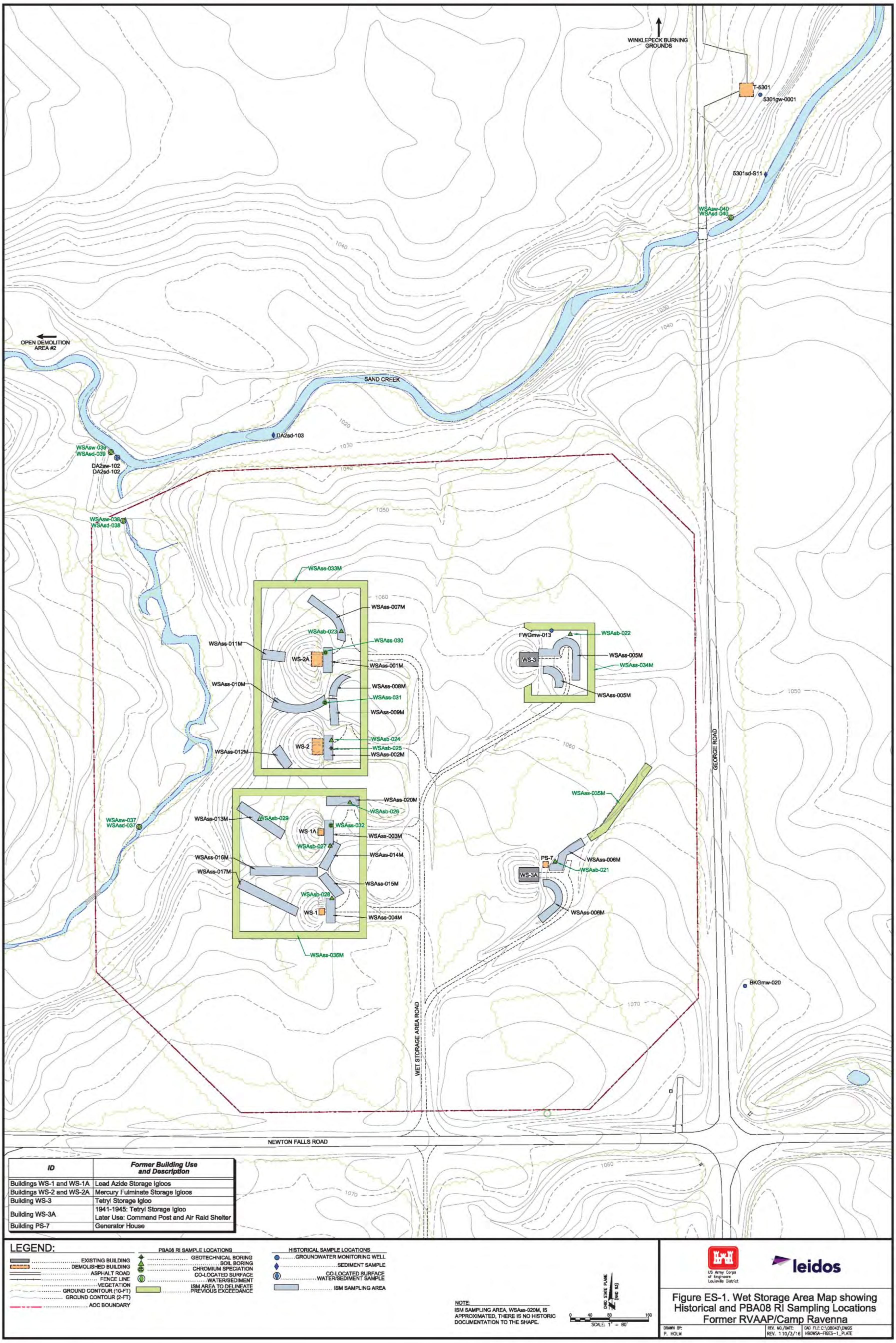
The Level I ERA presents important ecological resources on or near the AOC and evaluates the potential for current contamination to impact ecological resources. There is chemical contamination present in surface soil and sediment at Wet Storage Area. This contamination was identified using historical and PBA08 RI data. Various forest communities, shrubland, and other ecological resources were observed on the 36 acres in the AOC. There are important and significant ecological resources in the AOC. Specifically, wetlands and surface water (unnamed tributary to Sand Creek) are present and near contamination. These findings invoked a requirement of a Level II ERA.

The Level II ERA evaluated soil and sediment chemicals of potential ecological concern (COPECs). Seventeen integrated COPECs were identified for soil. Four integrated COPECs were identified for sediment. The integrated soil and sediment COPECs were further evaluated with technical and refinement factors in Step 3A. The factors in Step 3A showed there are no integrated COPECs that are of ecological concern requiring remediation or further evaluation. Consequently, the Level II Screening ERA for Wet Storage Area concludes with a recommendation that no further action is necessary to be protective of important ecological receptors.

ES.3 CONCLUSIONS OF THE REMEDIAL INVESTIGATION

Based on the investigation results, Wet Storage Area has been adequately characterized and the recommended path forward is no further action for soil, sediment, and surface water at Wet Storage Area to attain Unrestricted (Residential) Land Use. Further investigation is not warranted at this AOC for the following reasons: (1) the current nature and extent of impacted media has been sufficiently characterized; (2) the fate and transport modeling did not identify soil CMCOCs requiring further evaluation or remediation to protect groundwater; (3) there are no CERCLA release-related human health COCs identified in soil, sediment, or surface water requiring further evaluation in an FS or additional remediation; and (4) remedial actions to protect ecological resources are not warranted.

The next step in the CERCLA process is to prepare a PP to solicit public input with respect to no further action for soil, sediment, and surface water. The PP will briefly summarize the history, characteristics, risks, and the basis for no further action. Comments on the PP received from state and federal agencies and the public will be considered in preparing a ROD to document the final remedy. The ROD will also include a responsiveness summary addressing comments received on the PP.



ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

NOTE:
ISM SAMPLING AREA, WSAss-020M, IS APPROXIMATED, THERE IS NO HISTORIC DOCUMENTATION TO THE SHAPE.

Figure ES–1. Wet Storage Area Map Showing Historical and PBA08 RI Sampling Locations - Former RVAAP/Camp Ravenna

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1.0 INTRODUCTION

This document has been revised by Leidos under U.S. Army Corps of Engineers (USACE) Louisville District Contract Number W912QR-15-C-0046. This Remedial Investigation (RI) Report addresses soil, sediment, and surface water at Wet Storage Area within the former Ravenna Army Ammunition Plant (RVAAP) [now known as Camp Ravenna Joint Military Training Center (Camp Ravenna)] in Portage and Trumbull counties, Ohio (Figures 1-1 and 1-2). Wet Storage Area is designated as area of concern (AOC) RVAAP-45.

This report has been prepared in accordance with the requirements of the Ohio Environmental Protection Agency (Ohio EPA) *Director's Final Findings and Orders* (DFFO) for RVAAP, dated June 10, 2004 (Ohio EPA 2004). The DFFO requires conformance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP) to implement an RI to characterize the AOC, develop a Feasibility Study (FS) Report (if remediation is necessary) and evaluate remedial alternatives to address contamination presenting unacceptable risk to human health and the environment, present a preferred alternative in a proposed plan (PP), and document stakeholder selection and acceptance of the preferred final remedy in a record of decision (ROD).

This RI Report includes the following components:

- A description of the operational history and environmental setting for the AOC.
- A summary of all historical assessments and investigations at Wet Storage Area.
- A description of the nature and extent of contamination, including the identification of by screening applicable data against background concentrations, essential human nutrients, and frequency of detection/weight-of-evidence (WOE) screening.
- An evaluation of contaminant fate and transport by identifying contaminant migration chemicals of potential concern (CMCOPCs) and contaminant migration chemicals of concern (CMCOCs) that may pose a future threat to groundwater.
- A human health risk assessment (HHRA) to identify chemicals of potential concern (COPCs) and chemicals of concern (COCs).
- An ecological risk assessment (ERA) to identify chemicals of potential ecological concern (COPECs) and chemicals of ecological concern.
- Conclusions of the RI Report.

1.1 PURPOSE

The purpose of this RI Report is to use RI data to evaluate the nature and extent of contamination; fate and transport of contaminants in the environment; and risk assessments for surface and subsurface soil, sediment, and surface water at Wet Storage Area. This report includes sample results and information from the Characterization of 14 AOCs, and also provides a summary of the Performance-based Acquisition 2008 Remedial Investigation (PBA08 RI) at Wet Storage Area that was performed to supplement data from previous sampling events. Depending on the results of the evaluations contained in this report, a conclusion of no further action is provided or a recommendation to complete an FS to evaluate potential remedies and future actions will be made.

1.2 SCOPE

The scope of this RI Report is to present: (1) the nature and extent of contamination, fate and transport of contaminants in the environment, and risk assessments for surface and subsurface soil, sediment, and surface water at the AOC; (2) the results of the evaluation of remedial alternatives for meeting remedial action objectives for any CERCLA-related COCs identified in these media at the AOC; and (3) a conclusion of no further action or a preferred alternative to present to the public in a PP.

For the purposes of this report, the term “surface soil” includes dry sediment. Dry sediment refers to unconsolidated inorganic and organic material within conveyances, ditches, or low-lying areas that occasionally may be covered with water, usually following a precipitation event or due to snowmelt. Dry sediment is not covered with water for extended periods and typically is dry within seven days of a precipitation event. Dry sediment does not function as a permanent habitat for aquatic organisms, although it may serve as a natural medium for the growth of terrestrial organisms. Dry sediment is addressed the same as surface soil [0–1 ft below ground surface (bgs)] in terms of contaminant nature and extent, fate and transport, and risk exposure models. The term “sediment,” as used in this report, refers to wet sediment within conveyances, ditches, wetlands, or water bodies that are inundated for extended periods. These definitions and terminology usage are consistent with the *Facility-wide Human Health Cleanup Goals for the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2010a) (herein referred to as the FWCUG Report).

Potential impacts to groundwater from soil (e.g., contaminant leaching) are evaluated in this report, as protectiveness to groundwater is included in the fate and transport analysis. However, groundwater will be evaluated as an individual AOC for the entire facility (designated as RVAAP-66) and addressed in a separate RI/FS Report.

Four of six storage igloos and Building PS-7 have been demolished; however, two inactive igloos are currently present; therefore, they are not evaluated as continuing sources of contamination in this report. No sanitary or storm water sewer system exists within the AOC boundary.

1.3 REPORT ORGANIZATION

This report is organized in accordance with Ohio EPA and U.S. Environmental Protection Agency (USEPA) CERCLA RI/FS guidance and applicable USACE guidance. The following is a summary of the components of the report and a list of appendices:

- Section 2.0 provides a description and history of the former RVAAP and Wet Storage Area, presents potential sources of contamination, presents potential receptors, and summarizes co-located or proximate sites.
- Section 3.0 describes the environmental setting at Camp Ravenna and Wet Storage Area, including the geology, hydrogeology, climate, and population.
- Section 4.0 summarizes previous assessments and investigations at Wet Storage Area, as well as the data used to support this RI.
- Section 5.0 discusses the occurrence and distribution of contamination at the AOC.
- Section 6.0 presents an evaluation of contaminant fate and transport.
- Section 7.0 includes the methods and results of the HHRA and ERA.
- Section 8.0 provides the conclusions and recommendations of this RI.
- Section 9.0 summarizes the framework for conducting the necessary agency and public involvement activities.
- Section 10.0 provides a list of references used to develop this report.
- Appendices:
  Appendix A: Field Sampling Logs,
  Appendix B: Project Quality Assurance Summary,
  Appendix C: Data Quality Control Summary Report,
  Appendix D: Laboratory Analytical Results and Chains-of-Custody,
  Appendix E: Fate and Transport Modeling Results,
  Appendix F: Investigation-derived Waste Management Reports,
  Appendix G: Human Health Risk Assessment Tables,
  Appendix H: Ecological Risk Assessment Information and Data, and
  Appendix I: PBA08 RI Summary.

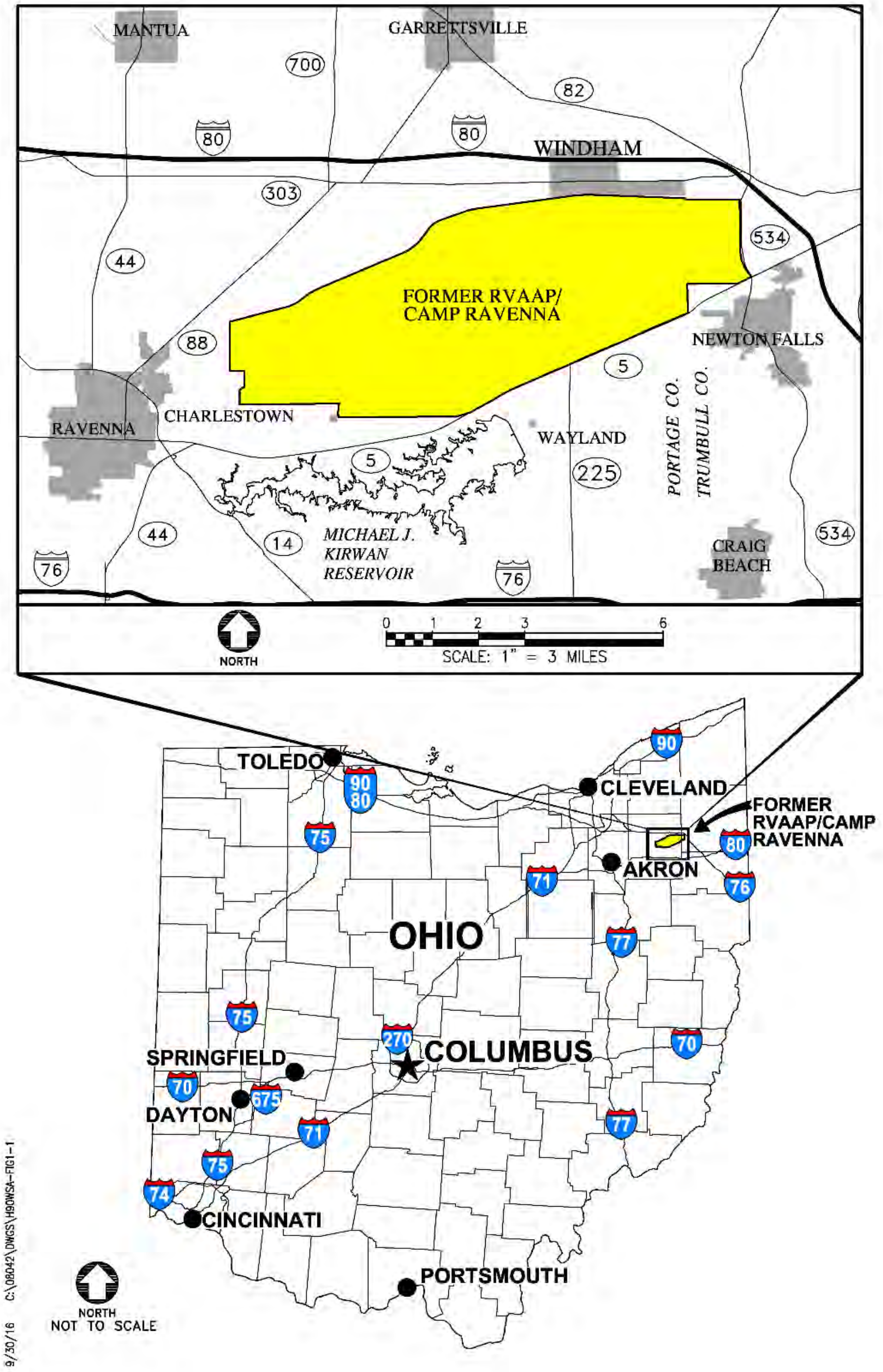

Figure 1–1. General Location and Orientation of Camp Ravenna

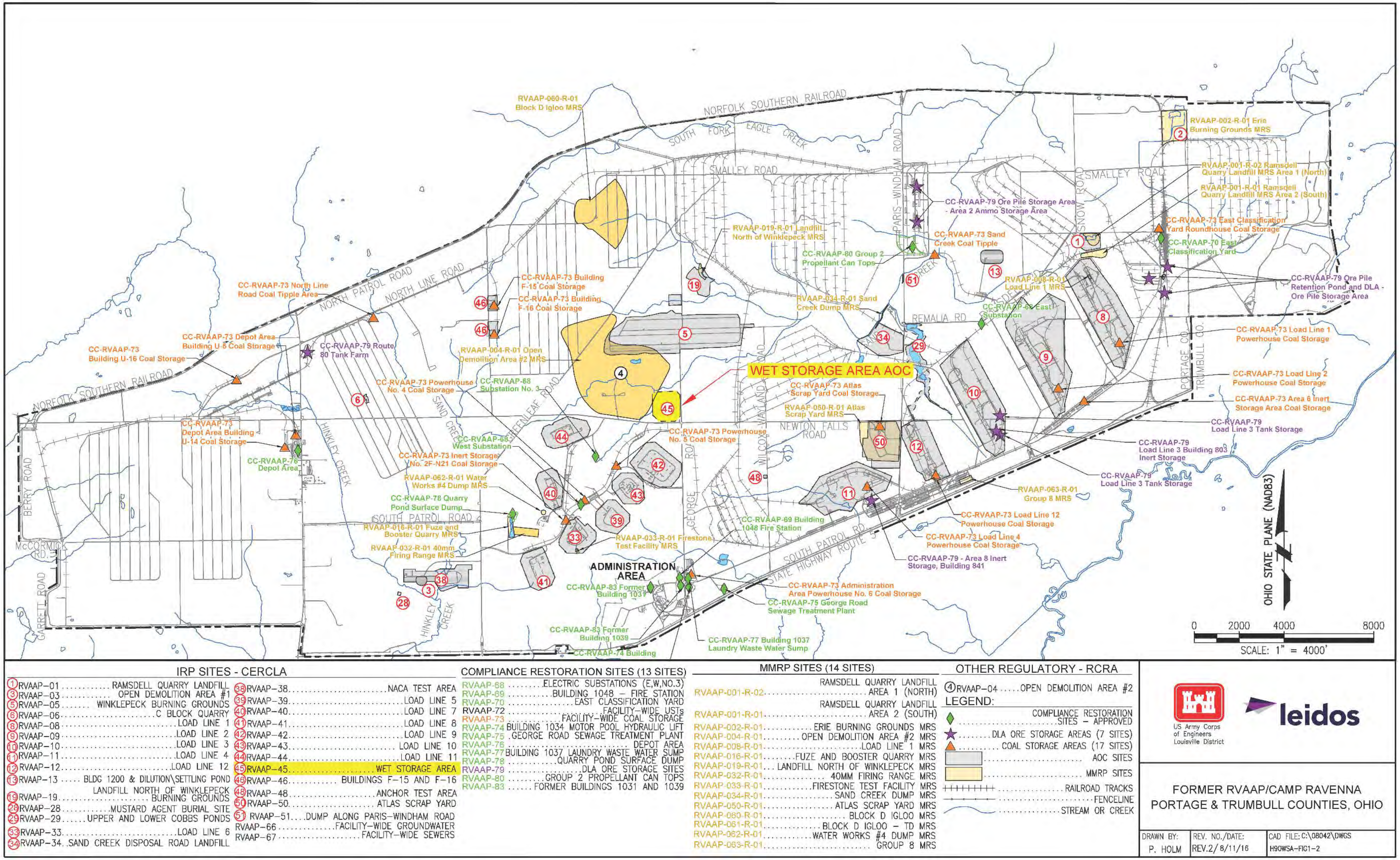

Figure 1–2. Location of AOCs and Munitions Response Sites at Camp Ravenna

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2.0 BACKGROUND

This section provides a description of the facility. In addition, it provides a summary of Wet Storage Area operational history, potential sources, building demolition activities, potential human health and ecological receptors, co-located or proximate sites, and potential site-related releases.

2.1 FACILITY-WIDE BACKGROUND INFORMATION

2.1.1 General Facility Description

The facility, consisting of 21,683 acres, is located in northeastern Ohio within Portage and Trumbull counties, approximately 4.8 kilometers (3 miles) east/northeast of the city of Ravenna and approximately 1.6 kilometers (1 mile) northwest of the city of Newton Falls (Figure 1-1). The facility, previously known as RVAAP, was formerly used as a load, assemble, and pack facility for munitions production. As of September 2013, administrative accountability for the entire acreage of the facility has been transferred to the U.S. Property and Fiscal Officer (USP&FO) for Ohio and subsequently licensed to the Ohio Army National Guard (OHARNG) for use as a military training site (Camp Ravenna). References in this document to RVAAP relate to previous activities at the facility as related to former munitions production activities or to activities being conducted under the restoration/cleanup program.

In 1978, the U.S. Army Toxic and Hazardous Materials Agency conducted an Installation Assessment of RVAAP to review the potential for contaminant release at multiple former operations areas, as documented in *Installation Assessment of Ravenna Army Ammunition Plant* (USATHAMA 1978). The Installation Assessment indicated the igloos at Wet Storage area contained the primary explosive lead azide. According to this assessment, from 1941–1945 Load Lines 5-11 produced 19,257,297 miscellaneous fuzes, 44,297,485 miscellaneous boosters, 79,580,576 miscellaneous detonators, 226,387,306 percussion elements, and 50,660,725 primers.

The former RVAAP received bulk 2,4,6-trinitrotoluene (TNT) product during operational activities and did not manufacture/produce dinitrotoluene (DNT) or TNT. A facility where DNT is manufactured will have the following isomers of DNT in the finished product: 2,4-DNT; 2,6-DNT; 2,5-DNT; 3,4-DNT; 2,3-DNT; and 3,5-DNT. This is not applicable to the former RVAAP. Degradation of TNT to 2,4-DNT occurs in soil; however, 2,4-DNT and 2,6-DNT do not degrade to the lesser isomers. It is the U.S. Department of the Army's (Army) position that testing DNT isomers other than 2,4- and 2,6-DNT is unnecessary and has no additional value of being protective to human health and the environment at the former RVAAP (RVAAP 2013).

2.1.2 Demography and Land Use

Camp Ravenna occupies east-central Portage County and southwestern Trumbull County. Census projections for 2010 indicated the populations of Portage and Trumbull counties are 161,419 and 210,312, respectively. Population centers closest to Camp Ravenna are Ravenna, with a population of 11,724, and Newton Falls, with a population of 4,795.

The facility is located in a rural area and is not close to any major industrial or developed areas. Approximately 55% of Portage County, in which the majority of Camp Ravenna is located, consists of either woodland or farmland acreage. The closest major recreational area, the Michael J. Kirwan Reservoir (also known as West Branch Reservoir), is located adjacent to the western half of Camp Ravenna, south of State Route 5.

Camp Ravenna is federally owned and is licensed to OHARNG for use as a military training site. Restoration activities at Camp Ravenna are managed by the Army National Guard and OHARNG. Training and related activities at Camp Ravenna include field operations and bivouac training, convoy training, maintaining equipment, C-130 aircraft drop zone operations, helicopter operations, and storing heavy equipment.

2.2 WET STORAGE AREA BACKGROUND INFORMATION

2.2.1 Operational History

Wet Storage Area is a 36-acre fenced AOC located near the geographic center of RVAAP (Figure 1-2 and 2-1). The AOC is located directly northwest of the intersection of George Road and Newton Falls Road. An unnamed tributary to Sand Creek is located in the western portion of the AOC, and Sand Creek is located outside of the AOC, north of the fence line.

From 1941–1945, Wet Storage Area was used to store highly explosive, shock-sensitive, primary explosives, including lead azide, mercury fulminate, and tetryl (USACHPPM 1998), and potentially nitroguanidine (USACE 2015). During storage activities, explosive material was containerized and covered with water within drums that were stored separately in six storage igloos at the AOC. Buildings WS-1 and WS-1A were used to store lead azide, and Buildings WS-2 and WS-2A were used to store mercury fulminate. Tetryl was stored at Buildings WS-3 and WS-3A. Historical drawings indicate igloo WS-3A was later used as a Command Post and as an air raid shelter. Building PS-7, Generator House, presumably serviced the adjacent Building WS-3A while being utilized as a Command Post. There is no documentation indicating any spills occurred at the AOC. No historical information exists to indicate a fuel storage tank was present at Wet Storage Area; however, Building PS-7 was a generator house, which likely used diesel fuel.

Four storage igloos located in the western portion of the AOC (designated WS-1, WS-1A, WS-2, and WS-2A) were built approximately 150 ft apart. Two igloos (WS-3 and WS-3A) are located in the eastern portion of the AOC and are spaced 400 ft apart. All six igloos were earth-covered, and the floors, walls, and ceilings were constructed of reinforced concrete. The four westernmost igloos were constructed with a conductive lead floor liner in order to dissipate static electricity.

During 2011 remedial action activities at RVAAP-004-R-01 Open Demolition Area #2 (ODA2) munitions response site (MRS), a temporary staging area was established in Wet Storage Area. This site is where the drums were stored that contained soil and debris contaminated with white phosphorus. The drums were inspected weekly until being transported offsite for disposal. The drum storage area was constructed along the access roadway within the Wet Storage Area perimeter fence, which consisted of a 3,000 tensile strength geotextile membrane placed on top of existing soil and covered with 6 inches of compacted #304 limestone gravel. PIKA International, Inc. constructed an earthen berm with capped drainage to the north and south of the drum staging area. The drum staging occurred between April and October 2011, and was documented in the *Disposal of Drums from RVAAP-004-R-01 Open Demolition Area #2 MRS Containing White Phosphorus Contaminated Soil and Debris and Stored in RVAAP-45 Wet Storage Area* (Toltest 2012). On-site accumulation times at the drum staging area for drum storage did not exceed 90 days [in accordance with the Ohio Administrative Code (OAC) 3745-52-34], and no more than 115 drums were stored at the staging area at any given time. A total of 517 drums of soil and debris contaminated with white phosphorus were transported by Triad Transport, Inc. and disposed at an approved off-site disposal facility. After being demobilized from Wet Storage Area, an inspection was requested by the RVAAP Facility Manager and was conducted along with the Ohio EPA on October 11, 2011. The area was considered acceptable, and there were no further actions required. All project activities were completed with no spills, leaks, accidents, or incidents (Toltest 2012).

As discussed in Section 2.2.3, four storage igloos (WS-1, WS-1A, WS-2, and WS-2A) (including slabs and foundations) were removed in 2003–2004. Remaining features at Wet Storage Area include storage igloos WS-3 and WS-3A and access roads that enter the AOC from the south. The Wet Storage Area perimeter fence is still in place, but it is not currently maintained. Small construction drainage ditches border the access roads near the igloo locations.

2.2.2 Potential Sources

Historical facilities at Wet Storage Area included six high explosives storage igloos and one support building ranging in size from 131–616 ft^2. The locations of the former storage igloos and generator house are shown on Figure 2-1 and in the aerial photograph shown in Figure 2-2.

Table 2-1 presents a summary of potential sources of contamination at Wet Storage Area. This table identifies potential sources, previous uses, if there were documented releases to the environment, and potential contaminants associated with the previous use. Some of the potential contaminants are documented; however, some professional judgment was made to determine if additional contaminants should be considered as products of historical use of the site.

The 1978 Installation Assessment identified the major contaminants of the former RVAAP to be TNT, composition B [a combination of TNT and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)], sulfates, nitrates, lead styphnate, and lead azide. Additional site-specific contaminants include mercury fulminate; tetryl; octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX); nitroglycerine; nitrocellulose; nitroguanidine (as identified in USACE 2015); and heavy metals (lead, chromium, mercury, and arsenic) from other secondary explosives storage activities. Polycyclic aromatic hydrocarbons (PAHs) from potential diesel fuel use at the Generator House (Building PS-7) and polychlorinated biphenyls (PCBs) from the on-site transformer are also considered site-specific contaminants. The evaluation of historical chemical contamination is not limited to these chemicals; rather, this evaluation is expanded to include all eligible chemical data that is available.

In summary, the following chemicals were targeted to investigate these potential site-related contaminants (SRCs):

- Inorganic chemicals – arsenic, chromium, lead, and mercury.
- Explosives and propellants – lead azide, mercury fulminate, tetryl, TNT, RDX, HMX, nitroglycerine, nitrocellulose, and nitroguanidine.
- Other – PAHs.

Many other chemicals were analyzed in the site investigations and are discussed in this report.

2.2.3 Building Decontamination and Demolition

Multiple activities were conducted at Wet Storage Area to decontaminate and demolish storage igloos, headwalls, slabs, and foundations. The following subsections summarize these activities.

2.2.3.1 <u>Thermal Decomposition and 5X Certification of Igloos WS-1, WS-1A, WS-2, and WS-2A</u>

Since the Wet Storage Area igloos were used for storing primary explosives (lead azide and mercury fulminate), four igloos (WS-1, WS-1A, WS-2, and WS-2A) were remediated for explosive contamination through thermal decomposition and 5X Certification prior to demolition, as documented in the *Thermal Decomposition and 5X Certification of Load Lines 6, 9 and Wet Storage Igloos 1, 1A, 2, & 2A* (MKM 2005). Thermal decomposition activities occurred in February 2003, and involved burning structures in-place to remove potentially explosive residue from building material in order to achieve a 5X status.

Prior to burning, the following activities took place or observations were made:

- Unexploded ordnance personnel conducted building walkthroughs to confirm existing conditions, and inspected wall, floor slab, and structural steel surfaces for explosives contamination and other potential explosive hazards. Wall and floor penetrations, openings/cavities, and large cracks were inspected to determine if accumulated explosives were present.
- Due to the condition of the wet storage igloos (i.e., not painted and high potential for the presence of residual explosives), floor sweeping was not conducted within these structures.
- No fluorescent lights or PCB light ballasts were present in igloos WS-1, WS-1A, WS-2, and WS-2A.
- No transite or other asbestos-containing material roofing material was present at igloos WS-1, WS-1A, WS-2, and WS-2A.

Based upon historical storage of primary explosives (lead azide and mercury fulminate) at these facilities, the target decomposition temperature for Wet Storage Area was 570°F. The igloos were loaded with clean wooden pallets to augment the burning process. The target temperature was sustained for a period of 30 min.

Following completion of the burn operations, composite samples of the resultant ash material were collected from each site for waste characterization purposes. Upon receiving the analytical results, the ash was collected and loaded into roll off containers during the debris removal operations for transport to the appropriate off-site permitted disposal facility.

2.2.3.2 2003-2004 Igloo Demolitions

Demolition and removal of headwalls, slabs, and foundations of storage igloos WS-1, WS-1A, WS-2, and WS-2A at Wet Storage Area were completed in 2003–2004 by the U.S. Army Tank-Automotive and Armaments Command as documented in the *Thermal Decomposition and 5X Certification of Load Lines 6, 9 and Wet Storage Igloos 1, 1A, 2, & 2A* (MKM 2005).

Demolition of the igloos was initiated in November 2003, and activities were completed in July 2004. Prior to demolition, the lead floor liners within the igloos were removed and recycled offsite. All above-grade concrete structures and floor slabs were removed from the four igloos, and any foundations were removed to 1 ft bgs. All concrete from the demolition of the four igloos was transported to the RVAAP-approved, clean hard-fill area in Load Line 1.

Following completion of demolition activities, confirmation samples were collected from beneath the sub-floors of the four igloos. On June 24, 2004, eight samples (WS1-001-CONF, WS1-002-CONF, WS1A-001-CONF, WS1A-002-CONF, WS2-001-CONF, WS2-002-CONF, WS2A-001-CONF, and WS2A-002-CONF) were collected at Wet Storage Area, with two sub-floor samples collected at each igloo location. The samples from WS-1 and WS-1A were analyzed for total lead, and the samples from WS-2 and WS-2A were analyzed for mercury. Results indicated no hazardous concentrations of the explosives lead azide or mercury fulminate were present (Table 2-2). All mercury sample results were reported below the facility-wide background concentration. Only one of the lead samples was detected slightly above the facility-wide background concentration at a concentration of 49 mg/kg in sample WS1A-001-CONF. Specific locations and data quality associated with the samples were not presented in the report (MKM 2005).

After the demolition activities, the earthen mounds were re-graded to ensure positive drainage and seeded and mulched. Final site restoration operations were completed at the Wet Storage Igloos in July 2004 (MKM 2005).

Remnant infrastructure within the eastern part of Wet Storage Area consists of refurbished and maintained igloos WS-3 and WS-3A (as of August 24, 2016); however, Building PS-7 is not present (there is no documentation of its removal). At the western portion of the AOC, the earthen mounds that backed the four demolished igloos are still visible. Wet Storage Area is forested with the exception of those areas within the AOC consisting of access roads and the former and extant igloos.

2.2.4 AOC Boundary

Wet Storage Area is an approximately 36-acre AOC bound by the existing perimeter fence, as presented in Figure 2-1. Wet Storage Area is located directly northwest of the intersection of George Road and Newton Falls Road, near the geographic center of RVAAP (Figure 1-2).

The surface and subsurface soil investigation at Wet Storage Area generally focused on soil within the AOC boundary or fence line and includes samples collected from the drainage ditches leading away from the storage igloos and adjacent to the earthen mounds. Potential off-AOC contaminant migration has been evaluated by the samples collected in ditch lines leading to the unnamed tributary to Sand Creek in the western portion of AOC, the eastern fence line, and from the unnamed tributary to Sand Creek. In addition to the samples collected within the AOC boundaries, this RI Report discusses samples WSAsd/sw-039 and WSAsd/sw-040 that were collected north of Wet Storage Area within Sand Creek to assess the potential transport beyond the AOC boundary.

2.3 POTENTIAL RECEPTORS AT WET STORAGE AREA

The following sections discuss potential human and ecological receptors at Wet Storage Area.

2.3.1 Human Receptors

Camp Ravenna is a controlled-access facility. Wet Storage Area is located near the geographic center of the facility and is not currently used for training (Figure 1-2).

In February 2014, the Army and Ohio EPA amended the risk assessment process to address changes in the RVAAP restoration program. The *Final Technical Memorandum: Land Uses and Revised Risk Assessment Process for the RVAAP Installation Restoration Program* (ARNG 2014) (herein referred to as the Technical Memorandum) identified the following three Categorical Land Uses and Representative Receptors to be considered during the RI phase of the CERCLA process.

1. Unrestricted (Residential) Land Use – Resident Receptor (Adult and Child) (formerly called Resident Farmer).
2. Military Training Land Use – National Guard Trainee.
3. Commercial/Industrial Land Use – Industrial Receptor (USEPA Composite Worker).

Unrestricted (Residential) Land Use is considered protective for all three Land Uses at Camp Ravenna. Therefore, if an AOC meets the requirements for Unrestricted (Residential) Land Use, then the AOC is also considered to have met the requirements of the other Land Uses (i.e., Commercial/Industrial and Military Training), and the other Land Uses do not require evaluation.

2.3.2 Ecological Receptors

Camp Ravenna has a diverse range of vegetation and habitat resources. Habitats present within the facility include large tracts of closed-canopy hardwood forest, scrub/shrub open areas, grasslands, wetlands, open-water ponds and lakes, and semi-improved administration areas.

An abundance of wildlife is present on the facility: 35 species of land mammals, 214 species of birds, 41 species of fish, and 34 species of amphibians and reptiles have been identified. The northern long-eared bat (*Myotis septentrionalis*; federally threatened) exists at Camp Ravenna. There are no other federally listed species and no critical habitat occurs (OHARNG 2014). Ohio state-listed plant and animal species have been identified through confirmed sightings and/or biological inventories at the facility and are presented in Table 2-3. With the exception of the clearing containing the mounds remaining from the former igloos, the two existing igloos (WS-3 and WS-3A) and adjacent hut (PS-7), and the access roads around these structures, Wet Storage Area is surrounded by forest. An unnamed tributary to Sand Creek is located in the western portion of the AOC, and Sand Creek is located outside of the AOC, north of the fence line. Additional information specific to ecological resources at Wet Storage Area is included in Section 7.3.

2.4 CO-LOCATED OR PROXIMATE SITES

The following subsections summarize sites that are co-located or proximate to Wet Storage Area but are addressed separately.

2.4.1 Facility-wide Sewers

There are no sanitary or storm water sewers within the perimeter of Wet Storage Area.

2.4.2 Facility-wide Groundwater

As part of the Installation Restoration Program, the Army implements the Facility-wide Groundwater Monitoring Program (FWGWMP) in accordance with previous agreements made with Ohio EPA. The FWGWMP was initiated in 2005 and involves quarterly sampling of selected wells within the former RVAAP. Monitoring well FWGmw-013 was installed in 2012 within Wet Storage Area, northeast of Building WS-3. Monitoring well BKGmw-020 is upgradient of the AOC, approximately 100 ft from the east Wet Storage Area fence line and on the opposite side of George Road (Figure 3-1).

In 2006–2007 and October 2009, the FWGWMP collected groundwater samples from BKGmw-020. Quarterly groundwater samples from FWGmw-013 were collected from April 2012 through January 2013. Most chemical concentrations in groundwater were below the maximum contaminant level (MCL) or regional screening level (RSL) [target risk (TR) of 1E-05, hazard quotient (HQ) of 1]. The only exception was manganese. Manganese exceeded the MCL (50 µg/L) and RSL of 1E-05 (430 µg/L) in each of the samples collected with a maximum concentration of 829 µg/L in the upgradient well (BKGmw-020) in the first quarter sampled.

Facility-wide groundwater AOC is currently at the RI phase of the CERCLA process. Any future decisions or actions respective to groundwater at Wet Storage Area will be addressed as part of that AOC.

2.4.3 Munitions Response Sites

No MRSs have been documented within Wet Storage Area.

2.4.4 Compliance Restoration Sites

There are no compliance restoration sites, such as former or existing underground storage tanks, within or adjacent to the AOC boundary.

2.5 POTENTIAL SITE-RELATED RELEASES

As presented in Table 2-1, there have been no documented site-related releases at Wet Storage Area. Table 2-1 presents potential contaminants that may be present in Wet Storage Area media from previous use of the site.

Table 2–1. Potential Source Area Description and Potential Impacts

Potential Sources or Areas for Investigation	Previous Use and/or Description	Documented Release	Potential Contaminants from Use
Buildings WS-1 and WS-1A	1941–1945: Buildings WS-1 and WS-1A were two high explosive storage igloos used for lead azide storage (primary explosive). These two underground storage structures were located in the western portion of the AOC and are spaced 150 ft apart. Each igloo was identical in size and design, and consisted of a storage house, vestibule, and headwall. The highly explosive and shock sensitive materials were stored in water-filled drums within each igloo. These igloos were earth-covered, and the floors, walls, and ceilings were constructed of reinforced concrete, and a conductive lead floor liner was in place in order to dissipate static electricity. These igloos were decontaminated and demolished in 2004, leaving only the adjacent earthen mounds.	None	Lead azide, nitroguanidine
Buildings WS-2 and WS-2A	1941–1945: Buildings WS-2 and WS-2A were two high explosive storage igloos used for mercury fulminate storage (primary explosive). These two underground storage structures were located in the western portion of the AOC and are spaced 150 ft apart. Each igloo was identical in size and design, and consisted of a storage house, vestibule, and headwall. The highly explosive and shock sensitive materials were stored in water-filled drums within each igloo. These igloos were earth-covered, and the floors, walls, and ceilings were constructed of reinforced concrete, and a conductive lead floor liner was in place in order to dissipate static electricity. These igloos were decontaminated and demolished in 2004, leaving only the adjacent earthen mounds.	None	Mercury fulminate, lead, nitroguanidine
Buildings WS-3 and WS-3A	1941–1945: Buildings WS-3 and WS-3A were two high explosive storage igloos used for tetryl storage. These two underground storage structures were located in the eastern portion of the AOC and are spaced 400 ft apart. Each igloo consisted of a storage house, vestibule, and headwall. The highly explosive and shock sensitive materials were stored in water-filled drums within each igloo. These igloos were earth-covered, and the floors, walls, and ceilings were constructed of reinforced concrete. Historical drawings also indicate that WS-3A was also used as a command post as well as an air raid shelter. In 2004, the two igloos were rehabilitated for administrative use and remain intact.	None	Tetryl, nitroguanidine
Building PS-7	Generator House, located near the northeast corner of Building WS-3A (which was later used as a Command Post and Air Raid Shelter). No documentation of fuel source or storage tank, presumably diesel fuel.	None	Diesel (PAHs)

Table 2–1. Potential Source Area Description and Potential Impacts (continued)

Potential Sources or Areas for Investigation	Previous Use and/or Description	Documented Release	Potential Contaminants from Use
Transformers	Historical PCB Disposition Records indicated 1 transformer located at Wet Storage Area and serviced the Command Post (Building WS-3A). The transformer was tested for PCBs and was non-detect for PCBs (<2ppm). The transformer was removed on September 30, 1992, and stored at Building 854 (RVAAP-27, PCB Storage) awaiting final disposition by the Defense Reutilization Material Office.	None	PCBs

Target metals = Lead, chromium, mercury, and arsenic.
Target explosives = Black powder; 2,4,6-trinitrotoluene; octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocane; and hexahydro-1,3,5-trinitro-1,3,5-triazine.
AOC = Area of concern.
ft = Feet.
PAH = Polycyclic aromatic hydrocarbon.
PCB = Polychlorinated biphenyl.
Ppm = Parts per million.
< = less than.

Table 2–2. Subfloor Soil Confirmation Results from 2004 Igloo Demolitions

Sample ID	Soil Background Criteria (0-1 ft) mg/kg	Region 9 PRG Data (Residential Soil) mg/kg	WS1-001-CONF	WS1-002-CONF	WS1A-001-CONF	WS1A-002-CONF	WS2-001-CONF	WS2-002-CONF	WS2A-001-CONF	WS2A-002-CONF
Igloo ID			**WS-1**	**WS-1**	**WS-1A**	**WS-1A**	**WS-2**	**WS-2**	**WS-2A**	**WS-2A**
Sample Date			**6/24/2004**	**6/24/2004**	**6/24/2004**	**6/24/2004**	**6/24/2004**	**6/24/2004**	**6/24/2004**	**6/24/2004**
Metals			**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Lead	26.1	400	20	18	**49**	16	NT	NT	NT	NT
Mercury	0.04	23	NT	NT	NT	NT	0.028	0.025	0.037	0.018 (B)

Source: *Thermal Decomposition and 5X Certification of Load Lines 6, 9 and Wet Storage Igloos 1, 1A, 2, & 2A* (MKM 2005).
bgs = Below ground surface.
ft = Feet.
ID = Identification.
mg/kg = Milligrams per kilogram.
NT = Not tested.
PRG = Preliminary remediation goal.
B = Result is less than contract required detection limit/reporting limit but greater than or equal to instrument detection limit /method detection limit.
Bold = Concentration greater than Region 9 PRG data.

Table 2–3. Federal- and State-listed Species List

CAMP RAVENNA JOINT MILITARY TRAINING CENTER RARE SPECIES LIST

December 2014

I. Species confirmed to be on Camp Ravenna property by biological inventories and confirmed sightings.

A. Federal Threatened

1. Northern long-eared bat, *Myotis septentrionalis*

B. State Endangered

1. American bittern, *Botaurus lentiginosus* (migrant)
2. Northern harrier, *Circus cyaneus*
3. Sandhill Crane, *Grus Canadensis* (probable nester)
4. Black bear, *Ursus americanus*
5. Mountain Brook Lamprey, *Ichthyomyzon greeleyi*
6. Brush-tipped emerald, *Somatochlora walshii*
7. Graceful Underwing, *Catocala gracilis*
8. Tufted Moisture-loving Moss, *Philonotis Fontana var. caespitosa*
9. Appalachian quillwort, *Isoetes engelmannii*
10. Handsome sedge, *Carex formosa*
11. Narrow-necked Pohl's Moss, *Pohlia elongata var. elongate*
12. Philadelphia panic-grass, *Panicum philadelphicum*
13. Variegated scouring-rush, *Equisetum variegatum*

C. State Threatened

1. Barn owl, *Tyto alba*
2. Least bittern, *Ixobrychus exilis*
3. Trumpeter swan, *Cygnus buccinators* (migrant)
4. Bobcat, *Felis rufus*
5. Caddis fly, *Psilotreta indecisa*
6. Northern long-eared bat, *Myotis septentrionalis*
7. Hobblebush, *Viburnum alnifolium*
8. Simple willow-herb, *Epilobium strictum*
9. Lurking leskea, *Plagiothecium latebricola*
10. Strict blue-eyed grass, *Sisyrinchium montanum*

D. State Potentially Threatened Plants

1. Arborvitae, *Thuja occidentalis*
2. False hop sedge, *Carex lupiliformis*
3. Greenwhite sedge, *Carex albolutescens*
4. Long Beech Fern, *Phegopteris connectilis* (*Thelypteris phegopteris*)
5. Pale sedge, *Carex pallescens*
6. Sharp-glumed manna-grass, *Glyceria acutifolia*
7. Straw sedge, *Carex straminea*
8. Water avens, *Geum rivale*
9. Woodland Horsetail, *Equisetum sylvaticum*
10. Shining ladies'-tresses, *Spiranthes lucida*

E. State Species of Concern

1. Big brown bat, *Eptesicus fuscus*
2. Deer mouse, *Peromyscus maniculatus*
3. Eastern red bat, *Lasiurus borealis*
4. Hoary bat, *Lasiurus cinereus*
5. Little brown bat, *Myotis lucifugus*
6. Pygmy shrew, *Sorex hovi*
7. Southern bog lemming, *Svnaptomys cooperi*
8. Star-nosed mole, *Condylura cristata*
9. Tri-colored bat, *Perimyotis subflavus*
10. Woodland jumping mouse, *Napaeozapus insignis*
11. Sharp-shinned hawk, *Accipiter striatus*
12. Marsh wren, *Cistothorus palustris*
13. Henslow's sparrow, *Ammodramus henslowii*
14. Cerulean warbler, *Dendroica cerulean*
15. Prothonotary warbler, *Protonotaria citrea*
16. Bobolink, *Dolichonyx oryzivorus*
17. Northern bobwhite, *Colinus virginianus*
18. Common moorhen, *Gallinula chloropus*
19. Great egret, *Ardea alba* (migrant)
20. Sora, *Porzana carolina*
21. Virginia Rail, *Rallus limicola*
22. Yellow-bellied Sapsucker, *Sphyrapicus varius*
23. Creek heelsplitter, *Lasmigona compressa*
24. Eastern box turtle, *Terrapene carolina*
25. Four-toed Salamander, *Hemidacrylium scutatum*
26. Eastern garter snake, *Thamnophis sirtalis*
27. Smooth green snake, *Opheodrys vernalis*
28. Eastern sand darter, *Ammocrypta pellucida*
29. Mayfly, *Stenonema ithica*
30. Moth, *Apamea mixta*
31. Moth, *Brachylomia algens*
32. Scurfy quaker, *Homorthodes furfurata*
33. Sedge wren, *Cistothorus platensis*

Table 2–3. Federal- and State-listed Species List (continued)

CAMP RAVENNA JOINT MILITARY TRAINING CENTER RARE SPECIES LIST
December 2014

F. State Special Interest

1. American black duck, *Anas rubripes*
2. Canada warbler, *Wilsonia Canadensis*
3. Dark-eyed junco, *Junco hyemalis* (migrant)
4. Hermit thrush, *Catharus guttatus* (migrant)
5. Least flycatcher, *Empidonax minimus*
6. Magnolia warbler, *Dendroica magnolia*
7. Northern waterthrush, *Seiurus noveboracensis*
8. Winter wren, *Troglodytes troglodytes*
9. Back-throated blue warbler, *Dendroica caerulescens*
10. Brown creeper, *Certhia Americana*
11. Mourning warbler, *Oporornis Philadelphia*
12. Pine siskit, *Carduelis pinus*
13. Purple finch, *Carpodacus purpureus*
14. Red-breasted nuthatch, *Sitta Canadensis*
15. Golden-crowned kinglet, *Regulus satrapa*
16. Blackburnian warbler, *Dendroica fusca*
17. Gadwall, *Anas strepera*
18. Green-winged teal, *Anas crecca*
19. Northern shoveler, *Anas clypeata*
20. Redhead duck, *Aytya Americana*
21. Ruddy duck, *Oxyura jamaicensis*
22. Wilson's snipe, *Gallinago delicata*
23. Subflava sedge borer, *Capsula subflava*

Note: The Integrated Natural Resource Management Plan (OHARNG 2014) indicated that no federally listed species are known to reside at Camp Ravenna, and no critical habitat occurs. However, the northern long-eared bat exists at Camp Ravenna and was expected to be listed as an endangered species in mid-2015. Accordingly, this table indicates the northern long-eared bat is federally threatened (USFWS 2016) and state threatened (ODNR 2016).

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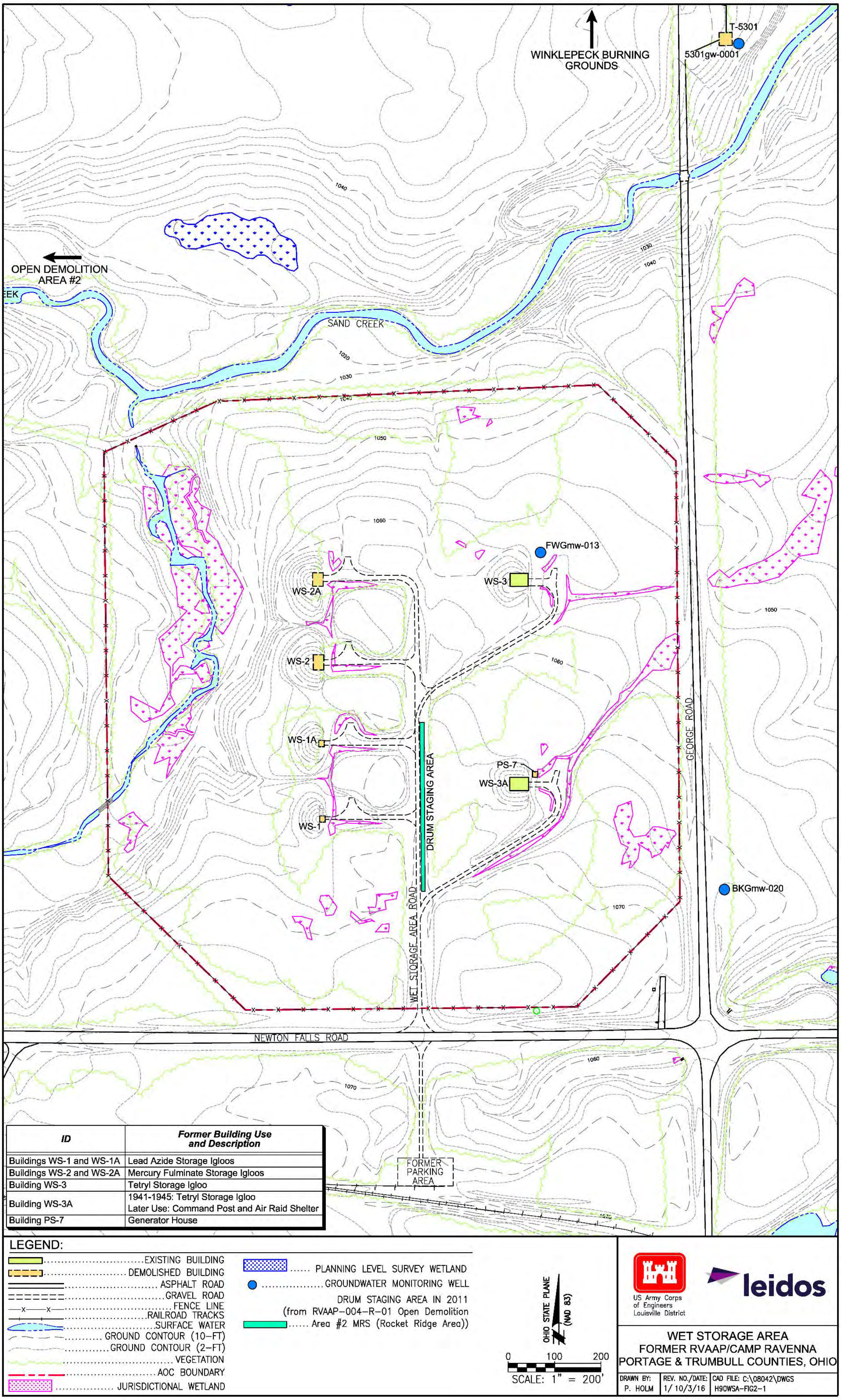

ID	***Former Building Use and Description***
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

Figure 2–1. Wet Storage Area Site Features

ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

LEGEND:

▬	SURFACE WATER
- -	AOC BOUNDARY

NOTE:
SOURCE OF AERIAL PHOTO: GOOGLE EARTH, USGS–THE NATIONAL MAP, IMAGE DATE: 12/31/2002

WET STORAGE AREA
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\08042\DWGS
P. HOLM	1/ 10/3/16	H90WSA-FIG2-2

Figure 2–2. Wet Storage Area Site Features Prior to Building Demolition (Aerial Photo dated 12/31/2002)

3.0 ENVIRONMENTAL SETTING

This section describes the physical features, topography, geology, hydrogeology, and environmental characteristics of Camp Ravenna and Wet Storage Area that are factors in identifying the potential contaminant transport pathways, receptor populations, and exposure scenarios to evaluate human health and ecological risks.

3.1 CAMP RAVENNA PHYSIOGRAPHIC SETTING

Camp Ravenna is located within the southern New York section of the Appalachian Plateaus physiographic province (USGS 1968). This province is characterized by elevated uplands underlain primarily by Mississippian-age and Pennsylvanian-age bedrock units that are horizontal or gently dipping. The province is also characterized by its rolling topography with incised streams having dendritic drainage patterns. The southern New York section has been modified by glaciation, which rounded ridges, filled major valleys, and blanketed many areas with glacially-derived unconsolidated deposits (e.g., sand, gravel, and finer-grained outwash deposits). As a result of glacial activity in this section, old stream drainage patterns were disrupted in many locales, and extensive wetland areas developed.

3.2 SURFACE FEATURES AND AOC TOPOGRAPHY

The topography of Camp Ravenna is gently undulating with an overall decrease in ground elevation from a topographic high of approximately 1,220 ft above mean sea level (amsl) in the far western portion of the facility to low areas at approximately 930 ft amsl in the far eastern portion of the facility. USACE mapped the facility topography in February 1998 using a 2-ft (60.1-cm) contour interval with an accuracy of 0.02 ft (0.61 cm). USACE based the topographic information on aerial photographs taken during the spring of 1997. The USACE survey is the basis for the topographical information illustrated in figures included in this report.

Wet Storage Area is an approximately 36-acre AOC located directly northwest of the intersection of George Road and Newton Falls Road, near the geographic center of Camp Ravenna (Figure 1-2). A fence exists as the perimeter boundary of the AOC, although it is not currently maintained.

Four of the six igloos (WS-1, WS-1A, WS-2, and WS-2A) within the Wet Storage Area fence line have been demolished, and building slabs and footers have been removed. Soil in the vicinity of former production buildings was extensively disturbed during building demolition activities. The work areas were re-graded, cavities were filled with existing mound dirt as needed, and the area was vegetated following the building decontamination and demolition activities discussed in Section 2.2.3. The remaining surface features at Wet Storage Area consist of the access roads within the AOC, two refurbished igloos in the eastern portion of the AOC, and residual earthen mounds from the demolished igloos in the western portion of the AOC (Figures 2-1 and 3-1). Small drainage ditches border some portions of the access roads, and drainage conveyances are located throughout the AOC boundary.

Wet Storage Area is located on a topographic high relative to adjacent streams. Ground elevations within Wet Storage Area range from approximately 1,028–1,077 ft amsl (Figure 3-1). The former operations area of the AOC is generally flat to gently sloping. The extent of Wet Storage Area is defined by a fence line surrounding the entire AOC. The terrain west of the razed igloos falls steeply toward the unnamed tributary to Sand Creek.

3.3 SOIL AND GEOLOGY

3.3.1 Regional Geology

The regional geology at Camp Ravenna consists of horizontal to gently dipping bedrock strata of Mississippian and Pennsylvanian age overlain by varying thicknesses of unconsolidated glacial deposits. The bedrock and unconsolidated geology at Camp Ravenna and the geology specific to Wet Storage Area are presented in the following subsections.

3.3.2 Soil and Glacial Deposits

Bedrock at Camp Ravenna is overlain by deposits of the Wisconsin-aged Lavery Till in the western portion of the facility and the younger Hiram Till and associated outwash deposits in the eastern two-thirds of the facility (Figure 3-2). Unconsolidated glacial deposits vary considerably in their character and thickness across Camp Ravenna, from zero in some of the eastern portions of the facility to an estimated 150 ft in the south-central portion.

Thin coverings of glacial material have been completely removed as a consequence of human activities at locations such as Ramsdell Quarry. Bedrock is present at or near the ground surface in locations such as at Load Line 1 and the Erie Burning Grounds (USACE 2001b). Where this glacial material is still present, the distribution and character indicate their origin as ground moraine. These tills consist of laterally-discontinuous assemblages of yellow-brown, brown, and gray silty clays to clayey silts, with sand and rock fragments. Lacustrine sediment from bodies of glacial-age standing water also has been encountered in the form of deposits of uniform light gray silt greater than 50-ft thick in some areas (USACE 2001b).

Soil at Camp Ravenna is generally derived from the Wisconsin-age silty clay glacial till. Distributions of soil types are discussed and mapped in the *Soil Survey of Portage County, Ohio*, which describes soil as nearly level to gently sloping and poor to moderately well drained (USDA 1978). Much of the native soil at Camp Ravenna was disturbed during construction activities in former production and operational areas of the facility.

The Sharon Member of the Pennsylvanian Pottsville Formation is the primary bedrock beneath Camp Ravenna. In the western half of the facility, the upper members of the Pottsville Formation, including the Connoquenessing Sandstone (also known as the Massillon Sandstone), Mercer Shale, and uppermost Homewood Sandstone, have been found. The regional dip of the Pottsville Formation measured in the west portion of Camp Ravenna is between 5–11.5 ft per mile to the south.

3.3.3 Geologic Setting of Wet Storage Area

The bedrock formation underlying the unconsolidated deposits at Wet Storage Area, as inferred from existing geologic data, is the Pennsylvanian-age Pottsville Formation, Sharon Shale Member (Figure 3-3). The Sharon Shale Member is a gray to black sandy shale containing thin coal, underclay, sandstone, and siderite zones. The Sharon Shale is generally fissile. Prior to the PBA08 RI, no investigations included subsurface characterization at Wet Storage Area, and no monitoring wells were located at the AOC (at the time of the PBA08 RI). During the PBA08 RI, weathered bedrock was encountered at 23.3 ft bgs in the western portion of the AOC (Appendix A). However, Sharon Shale was encountered in shallower soil at 11 ft bgs and Sharon Sandstone was encountered at 29.4 ft bgs during the 2012 installation of monitoring well FWGmw-013 in the northeastern portion of the AOC (EQM 2012).

Wet Storage Area is located within Hiram Till glacial deposits. The primary soil types found at Wet Storage Area are the Mahoning silt loam (2-6% slopes), which covers approximately 90% of the AOC, and the Ellsworth silt loam (6-12% slopes) along the western and northern edges of the AOC as soil slopes to the creek (USDA 2010). Mahoning silt loam is a gently sloping, poorly-drained soil formed in silty clay loam or clay loam glacial till, generally where bedrock is greater than 6 ft bgs. The Mahoning silt loam has low permeability, rapid runoff, and seasonal wetness. The Ellsworth series consists of gently sloping to steep slopes of soil located adjacent to drainageways formed in silty clay loam and silty clay glacial till. The Ellsworth silt loam is moderately well drained, with rapid runoff and potential for severe erosion.

Geologic descriptions and geotechnical analyses of subsurface soil samples collected during the PBA08 RI indicate the soil consists predominantly of clay to sand-rich silt tills. Discontinuous saturated silty-sand seams were observed in three subsurface borings from 7.5–10.3 ft bgs across the AOC. Two undisturbed geotechnical samples were collected during the PBA08 RI. The geotechnical sample collected from 4–5.2 ft bgs was characterized as clay-rich silt. The geotechnical sample collected from 12–13.1 ft bgs was characterized as sand-rich silt. A summary of the PBA08 RI geotechnical analyses, including porosity, density, and moisture content, is presented in Section 5.4.5 and Table 5-2. PBA08 RI boring logs containing geologic descriptions of unconsolidated deposits at Wet Storage Area are presented in Appendix A.

3.4 HYDROGEOLOGY

3.4.1 Regional Hydrogeology

Sand and gravel aquifers are present in the buried-valley and outwash deposits in Portage County, as described in the *Phase I Remedial Investigation Report for High-Priority Areas of Concern* (USACE 1998). Generally, these saturated zones are too thin and localized to provide large quantities of water for industrial or public water supplies; however, yields are sufficient for residential water supplies. Lateral continuity of these aquifers is unknown. Recharge of these units comes from surface water infiltrating precipitation and surface streams. Specific groundwater recharge and discharge areas at Camp Ravenna have not been delineated.

The thickness of the unconsolidated interval at Camp Ravenna ranges from thin to absent in the eastern and northeastern portion of Camp Ravenna to an estimated 150 ft (46 m) in the central portion of the facility. The groundwater table occurs within the unconsolidated zone in many areas of the facility. Because of the heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns are difficult to determine with a high degree of accuracy. Vertical recharge from precipitation likely occurs via infiltration along root zones, desiccation cracks, and partings within the soil column. Laterally, most groundwater flow likely follows topographic contours and stream drainage patterns, with preferential flow along pathways (e.g., sand seams, channel deposits, or other stratigraphic discontinuities) having higher permeabilities than surrounding clay or silt-rich material. Figure 3-4 illustrates facility-wide potentiometric surface data in the unconsolidated interval from the January 2010 contemporaneous measurement event (EQM 2010).

Within bedrock units at Camp Ravenna, the principle water-bearing aquifer is the Sharon Sandstone/Conglomerate. Depending on the existence and depth of overburden, the Sharon Sandstone/Conglomerate ranges from an unconfined to a leaky artesian aquifer. Water yields from on-site water supply wells completed in the Sharon Sandstone/Conglomerate ranged from 30–400 gallons per minute (gpm) (USATHAMA 1978). Well yields of 5–200 gpm were reported for on-site bedrock wells completed in the Sharon Sandstone/Conglomerate (Kammer 1982). Other local bedrock units capable of producing water include the Homewood Sandstone, which is generally thinner and only capable of well yields less than 10 gpm, and the Connoquenessing Sandstone. Wells completed in the Connoquenessing Sandstone in Portage County have yields ranging from 5–100 gpm but are typically less productive than the Sharon Sandstone/Conglomerate due to lower permeabilities (Winslow et al. 1966).

Figure 3-5 shows the potentiometric surface within bedrock strata at Camp Ravenna in January 2010 (EQM 2010). The bedrock potentiometric map shows a more uniform and regional eastward flow direction than the unconsolidated zone that is not as affected by local surface topography. Due to the lack of well data in the western portion of Camp Ravenna, general flow patterns are difficult to discern. For much of the eastern half of Camp Ravenna, bedrock potentiometric elevations are higher than the overlying unconsolidated potentiometric elevations, indicating an upward hydraulic gradient. This evidence suggests there is a confining layer that separates the two aquifers. In the far eastern area, the two potentiometric surfaces are at approximately the same elevation, suggesting that hydraulic communication between the two aquifers is occurring.

3.4.2 Wet Storage Area Hydrologic/Hydrogeologic Setting

Groundwater at RVAAP is evaluated on a facility-wide basis, sampled under the FWGWMP, and will be evaluated through the CERCLA process in a separate report. Potential leaching of soil contaminants to groundwater is evaluated through fate and transport modeling.

During the PBA08 RI, the nearest monitoring well was BKGmw-020, located approximately 100 ft from the east Wet Storage Area fence line and on the opposite side of George Road from Wet Storage Area (Figure 3-1). Well gauging data collected at this well during the January 2010 facility-wide groundwater sampling event indicated a water level at 20.14 ft below top of casing (btoc) (EQM 2010)

[1,044.86 ft amsl (USACE 2001b)]. Monitoring well BKGmw-020 is completed in bedrock to a depth of 30.7 ft bgs (1,034.30 ft amsl). The generalized regional groundwater flow direction in the vicinity of Wet Storage Area is towards Sand Creek to the north, based on the results of facility-wide groundwater monitoring.

However, an additional monitoring well (FWGmw-013) was installed near storage igloo WS-3 within Wet Storage Area under the FWGWMP in 2012 (Figure 3-1). This monitoring well was completed to 34.5 ft bgs (1058.97 ft amsl) and screened in the Sharon Sandstone to monitor groundwater in the bedrock (EQM 2015). Initial depth to groundwater was 17.05 ft btoc (1041.92 ft amsl). The groundwater elevation for FWGmw-013 was 16.18 ft btoc (1043.33 ft amsl) in May 2014 (EQM 2015) and 17.31 ft btoc (1042.20 ft amsl) in July 2015 (TEC-WESTON 2016).

3.4.3 Surface Water

The following sections describe the regional and AOC-specific surface water.

3.4.3.1 Regional Surface Water

Camp Ravenna resides within the Mahoning River watershed, which is part of the Ohio River basin. The west branch of the Mahoning River is the main surface stream in the area. The west branch flows adjacent to the west end of the facility, generally in a north to south direction, before flowing into the Michael J. Kirwan Reservoir, located to the south of State Route 5 (Figure 1-1). The west branch flows out of the reservoir and parallels the southern Camp Ravenna boundary before joining the Mahoning River east of Camp Ravenna. The western and northern portions of Camp Ravenna display low hills and a dendritic surface drainage pattern. The eastern and southern portions are characterized by an undulating to moderately level surface, with less dissection of the surface drainage. The facility is marked with marshy areas and flowing and intermittent streams whose headwaters are located in the upland areas of the facility.

The three primary watercourses that drain Camp Ravenna are (Figure 1-2):

- South Fork Eagle Creek,
- Sand Creek, and
- Hinkley Creek.

These watercourses have many associated tributaries. Sand Creek, with a drainage area of 13.9 square miles, generally flows in a northeast direction to its confluence with South Fork Eagle Creek. In turn, South Fork Eagle Creek continues in a northerly direction for 2.7 miles to its confluence with Eagle Creek. The drainage area of South Fork Eagle Creek is 26.2 square miles, including the area drained by Sand Creek. Hinkley Creek originates just southeast of the intersection between State Route 88 and State Route 303 to the north of the facility. Hinkley Creek, with a drainage area of 11 square miles, flows in a southerly direction through the facility, and converges with the west branch of the Mahoning River south of the facility (USACE 2001a).

Approximately one-third of Camp Ravenna meets the regulatory definition of a wetland, with the majority of the wetland areas located in the eastern portion of the facility. Wetland areas at RVAAP include seasonal wetlands, wet fields, and forested wetlands. Many of the wetland areas are the result of natural drainage or beaver activity; however, some wetland areas are associated with anthropogenic settling ponds and drainage areas.

Approximately 50 ponds are scattered throughout the facility. Many were constructed within natural drainageways to function as settling ponds or basins for process effluent and runoff. Others are natural in origin, resulting from glacial action or beaver activity. Water bodies at Camp Ravenna could support aquatic vegetation and biota as described in Section 2.3.2. Storm water runoff is controlled primarily by natural drainage, except in former operations areas where an extensive storm sewer network helps direct runoff to drainage ditches and settling ponds. In addition, the storm sewer system was one of the primary drainage mechanisms for process effluent while production facilities were operational.

3.4.3.2 Wet Storage Area Surface Water

Perennial surface water at Wet Storage Area is present within the unnamed tributary on the west side of the AOC which flows from south to north and enters into Sand Creek northwest of the AOC. Sand Creek flows from west to east roughly parallel to the northern fence line of Wet Storage Area, turning more northward after crossing under George Road. Sand Creek drains to the northeast into South Fork Eagle Creek.

A drainage divide that is oriented in an east/west direction divides the centerline of the igloos. The terrain west of the razed igloos falls steeply toward the unnamed tributary to Sand Creek. Within the former operational area at Wet Storage Area, surface water only occurs as intermittent storm water runoff associated with heavy rainfall events and travels as either overland flow or within discontinuous ditch lines immediately adjacent to the intra-AOC access roads (Figure 3-1). Surface water drainage generally follows the topography of the AOC toward the west and the north. During the 2010 PBA08 RI, surface water was observed throughout the AOC flowing through ditches in some areas. Surface water flow is the primary migration pathway for contamination to leave the AOC flowing through ditches or surface water drainage features that exit the AOC. A storm sewer system is not present at Wet Storage Area.

Significant aquatic and wetland resources exist on and near the AOC. A wetland delineation conducted in 2006 identified 26 wetlands of varying sizes and quality (from Category 1 to Category 3) on the AOC (EnviroScience 2006). Most wetlands on the AOC are associated with drainage conveyances or ditches. A wetland complex consisting of approximately 1.2 acres of high quality, Category 3 wetlands exists on the floodplain of the unnamed tributary to Sand Creek along the western edge of the AOC. This wetland complex is considered a potentially significant ecological resource.

3.5 CLIMATE

The general climate of Camp Ravenna is continental and is characterized by moderately warm and humid summers, reasonably cold and cloudy winters, and wide variations in precipitation from year to year. The climate data presented below for Camp Ravenna were obtained from available National Weather Service records for the 30-year period of record from 1981–2010 at the Youngstown Regional Airport, Ohio (http://www.weather.gov/climate/xmacis.php?wfo=cle). Wind speed data for Youngstown, Ohio, are from the National Climatic Data Center (http://www1.ncdc.noaa.gov/pub/data/ccd-data/wndspd14.txt) for the available 30-year period of record from 1984–2014.

Average annual rainfall at Camp Ravenna is 38.86 inches, with the highest monthly average occurring in July (4.31 inches) and the lowest monthly average occurring in February (2.15 inches). Average annual snowfall totals approximately 62.9 inches, with the highest monthly average occurring in January (17.1 inches). Due to the influence of lake-effect snowfall events associated with Lake Erie (located approximately 35 miles to the northwest of Camp Ravenna), snowfall totals vary widely throughout northeastern Ohio.

The average annual daily temperature in the Camp Ravenna area is 49.3ºF, with an average daily high temperature of 70.9ºF and an average daily low temperature of 26.1ºF. The record high temperature of 100ºF occurred in July 1988, and the record low temperature of -22ºF occurred in January 1994. The prevailing wind direction at Camp Ravenna is from the southwest, with the highest average wind speed occurring in January (10.3 miles per hour) and the lowest average wind speed occurring in August (6.5 miles per hour). Thunderstorms occur approximately 35 days per year and are most abundant from April through August. Camp Ravenna is susceptible to tornadoes; minor structural damage to several buildings on facility property occurred as the result of a tornado in 1985.

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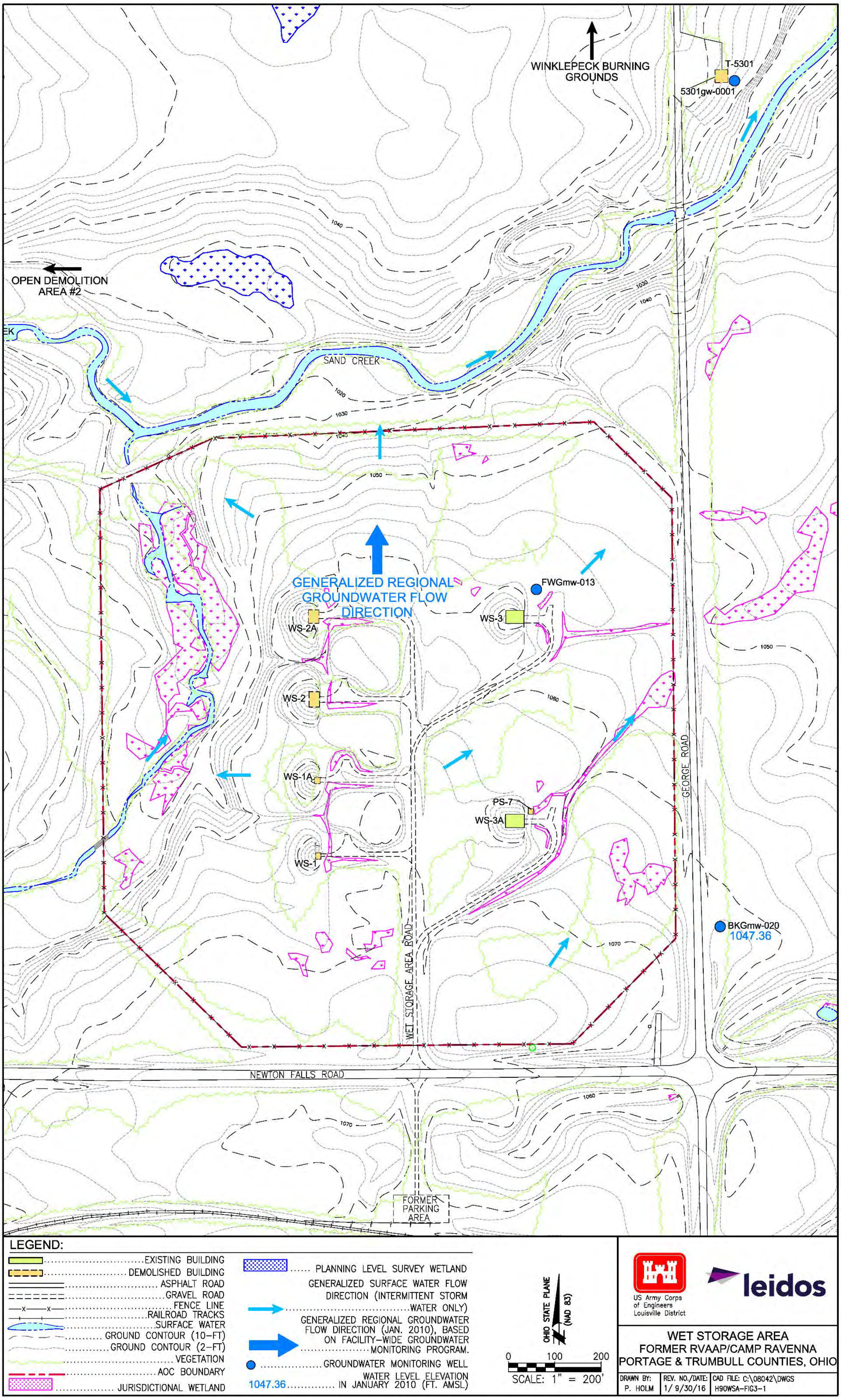
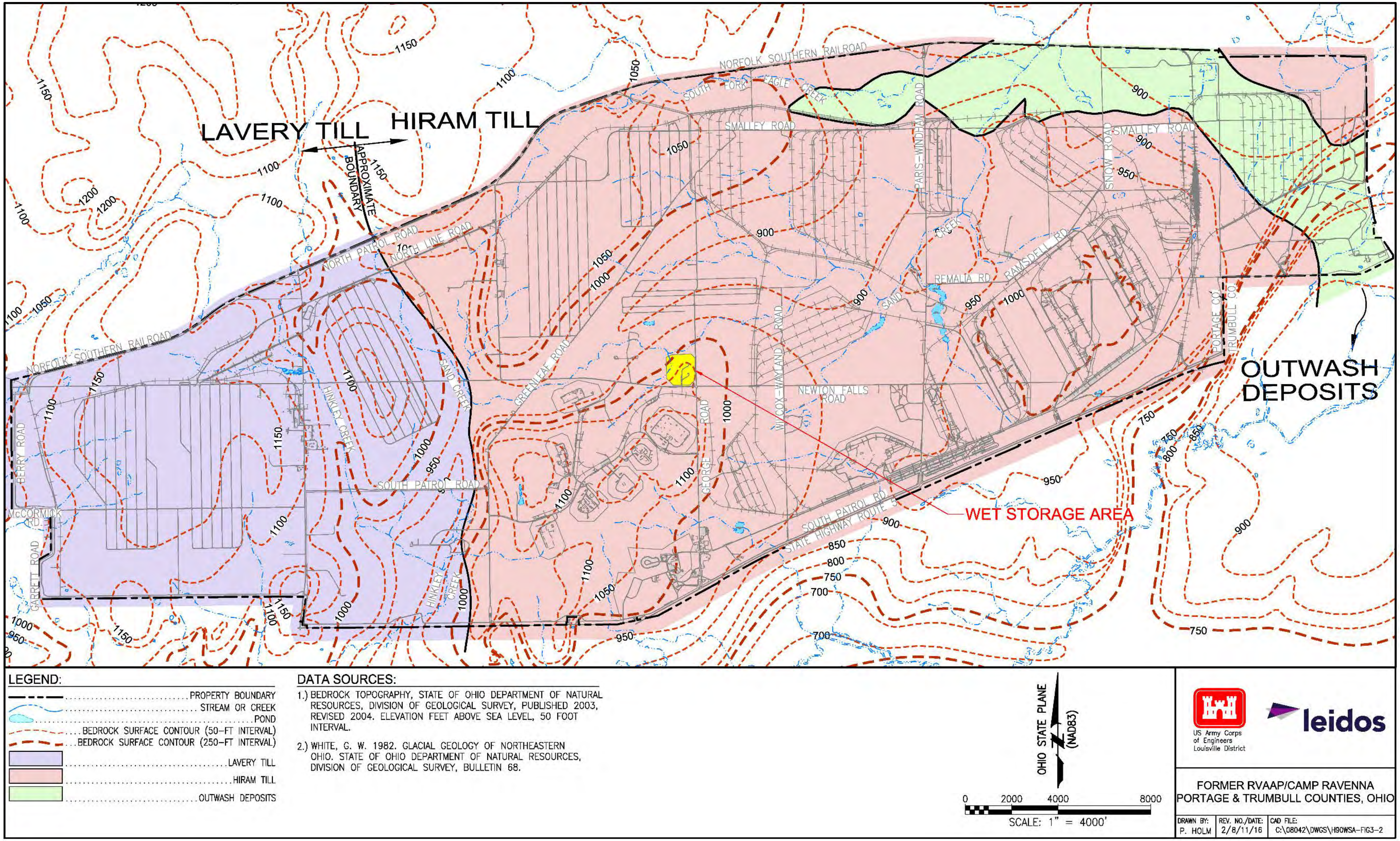


Figure 3–1. Topography, Groundwater Flow, and Surface Water Flow at Wet Storage Area



DATA SOURCES:

1.) BEDROCK TOPOGRAPHY, STATE OF OHIO DEPARTMENT OF NATURAL RESOURCES, DIVISION OF GEOLOGICAL SURVEY, PUBLISHED 2003, REVISED 2004. ELEVATION FEET ABOVE SEA LEVEL, 50 FOOT INTERVAL.

2.) WHITE, G. W. 1982. GLACIAL GEOLOGY OF NORTHEASTERN OHIO. STATE OF OHIO DEPARTMENT OF NATURAL RESOURCES, DIVISION OF GEOLOGICAL SURVEY, BULLETIN 68.

Figure 3–2. Geologic Map of Unconsolidated Deposits on Camp Ravenna

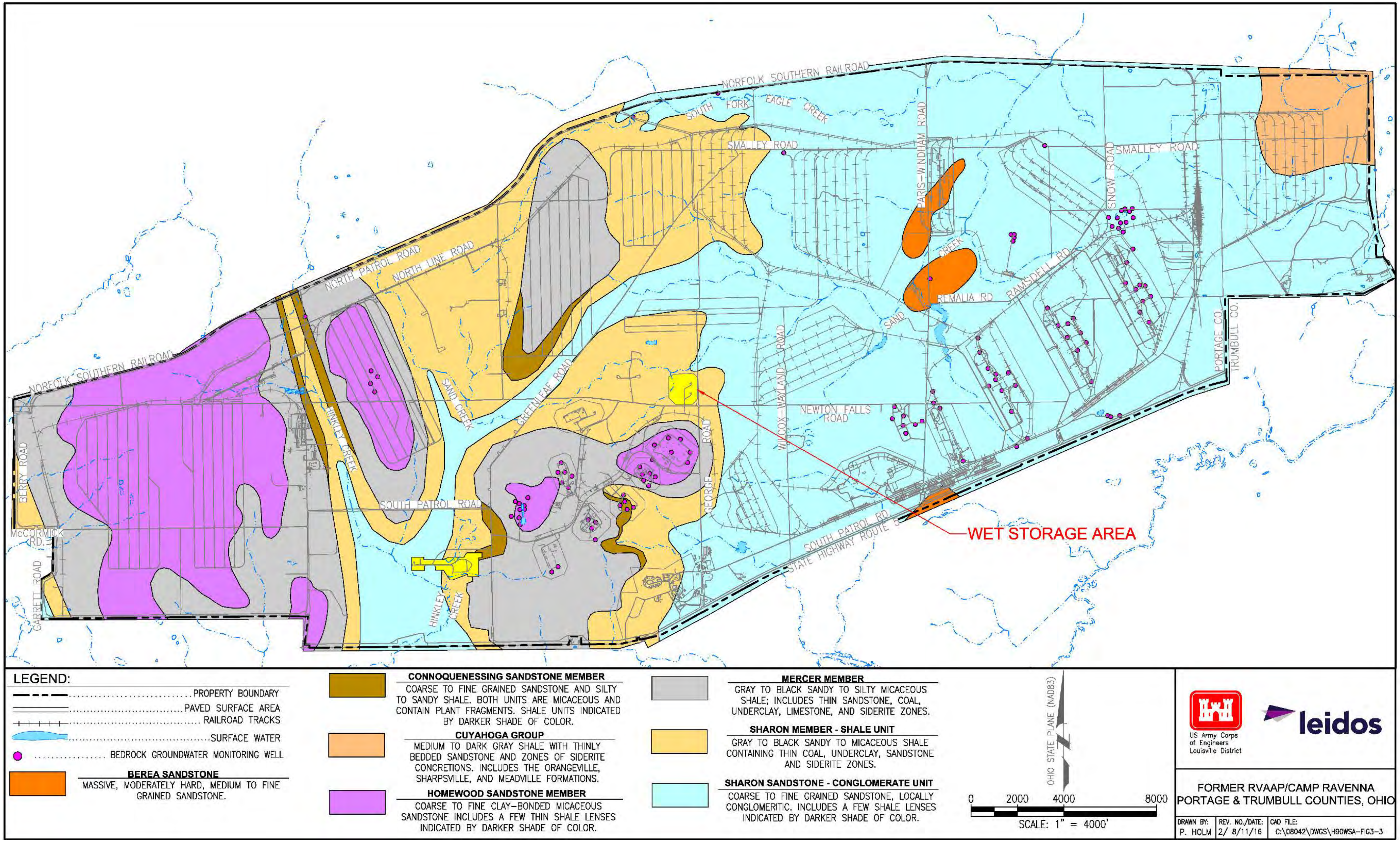


Figure 3–3. Geologic Bedrock Map and Stratigraphic Description of Units on Camp Ravenna

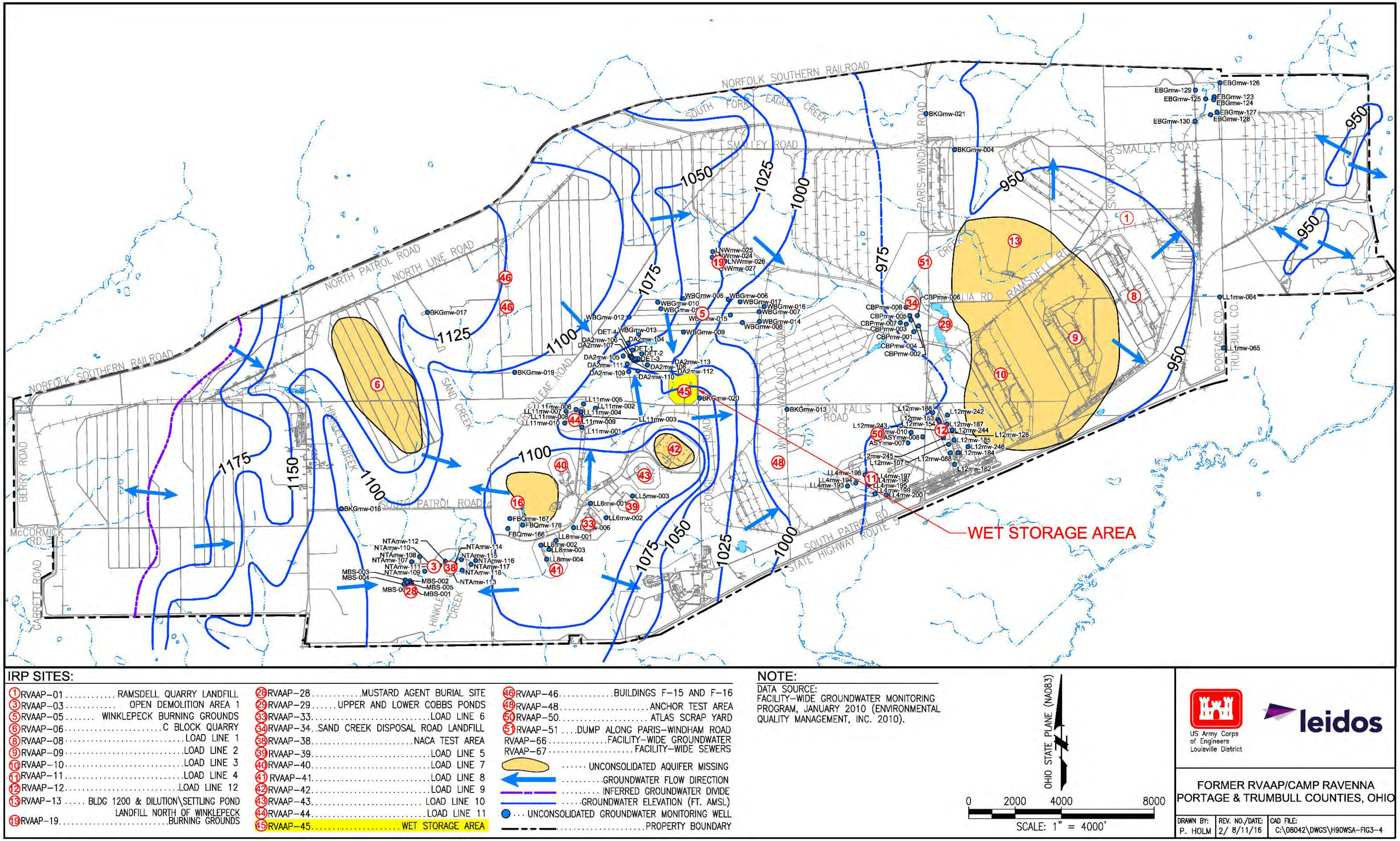


Figure 3–4. Potentiometric Surface of Unconsolidated Aquifer at Camp Ravenna

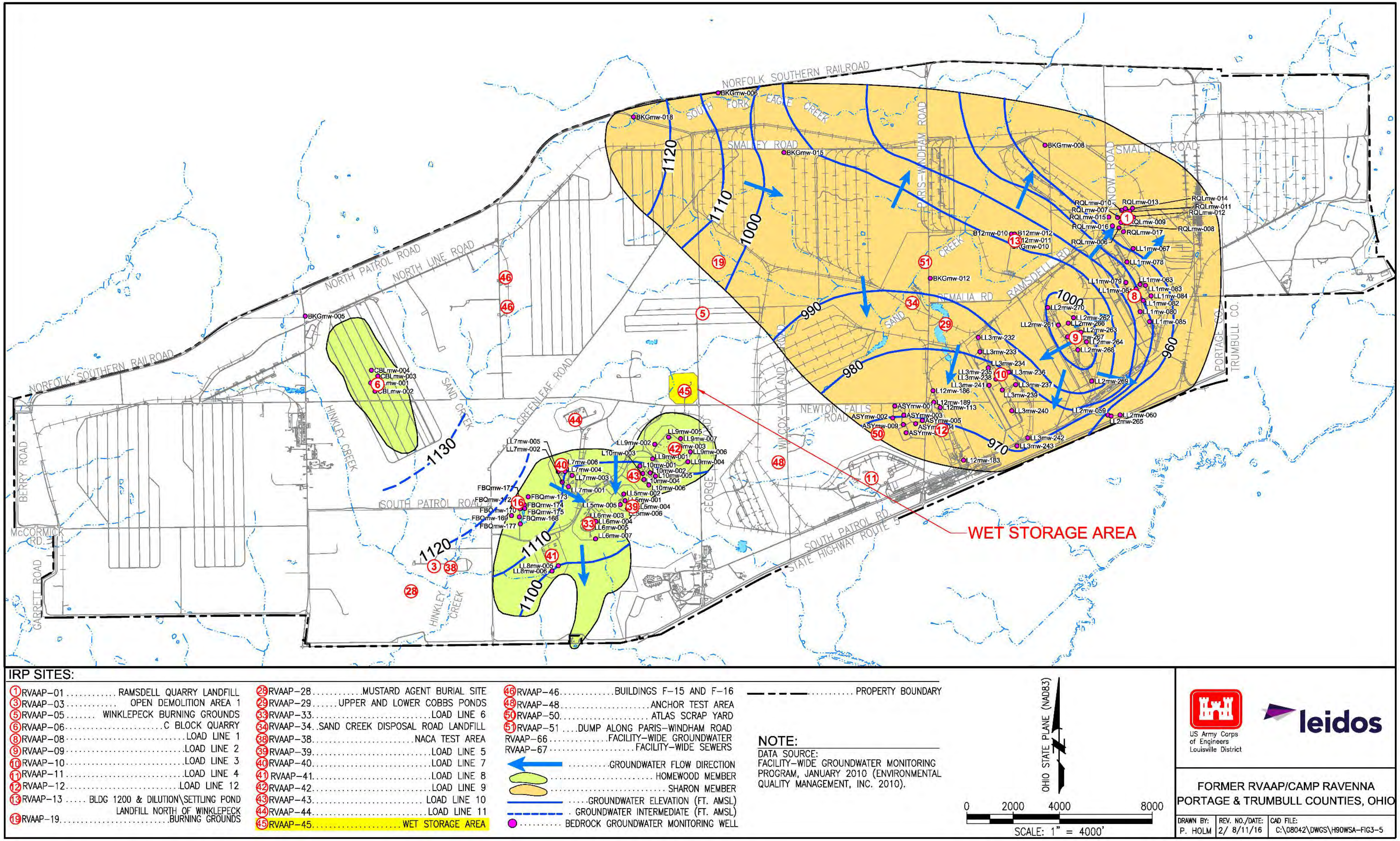


Figure 3–5. Potentiometric Surface of Bedrock Aquifers at Camp Ravenna

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4.0 SITE ASSESSMENTS, INVESTIGATIONS, AND DATA ASSEMBLY

This section summarizes all previous site assessments and investigations conducted at Wet Storage Area. These previous activities include assessments to prioritize the AOC and investigations that collected data used in support of this RI. In addition, surface water and sediment samples outside the AOC from the 2002 ODA2 Phase II RI and the 2000 Building T-5301 Interim Removal Action (IRA) were considered with respect to contaminant migration.

4.1 WET STORAGE AREA PREVIOUS ASSESSMENTS AND EVALUATIONS

This section summarizes previous assessments and evaluations conducted at Wet Storage Area. These activities were generally performed to do an initial evaluation and/or prioritization assessment of the AOC. The data collected as part of these prioritization assessments and evaluations are not used in the nature and extent, fate and transport, HHRA, or ERA due to their age and lack of data quality documentation.

4.1.1 Installation Assessment of Ravenna Army Ammunition Plant

The *Installation Assessment of Ravenna Army Ammunition Plant* incorporated a review of historical operational information and available environmental data to assess the potential for contaminant releases from operational facilities. No sampling was performed at Wet Storage Area as part of the assessment. The assessment identified the following conditions at RVAAP as applicable to Wet Storage Area (USATHAMA 1978):

- Areas of RVAAP, including the production areas (i.e., Load Lines 5, 7, 8, 10, 11, and 12), burning grounds, test areas, demolition areas and storage areas were identified as AOCs contaminated with explosive waste, including TNT, composition B, lead azide, lead styphnate, and black powder;
- Approximately 650 igloos at RVAAP were used for storing toxic/hazardous material, including explosives;
- The igloos at Wet Storage area were identified as containing lead azide; and
- No environmental stress was identified at RVAAP.

4.1.2 Relative Risk Site Evaluation for Newly Added Sites

In 1998, the U.S. Army Center for Health Promotion and Preventative Medicine completed the *Relative Risk Site Evaluation for Newly Added Sites* (USACHPPM 1998) to “provide sufficient data to score RVAAP’s newly discovered previously uninvestigated sites…” This document identified and provided a risk evaluation for 13 newly discovered and previously uninvestigated sites for the purpose of prioritizing future remedial or corrective activities. Of the 13 identified AOCs, 5 were assigned a Relative Risk Site Evaluation (RRSE) score of “high,” and the remaining 8 were assigned a score of “medium.”

The RRSE also included collecting surface soil samples at Wet Storage Area. The data collected at the site "…are minimal Level III data, as defined by U.S. EPA, and are not intended to be used as definitive evidence of contamination presence or absence or to support health risk assessment." This section summarizes the samples collected as part of the RRSE data, the chemicals detected, and the associated prioritization recommendations, but the analytical results are not presented and are not used in subsequent evaluations in this RI Report.

The RRSE evaluated the soil pathway (human receptor endpoint) using data from the five surface soil samples collected near the storage igloos at Wet Storage Area (RV-451 to RV-455). These samples were analyzed for explosives and inorganic chemicals. Subsurface soil, sediment, surface water, and groundwater were not evaluated at Wet Storage Area as part of this RRSE.

Several inorganic chemicals and TNT were detected in surface soil. Analyte concentrations detected in surface soil are presented in Appendix D of the RRSE (USACHPPM 1998).

The surface soil data evaluation resulted in an RRSE score of "medium" based on a "moderate" contaminant hazard factor and "potential" ratings for both contaminant migration and receptor pathways. This "potential" rating is based on no observed evidence of contaminant migration and the AOC fence to help deter access. Overall, the RRSE classified Wet Storage Area as a "medium–priority" AOC and recommended additional investigative sampling (USACHPPM 1998).

The surface soil pathway was evaluated as follows:

1. Groundwater
   a. Not evaluated.
2. Surface soil
   a. Contaminant Hazard Factor: Moderate.
   b. Migration Pathway Factor: Potential. There is no evidence that site contaminants are migrating. However, there are no physical barriers in place to prevent migration.
   c. Receptor Pathway Factor: Potential. While this area is surrounded by a fence with locked gates, hunters, scrappers, and firewood cutters may have access to the site.
3. Sediment
   a. Not evaluated. Sediment was not identified during the RRSE at this AOC.
4. Surface water
   a. Not evaluated. Surface water was not identified during the RRSE at this AOC.

Human receptor endpoints were evaluated based on the available surface soil data. The RRSE scored Wet Storage Area as a "low-priority" AOC (USACHPPM 1998).

4.2 REMEDIAL INVESTIGATIONS

This section summarizes previous investigations conducted at Wet Storage Area. These investigations collected data of sufficient provenance and quality to be used to support the evaluations in this RI, including the nature and extent, fate and transport, HHRA, and/or ERA. In addition, brief summaries of activities at other AOCs (Building T-5301 IRA and ODA2 Phase II RI) are discussed, as data from these sites are used in the nature and extent evaluation within this RI Report.

The Characterization of 14 AOCs report (MKM 2007) presented SRCs and/or COPCs based on data evaluation protocols in use at the time the investigations were completed. The data and information is used in this RI Report; however, an updated screening process and the addition of new data and information may result in a different list of SRCs and/or COPCs.

References to "RVAAP full-suite analytes" generally include analyses of target analyte list (TAL) metals, explosives, propellants (nitrocellulose and nitroguanidine), semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs), PCBs, and pesticides.

4.2.1 Building T-5301 Interim Removal Action

The AOC designated as RVAAP-47, Building T-5301, is located approximately 1,000 ft northeast of the Wet Storage Area fence line. This AOC contained a building originally built as a smokehouse that was utilized to decontaminate and steam clean small miscellaneous explosives and propellants production equipment as the equipment left Winklepeck Burning Grounds. Sample results from the IRA conducted at Building T-5301 are used in the evaluating nature and extent of contamination in this RI Report.

The 1998 RRSE (USACHPPM 1998) identified surface soil and sediment to be potential media for contaminant migration due to the lack of any physical barriers/fencing around the AOC. In 2000, an IRA was conducted to plug and abandon the existing groundwater well, decontaminate and demolish the existing on-site structures; and excavate the contaminated soil (MKM 2000). Upon completion of the removal activities, confirmation samples were collected for laboratory analysis to ensure remediation goals were achieved, and the removal area was backfilled with soil approved for use by Ohio EPA.

The soil, sediment, and groundwater confirmation samples did not have detections of explosives or organics, and the inorganic concentrations were consistent with facility-wide background concentrations. Based upon the results of the IRA, the Ohio EPA concurred that no further action is warranted for Building T-5301. Sediment sample 5301sd-S11 was collected from Sand Creek northeast and downstream of Wet Storage Area and is used in the nature and extent of contamination within this report. Table 4-1 presents the results of the analytes detected from this sample.

4.2.2 Open Demolition Area #2 Phase II Remedial Investigation

ODA2 is designated AOC RVAAP-04. ODA2 had an RI performed, as summarized in the *Phase II Remedial Investigation Report for the Open Demolition Area #2 (RVAAP-04)* (USACE 2005c). This ODA2 Phase II RI Report characterized the nature and extent of contamination, evaluated the fate and transport of contaminants, and assessed potential risk to human health and the environment resulting from former operations at ODA2. These objectives were met through field activities conducted in July 2002 through April 2003.

Sediment samples (locations DA2sd-101 and DA2sd-103) and four surface water samples (location DA2sw-102) were collected from Sand Creek northwest of Wet Storage Area during the ODA2 Phase II RI and are used in the nature and extent evaluation in this report. Surface and subsurface soil, geotechnical, sediment, surface water, and groundwater samples were collected; however, these activities are not pertinent to Wet Storage Area and are not discussed further in this RI Report.

Figure 4-1 presents the pertinent sediment and surface water locations sampled under the ODA2 Phase II RI. Tables 4-2 and 4-3 present the results of the analytes detected from pertinent sediment and surface water samples collected during the ODA2 Phase II RI.

4.2.3 Characterization of 14 AOCs

The Characterization of 14 AOCs data quality objectives (DQOs) were developed to collect and provide sufficient, high-quality data for all applicable media such that future actions (i.e., HHRAs and ERAs) can be efficiently planned and accomplished at each AOC. Data generated by the characterization activities were used to determine if residual contaminants remain at the AOCs; if contaminants impact soil, sediment, surface water, or groundwater; if there is a need for more extensive risk assessments; and if remedial actions are appropriate.

From 2004–2005, sampling was conducted at Wet Storage Area in accordance with the *Final Sampling and Analysis Plan Addendum for the Characterization of 14 RVAAP AOCs* (MKM 2004) (herein referred to as the Characterization of 14 AOCs SAP).

The Characterization of 14 AOCs investigation was performed to accomplish the following:

- Provide data for future assessments that may be conducted,
- Develop a conceptual site model (CSM),
- Identify key elements to be considered in future actions,
- Assess potential sources of contamination,
- Identify whether releases of contamination extend beyond the AOC boundary,
- Provide an initial assessment of the nature and lateral extent of contamination, and
- Provide a preliminary human health risk screening (HHRS) evaluation and ecological risk screening (ERS) evaluation.

Results of this characterization are presented in the Characterization of 14 AOCs report (MKM 2007) and are summarized below.

4.2.3.1 Field Activities

The following investigation field activities were conducted from October 2004 to May 2005 to assess potential impacts from former operations at Wet Storage Area (MKM 2007):

- Collected 17 multi-increment (MI) surface soil (0–1 ft bgs) samples,
- Collected two discrete surface soil (0–1 ft bgs) samples for VOCs, and
- Completed sampling location survey.

The Characterization of 14 AOCs utilized MI samples. This sampling technique is currently referred to as incremental sampling methodology (ISM). Wet Storage Area was divided into 17 ISM samples located in dry drainage ditches near the former and extant storage igloos. All surface soil samples were analyzed for TAL metals and explosives. In addition, two discrete surface soil samples were collected from two ISM sample areas for VOC analyses to fulfill requirements to conduct a full-suite analysis for 10% of the MI sample population. Figure 4-1 presents the locations sampled under the Characterization of 14 AOCs.

Analytical laboratory procedures were completed in accordance with applicable professional standards, USEPA requirements, government regulations and guidelines, and specific project goals and requirements. Samples were analyzed as specified by the Facility-wide Sampling and Analysis Plan (FWSAP) current at the time of the investigation, the Characterization of 14 AOCs Sampling and Analysis Plan (MKM 2004), and USACE Louisville Chemistry Guideline (USACE 2002). DQOs were established for the Characterization of 14 AOCs and complied with USEPA Region 5 guidance. The requisite number of quality assurance (QA)/quality control (QC) samples was obtained during the investigation. The data validation determined that the data met the completeness requirements for the project (90% complete), was usable, and that it satisfied the DQOs for the project.

Table 4-4 presents the ISM sample locations, associated operations, and suite of chemicals analyzed as part of the Characterization of 14 AOCs. Table 4-5 presents the results of the analytes detected from samples collected during the Characterization of 14 AOCs.

4.2.3.2 Nature and Extent of Contamination

The nature of contamination for Wet Storage Area was characterized in surface soil (0–1 ft bgs) media only. Eighteen of the contaminants were inorganic chemicals that were detected above RVAAP background concentrations and/or Region 9 residential preliminary remediation goal (PRG) screening values at that time, and five SVOCs were also detected above screening criteria. Sample WSAss-004M, which was collected from just outside the doorway of a former storage igloo (WS-1), contained all five SVOCs which were detected above screening criteria. Figure 4-4 presents locations that exceed current screening criteria.

4.2.3.3 Human Health Risk Screening

The HHRS compared chemical concentrations detected in the AOC surface soil samples to RVAAP screening criteria in effect at that time, which included facility-wide background concentrations for inorganic constituents and USEPA Region 9 residential PRGs. Constituents were retained if they did not have screening values. The results of the HHRS identified contaminants above screening criteria in surface soil, as summarized in Table 4-6.

4.2.3.4 Ecological Risk Screening

The ERS compared chemical concentrations detected in Wet Storage Area surface soil to RVAAP facility-wide background concentrations for inorganic chemicals and ecological screening values (ESVs). The ERS followed screening methodology guidance presented in the *2003 RVAAP Facility-wide Ecological Risk Work Plan* (USACE 2003a) (herein referred to as the FWERWP) and *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2003). Chemicals were retained if they did not have screening values. Table 4-7 presents the chemicals identified in the ERS as exceeding screening values for Wet Storage Area surface soil.

4.2.3.5 Results and Conclusions

Seven metals, five SVOCs, one pesticide, one explosive, and one propellant were identified as COPCs in surface soil. All VOCs and PCBs were below Region 9 residential PRGs and/or laboratory detection limits. The Characterization of 14 AOCs report recommended that full HHRAs and ERAs should be considered to assist in the overall risk management decisions for Wet Storage Area.

4.2.4 PBA08 Remedial Investigation

In November 2008, Science Applications International Corporation (SAIC) scientists performed a site walk of Wet Storage Area. The site walk was conducted to develop the *Performance-based Acquisition 2008 Supplemental Investigation Sampling and Analysis Plan Addendum No. 1* (PBA08 SAP) (USACE 2009a), which supplemented historical data in this RI Report and completed the RI phase of the CERCLA process. The PBA08 SAP considered the prior investigations and changes in AOC conditions when developing the DQOs and sampling scheme for completing the Wet Storage Area RI. Section 4.4.4 discusses the suitability and use of samples collected to support this RI, with respect to changes in AOC conditions. The PBA08 SAP was reviewed and approved by representatives of the Army and Ohio EPA in January 2010.

As part of the PBA08 RI DQOs, an initial screening approach was used to help focus the investigation on specific chemicals and areas to be further evaluated by assessing the nature and extent of contamination observed in historical samples (Section 3.2.2 of the PBA08 SAP). Decision flowcharts for PBA08 RI surface and subsurface sampling are presented in Figures 4-2 and 4-3, respectively. The screening approach presented in the PBA08 SAP compared sample results from previous investigations at Wet Storage Area to chemical-specific facility-wide cleanup goals (FWCUGs) at the 1E-06 cancer risk level and non-carcinogenic risk HQ of 0.1, as presented in the *RVAAP Facility-wide Human Health*

Risk Assessors Manual - Amendment 1 (USACE 2005a) (herein referred to as the FWHHRAM). The most protective FWCUGs for the Resident Farmer (Adult and Child) and National Guard Trainee were referred to as "screening criteria." Previous results were also compared to FWCUGs at the higher TR of 1E-05, HQ of 1 to facilitate identifying potential source areas that may require additional sampling to refine the extent of contamination. Table 4-8 lists the chemicals with detected concentrations that exceeded screening criteria at the time of the PBA08 SAP in historical soil samples.

In March 2010, the PBA08 RI was implemented by collecting surface soil using ISM and discrete sampling techniques, subsurface soil and surface water were collected using discrete sampling techniques, and collecting sediment using composite sampling techniques. The results of the PBA08 RI sampling, combined with the results of the Characterization of 14 AOCs, were used to evaluate the nature and extent of contamination, assess potential future impacts to groundwater, conduct HHRAs and ERAs, and evaluate the need for remedial alternatives.

No groundwater samples were collected during the PBA08 RI, as the current conditions of groundwater will be evaluated as an individual AOC for the entire facility (designated as RVAAP-66) and addressed in a separate RI/FS Report.

A sample log for each sample and lithologic soil description for each soil boring collected during the PBA08 RI is included in Appendix A. The DQOs, field activities, sampling methodologies, QA/QC, and management of analytical data for the PBA08 RI are further expanded upon in Appendix I.

4.2.4.1 Surface Soil Sampling Rationale – Source Area Investigation

Samples were collected at the AOC to assess contaminant occurrence and distribution in surface soil. The PBA08 RI samples were designed to delineate the extent of areas previously identified as having the greatest likelihood of contamination (e.g., adjacent to storage igloos or within sediment accumulation areas such as ditches). Table 4-9 presents the specific rationale for each ISM surface soil sample collected during the PBA08 RI in March 2010. Table 4-10 presents the results of the analytes detected from ISM surface soil samples collected during the PBA08 RI in March 2010. All PBA08 RI and historical sample locations used in this evaluation are presented on Figure 4-6.

Four ISM samples were collected around historical ISM sample areas to further delineate surface soil above historical screening criteria presented in Table 4-8 (Figure 4-4). All surface soil samples collected during the PBA08 RI were collected using ISM sampling techniques, except at soil boring locations. ISM samples were analyzed for TAL metals, explosives, and PAHs. One sample (15% of the total number of ISM samples collected) was analyzed for RVAAP full-suite analytes. Table 4-9 presents the specific rationale for each surface soil sample collected.

4.2.4.2 Surface Soil Sampling Rationale – Chromium Speciation

As part of the PBA08 RI, three discrete chromium speciation samples were collected to evaluate the potential contribution of hexavalent chromium to the total chromium concentrations in soil. Samples from 0–1 ft bgs were collected in accordance with the bucket hand auger method described in Section

4.5.2.1.1 of the FWSAP (USACE 2001a). Two samples were collected from areas previously identified as having elevated total chromium concentrations (WSAss-001m and WSAss-003M), and one sample was collected from an area previously identified as having a total chromium concentration near background concentrations (WSAss-009M). The rationale for all samples collected as part of the PBA08 RI is summarized in Table 4-12. The locations of these samples are presented in Figure 4-4 and results are presented in Table 4-11.

4.2.4.3 Subsurface Soil Sampling Rationale and Methods

The PBA08 RI used discrete samples from soil borings to characterize subsurface soil. Subsurface soil sampling was conducted according to the decision rules approved in the PBA08 SAP. The subsurface soil borings were located based on two objectives:

- Borings at locations where previous surface soil sampling results exceeded screening criteria and vertical delineation was warranted.
- Borings at locations where previous surface soil sampling results only slightly exceeded screening criteria to confirm that contaminant concentrations did not increase with depth.

Soil samples from eight soil borings installed in historical ISM areas with historical screening criteria exceedances were collected to further delineate the vertical extent of contamination in subsurface soil at the AOC (Figure 4-4). Table 4-13 presents the specific rationale for each subsurface soil sample collected for the PBA08 RI. Results of detected analytes are presented in Table 4-14, except discrete surface soil (0–1 ft bgs), which are presented in Table 4-11.

The subsurface soil sampling depth intervals were documented in the PBA08 SAP. Each soil boring was sampled at 0–1, 1–4, 4–7, and 7–13 ft bgs. These sample intervals were selected to evaluate surface and subsurface exposure depths for the Resident Receptor (0–1 and 1–13 ft bgs) and National Guard Trainee (0–4 and 4–7 ft bgs). The sample collected from the 7–13 ft bgs interval was archived on site, while the 4–7 ft bgs interval sample was analyzed under an expedited five-day turnaround time. As specified in the PBA08 SAP, if any chemical concentration exceeded screening criteria in the 4–7 ft bgs sample, the 7-13 ft bgs sample was analyzed. One of the archived 7–13 ft bgs samples was analyzed because there were preliminary screening criteria exceedances for arsenic (21.3 mg/kg) in the 4–7 ft bgs sample interval from WSAsb-026. In addition, at least 10% of all subsurface samples from 7–13 ft bgs were submitted for laboratory analysis to adequately characterize the subsurface soil to 13 ft bgs. Two samples collected from the 7–13 ft bgs sample interval from WSAsb-024 and WSAsb-028 were submitted for laboratory analysis for this purpose.

All samples were analyzed for TAL metals, explosives, and PAHs; seven samples were analyzed for RVAAP full-suite analytes to satisfy the PBA08 SAP sample requirements of a minimum of 15% frequency for full-suite analysis. Three QC field duplicates and three QA split samples were collected to satisfy the QA/QC sample requirements of 10% frequency for subsurface soil samples.

Two geotechnical samples were collected from one boring location to provide soil data for fate and transport modeling. Geotechnical data is provided in Appendix D. A pilot boring was installed with a

Geoprobe at sample location WSAsb-025 to a depth of 28 ft bgs to allow lithological characterization of the soil and determine the appropriate geotechnical sample intervals (Appendix A). The geotechnical sample location was offset from the pilot boring and drilled with hollow stem auger attachments. Geotechnical samples were collected beneath the hollow stem augers directly into the Shelby tube. Undisturbed Shelby tube samples were collected from 4–5.2 and 12–13.1 ft bgs, directly above the only moist zones observed in the pilot boring. The Shelby tubes were sealed with wax, capped, and submitted for laboratory geotechnical analysis for porosity, bulk density, moisture content, total organic carbon, grain size fraction analysis, and permeability.

4.2.4.4 Surface Water and Sediment Rationale and Methods

Surface water and sediment samples were collected to characterize current conditions and assess potential entrance and exit pathways from the AOC (Figure 4-4). Four co-located surface water and sediment samples were collected during the PBA08 RI from streams within and exiting the AOC. The samples were collected in accordance with the following decision rules approved in the PBA08 SAP:

- At AOCs where overland flow of contaminants could occur to nearby perennial streams, those streams will be sampled. The sample locations may be outside of the AOC boundaries, but the samples represent the areas potentially impacted by the AOC (Wet Storage Area).
- At points where contamination may migrate out of the AOC area, such as a ditch or a stream near the AOC boundary, samples were collected to characterize current conditions and determine whether contaminant migration may occur at surface water runoff exit points.

Four surface water and four co-located sediment samples were collected during the PBA08 RI. Each surface water grab sample was collected by the handheld bottle method in accordance with Section 4.3 of the PBA08 SAP and analyzed for RVAAP full-suite analytes. Water quality parameters for temperature, pH, conductivity, dissolved oxygen, and turbidity were collected using calibrated water quality meters (Hanna Instruments, models 9828 and 98703). A surface water and sediment sample collection sheet was completed for each sample location and is included in Appendix A.

The surface water grab samples were collected by the handheld bottle method in accordance with Section 4.3 of the PBA08 SAP and analyzed for RVAAP full-suite analytes. Additionally, water quality parameters for temperature, pH, conductivity, dissolved oxygen, and turbidity were collected using calibrated water quality meters (Hanna Instrument Models 9828 and 98703). The sediment samples were collected in accordance with Section 4.2 of the PBA08 SAP. The samples consisted of a multi-aliquot composite with 10 aliquots selected randomly within a 5-ft radius of the identified sample location. Each aliquot was collected by a push probe to a maximum depth of 0.5 ft bgs. For VOC analysis, one discrete sample collected from 0.5 ft bgs was collected within the 5-ft sampling radius of the discrete sample location and placed directly in the appropriate, labeled sample container. Three sediment samples (and their associated QA/QC samples) were analyzed for explosives, TAL metals, and SVOCs, while one sample was analyzed for RVAAP full-suite analytes. Table 4-15 presents the specific rationale for the surface water and sediment samples collected for the PBA08 RI. The locations of these samples are presented in Figure 4-4 and results are presented in Table 4-16 and Table 4-17 for surface water and sediment, respectively.

4.2.4.5 Changes from the Work Plan

Significant changes to the PBA08 SAP are documented in the field change requests provided in Appendix B. Changes made in the field based on AOC-specific conditions are not documented on field change requests but on the field sampling logs (Appendix A). These changes are presented on Table 4-18. New coordinates for all station locations can be found on field sampling logs.

4.3 FACILITY-WIDE BACKGROUND EVALUATION

Facility-wide background values for inorganic constituents in soil, sediment, surface water, and groundwater were developed in 1998, as documented in the *Phase II Remedial Investigation Report for the Winklepeck Burning Grounds* (USACE 2001b). These facility-wide background values were employed in the data reduction and screening process described in Section 4.4.2 and the remainder of the evaluations in this RI (e.g., nature and extent, fate and transport). Background locations were selected using aerial photographs and during site visits from areas believed to be unaffected by RVAAP activities. Soil, sediment, surface water, and groundwater samples were collected from those locations to determine the range of background concentrations that could be expected in these media. Results from the site-specific background data collection were used to determine if detected metals and potential anthropogenic compounds (such as PAHs) are site-related, naturally occurring, or from non-RVAAP-related anthropogenic sources.

A total of 14 wells were installed in established background locations to collect filtered and unfiltered samples from the bedrock and unconsolidated zones. These samples were analyzed for TAL metals and cyanide to determine background concentrations.

Soil samples were collected from each of the background monitoring well locations at 0–1, 1–3, and greater than 3 ft bgs. Because boring locations were changed during sampling based on the lithological requirements for well screen intervals, all depth intervals for soil were not sampled for each boring. Background soil samples were analyzed for TAL metals, cyanide, SVOCs, total organic carbon, pesticides, PCBs, and VOCs.

Seven stream locations upstream of RVAAP activities were sampled for sediment and surface water to characterize background conditions. Seven locations were selected for sampling sediment and surface water representative of background conditions along Hinkley, Sand, and Eagle Creeks. Background sediment samples were analyzed for TAL metals, cyanide, SVOCs, pesticides, PCBs, and VOCs. Surface water samples were analyzed for TAL metals and cyanide.

Using the sampling results, an evaluation of outliers, data assessment, and statistical analysis were performed to determine background concentrations for each media. For surface soil samples, PAHs, in addition to metals, were elevated in four samples. PAHs are related to combustion products and could indicate human disturbance at the locations where they were detected. Visits to the sampling locations and a review of aerial photography prior to the establishment of RVAAP indicated that these sampling locations were near homes or farms and could have been influenced by activities associated with those structures.

During the finalization of background concentrations at the former RVAAP, the Army and Ohio EPA agreed that facility-wide background concentrations would only be applicable for inorganics. All organic analytes (e.g., PAHs, VOCs, or explosives) were classified as anthropogenic and potentially related to RVAAP operations; therefore, no background values were established for these classes of compounds. The final, approved facility-wide background concentrations or inorganics are presented in Table 4-19.

4.4 DATA EVALUATION METHOD

Data evaluation methods for Wet Storage Area are consistent with those established in the FWCUG Report and specified in the PBA08 SAP (USACE 2009a). The processes used to evaluate the analytical data involved three general steps: (1) defining data aggregates; (2) conducting data verification, reduction, and screening; and (3) presenting data.

4.4.1 Definition of Aggregates

Wet Storage Area data were aggregated in three ways to evaluate contaminant nature and extent and complete the HHRA and ERA. The initial basic aggregation of data was by environmental medium: surface soil, subsurface soil, sediment, and surface water. For each medium-specific aggregate, an evaluation was conducted to determine if further aggregation was warranted with respect to AOC characteristics, historical operations, ecological habitat, and potential future remedial strategy and Land Use (e.g., spatial aggregates). Data for soil were further aggregated based on depth and sample type for consistency with RVAAP human health risk exposure units (EUs) and guidance established in the FWHHRAM and FWCUG Report. Data aggregates for evaluating the nature and extent of contamination at Wet Storage Area are as follows:

- **Surface Soil (0–1 ft bgs) –** This medium is evaluated as an AOC-wide aggregate. Further subdivision into spatial aggregates was not warranted due to the small size of the AOC, consistent physical characteristics, and limited AOC historical operations. Using the above data aggregation criteria, surface soil within the geographic area of Wet Storage Area was evaluated as an AOC-wide aggregate.
- **Subsurface Soil (less than 1 ft bgs) –** Includes data from discrete sample intervals 1–4, 4–7, and 7–13 ft bgs. This medium is evaluated as an AOC-wide aggregate on the same basis as surface soil.
- **Sediment –** Discrete sediment samples were collected from the unnamed creek to the west and Sand Creek to the north of the AOC and were not divided further into spatial aggregates.
- **Surface Water –** This medium is evaluated as an AOC-wide aggregate. Surface water sampling data were obtained from the unnamed creek to the west and Sand Creek to the north of the AOC.

4.4.2 Data Verification, Reduction, and Screening

4.4.2.1 <u>Data Verification</u>

Data verification was performed on 47 surface and subsurface soil, sediment, and surface water samples (including QC duplicates) collected during the PBA08 RI in March 2010. Data from the Characterization of 14 AOCs were verified and completed as presented in the summary report. Analytical results were reported by the laboratory in electronic format and loaded into the Ravenna Environmental Information Management System (REIMS) database. Data verification was performed to ensure all requested data were received and complete. Data qualifiers were assigned to each result based on the laboratory QA review and verification criteria.

Results were qualified as follows:

- "U" not detected.
- "UJ" not detected, reporting limit estimated.
- "J" indicates the analyte was positively identified, but the associated numerical value is an approximate concentration of the analyte in the sample.
- "R" result not usable.

In addition to assigning qualifiers, the verification process also selected the appropriate result to use when re-analyses or dilutions were performed. Where laboratory surrogate recovery data or laboratory QC samples were outside of analytical method specifications, the verification chemist determined whether laboratory re-analysis should be used in place of an original reported result. If the laboratory reported results for diluted and undiluted samples, diluted sample results were used for those analytes that exceeded the calibration range of the undiluted sample. A complete discussion of verification process results is contained in the data QC summary report (Appendix C). The data QC summary report also includes a summary table of the assigned data qualifiers and an accompanying rationale. Independent, third-party validation of 10% of the RI data and 100% of the USACE QA laboratory data was performed by a subcontractor to the USACE Louisville District.

4.4.2.2 <u>Data Reduction</u>

Calculating data summary statistics was the initial step in the data reduction process to identify SRCs. Eligible historic and current AOC data were extracted from the database. Results from QC splits and field duplicates, as well as rejected results, were excluded from the data screening process. As stated in Section 5.4.7 of the FWSAP, "The duplicate is submitted as 'blind' to the laboratory and is used to determine whether the field sampling technique is reproducible and to check the accuracy of reported laboratory results." Therefore, duplicates are not used in the data screening process. All analytes having at least one detected value were included in the data reduction process.

Summary statistics calculated for each data aggregate included the minimum, maximum, and average (mean) values and the proportion of detected results to the total number of samples collected. For calculating mean values, non-detected results were addressed by using one-half of the reported detection limit as a surrogate value for each compound (USEPA 1989). Non-detected results with elevated detection limits (more than five times the contract-required detection limit) were excluded from the summary statistics in order to avoid skewing the mean value calculations.

4.4.2.3 Data Screening

After reduction, the data were screened to identify SRCs using the processes outlined below. The ISM and associated discrete (for VOC analysis) samples were used in the SRC screening process for surface soil (0–1 ft bgs). All subsurface soil samples collected under the PBA08 RI were discrete samples and screened for SRCs.

Additional screening of identified SRCs against applicable criteria (e.g., USEPA RSLs, FWCUGs, and ESVs) was conducted (1) in the fate and transport evaluation (Section 6.0) to identify CMCOPCs, (2) in the HHRA to identify human health COPCs and COCs (Section 7.2), and (3) in the ERA to evaluate COPECs (Section 7.3). Figure 4-5 illustrates the screening process to identify SRCs and COPCs at Wet Storage Area in accordance with the FWCUG Report. The steps involved in the SRC screening process are summarized below. All chemicals that were not eliminated during the screening steps were retained as SRCs.

- **Data quality assessment –** Review the usability of the RI data set with respect to established DQOs as discussed in Section I.4.5 of Appendix I.
- **Background screening –** The maximum detected concentrations (MDCs) of naturally occurring inorganic chemicals were compared to background concentrations. If background concentrations were exceeded, the respective inorganic chemicals were retained as SRCs. No background concentrations were established for organic chemicals. As such, all detected organic chemicals were retained as SRCs.
- **Screening of essential human nutrients –** Chemicals that are considered essential nutrients (e.g., calcium, chloride, iodine, iron, magnesium, potassium, phosphorous, and sodium) are an integral part of the human food supply and are often added to foods as supplements. USEPA recommends these chemicals not be evaluated unless they are grossly elevated relative to background concentrations or would exhibit toxicity at the observed concentrations at an AOC (USEPA 1989). Recommended daily allowance (RDA) and recommended daily intake (RDI) values are available for all of these chemicals (Table 4-20). Screening values were calculated for receptors ingesting 100 mg of soil per day or 1 L of groundwater per day to meet their RDA/RDI. In the case of calcium, magnesium, phosphorous, potassium, and sodium, a receptor ingesting 100 mg of soil per day would receive less than the RDA/RDI value, even if the soil consisted of the pure mineral (i.e., soil concentrations at 1,000,000 mg/kg). Essential nutrients detected at or below their RDA/RDI-based screening levels (SLs) were eliminated as SRCs.
- **Frequency of detection/WOE screening –** The FWCUG Report and *Final (Revised) USACE RVAAP Position Paper for the Application and Use of Facility-wide Human Health Cleanup Goals* (USACE 2012b) (hereafter referred to as the Position Paper for Human Health CUGs) establish the protocol for frequency of detection and WOE screening. These guidance documents denote that analytes (except for explosives and propellants) detected in less than 5% of the discrete samples are screened out from further consideration if the sample population

consists of 20 or more samples and evidence exists that the analyte is not AOC related. The WOE evaluated magnitude and location (clustering) of detected results and if the distribution of detected results indicated a potential source of the chemical. If the detected results for a chemical showed: (1) no clustering, (2) concentrations were not substantially elevated relative to detection limit, and (3) the chemical did not have an evident source, the results were considered spurious, and the chemical was eliminated from further consideration. This screening was applied to all organic and inorganic chemicals, except for explosives and propellants, which were considered SRCs regardless of frequency of detection. No frequency of detection/WOE screening was performed for soil, surface water, or sediment if fewer than 20 discrete samples were available for these media.

4.4.3 Data Presentation

Data summary statistics and screening results for SRCs in surface and subsurface soil, sediment, and surface water at Wet Storage Area are presented for each medium and spatial aggregate. Analytical results for SRCs are also presented in the following data summary tables: Table 4-21 for surface soil, Table 4-22 for subsurface soil, Table 4-23 for sediment, and Table 4-24 for surface water.

The complete laboratory analytical data packages are included in Appendix D. In order to maximize efficiency for laboratory reporting and data management activities, all of the samples received at the laboratory on a given day were reported in a single data package. Therefore, results may be present in data packages associated with different AOCs. All samples for Wet Storage Area have sample identifications beginning with “WSA.”

The tables in Appendix D present the analytical results for samples collected during the PBA08 RI and Characterization of 14 AOCs. Sample locations from the Characterization of 14 AOCs and PBA08 RI are presented on Figure 4-6. Analytical results are grouped by media (e.g., surface soil, subsurface soil, sediment, and surface water) and class of analyte (e.g., explosives and inorganic chemicals) for ease of reference.

4.4.4 Data Evaluation

All quality-assured sample data were further evaluated to determine suitability for use in the RI under two primary considerations: representativeness with respect to current AOC conditions and sample collection methods (e.g., discrete vs. ISM). Table 4-25 presents the designated use for all available Wet Storage Area samples.

4.4.4.1 Surface Soil

Surface soil samples at Wet Storage Area were collected during the 2003–2004 Igloo Demolitions, 2004–2005 Characterization of 14 AOCs, and the 2010 PBA08 RI. Historical surface soil samples collected beneath the sub-floors of the four former storage igloos, following completion of demolition activities in 2004, were not carried forward in the nature and extent evaluation or risk assessments to evaluate and characterize Wet Storage Area. These locations were likely disturbed during slab removal, but the soil itself was not removed.

The RRSE samples RV-451 to RV-455 were not included in this RI evaluation, as the RRSE data collected at the site "…are minimal Level III data, as defined by U.S. EPA, and are not intended to be used as definitive evidence of contamination presence or absence or to support health risk assessment."

Two types of surface soil samples were collected during the investigation of Wet Storage Area: discrete and ISM samples. Discrete surface soil samples were collected to evaluate VOCs and as part of the first interval (0-1 ft bgs) of a soil boring. The discrete surface soil samples collected to evaluate VOCs that were considered representative of the ISM sample in which they were taken were used in the SRC screening process and carried forward into the risk assessment along with their corresponding ISM sample. Discrete samples from the 0–1 ft bgs shallow soil interval collected from co-located subsurface soil boring locations during the PBA08 RI were retained for nature and extent evaluation only.

None of the ISM surface soil samples from the PBA08 RI were eliminated from the SRC screening process. Additionally, two subsurface soil samples (from one soil boring) were collected during the PBA08 RI for geotechnical analysis only.

4.4.4.2 Subsurface Soil

The SRC data set for subsurface soil is comprised only of PBA08 RI samples. All subsurface soil samples were applicable for use in this assessment and are included in the SRC screening data set.

4.4.4.3 Sediment

The SRC data set for sediment is comprised of PBA08 RI samples. In addition, sediment samples were collected from Sand Creek north/northeast of the AOC during the Building T-5301 IRA in 2000 and ODA2 Phase II RI in 2002; however, these samples were retained only for nature and extent evaluation. These sample locations include:

- 5301ss-S11
- DA2sd-101
- DA2sd-103

4.4.4.4 Surface Water

The SRC data set for sediment is comprised of surface water samples collected during the PBA08 RI. In addition, surface water samples were collected from location DA2sw-102 in Sand Creek northwest of the AOC during the ODA2 Phase II RI in 2002–2003; however, these samples were retained only for nature and extent evaluation. PBA08 RI data were utilized in screening for SRCs and COPCs and carried forward into the risk assessment. PBA08 RI data were utilized in screening for SRCs and COPCs and carried forward into the risk assessment.

Table 4–1. Analytes Detected in Building T-5301 Interim Removal Action Sediment Samples

Aggregate		Outside AOC
Station		5301sd-S11
Sample ID		5301ss-S11-0001-CS
Date		05/01/00
Depth (ft)		0.0 - 0.5
Parameters Analyzed		
Analyte	Background Criteria	TAL Metals, Explosives
Metals (mg/kg)		
Aluminum	13900	2490
Arsenic	19.5	6
Barium	123	15.1
Beryllium	0.38	0.13
Calcium	5510	549
Chromium	18.1	3.4
Cobalt	9.1	2.9
Copper	27.6	4.8
Iron	28200	7270
Lead	27.4	4.9
Magnesium	2760	588
Manganese	1950	207
Mercury	0.059	0.02
Nickel	17.7	5
Potassium	1950	444
Vanadium	26.1	4.3
Zinc	532	22.3

[a] Only detected site-related contaminants are presented in the table.

[b] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).

AOC = Area of concern.

ft = Feet.

ID = Identification.

mg/kg = Milligrams per kilogram.

TAL = Target analyte list.

Table 4–2. Analytes Detected in Open Demolition Area #2 Phase II Remedial Investigation Sediment Samples

Aggregate		**Outside AOC**	**Outside AOC**	**Outside AOC**
Station		**DA2sd-101**	**DA2sd-101**	**DA2sd-103**
Sample ID		**DA2sd-101-0849-SD**	**DA2sd-101-0776-SD**	**DA2sd-103-0778-SD**
Date		**07/10/02**	**07/10/02**	**07/10/02**
Depth (ft)		**0.0 - 0.1**	**0.0 - 0.1**	**0.0 - 0.1**
Parameters Analyzed				
Analyte	**Background Criteria**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**
Metals (mg/kg)				
Aluminum	13900	5440R	5610R	4000R
Antimony	0	0.28R	<0.25U	<0.23U
Arsenic	19.5	6.3J	5.7J	11.4J
Barium	123	41.2	42.1	30.8
Beryllium	0.38	**0.55***	**0.5***	**0.52***
Cadmium	0	**0.69***	**0.81***	**0.46***
Calcium	5510	957J	913J	1080J
Chromium	18.1	7.8	8.3	7.7
Cobalt	9.1	6.9	6.7	5.8
Copper	27.6	22.3	**28.6***	13.9
Iron	28200	11300	12400	24100
Lead	27.4	12J	11.3J	9.5J
Magnesium	2760	1390J	1630J	1250J
Manganese	1950	142J	156J	457J
Mercury	0.059	**0.2***	**0.13***	0.05
Nickel	17.7	16.9	**19.9***	12.4
Potassium	1950	722J	756J	587J
Sodium	112	85	<51.8UJ	<39.1UJ
Vanadium	26.1	10.5	10.3	9.7
Zinc	532	69.3J	81.2J	57.4J
Anions (mg/kg)				
Sulfide	None	**110***	**150***	**75***
Pesticides/PCBs (mg/kg)				
Dieldrin	None	<0.002U	<0.0022U	**0.00064J***
VOCs (mg/kg)				
Chloromethane	None	<0.012U	<0.013U	**0.004J***
Trichloroethene	None	<0.0061R	0.0038R	<0.0064R

[a] Only detected site-related contaminants are presented in the table.

[b] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).

AOC = Area of concern.
ft = Feet.
ID = Identification.
J = Estimated value less than reporting limits.
mg/kg = Milligrams per kilogram.
NR = Not reported/not analyzed.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
RVAAP = Ravenna Army Ammunition Plant.
SVOC= Semi-volatile organic compound.
TAL = Target analyte list.
U = Not detected.
UJ = Not detected, reporting limit estimated.
VOC = Volatile organic compound.
* = Result exceeds background criteria or no background criteria was available.
< = Less than.

Table 4–3. Analytes Detected in Open Demolition Area #2 Phase II Remedial Investigation Surface Water Samples

Aggregate		**Outside AOC**	**Outside AOC**	**Outside AOC**	**Outside AOC**
Station		**DA2sw-102**	**DA2sw-102**	**DA2sw-102**	**DA2sw-102**
Sample ID		**DA2sw-102-0787-SW**	**DA2sw-102-0788-SW**	**DA2sw-102-0789-SW**	**DA2sw-102-0790-SW**
Date		**07/09/02**	**09/09/02**	**11/26/02**	**04/03/03**
Depth (ft)		**RVAAP Full-suite analytes + nitrate**	**RVAAP Full-suite analytes + nitrate**	**RVAAP Full-suite analytes + nitrate**	**RVAAP Full-suite analytes + nitrate**
Parameters Analyzed	**Background Criteria**				
Analyte		**Total**	**Total**	**Total**	**Total**
Metals (mg/L)					
Aluminum	3.37	<0.0769UJ	<0.0667UJ	<0.071UJ	0.236
Barium	0.0475	0.0329	0.0339	0.0288	0.0218
Calcium	41.4	**56.1***	**63.6***	**42.5***	26.6
Iron	2.56	0.187	<0.0386UJ	0.356	0.538
Magnesium	10.8	**13.5***	**16.7***	**10.9***	6.43J
Manganese	0.391	0.0293	0.017	0.029	0.0584
Potassium	3.17	1.97	2.37	2.74J	1.41
Sodium	21.3	6.33	6.14	12.2	6.07
Anions (mg/L)					
Nitrate/Nitrite (NO3/NO2-N)	None	**0.24***	**0.06***	<0.05U	**0.07***
Explosives (mg/L)					
Nitrocellulose	None	<0.18U	**0.25***	<0.18U	<0.36U
SVOCs (mg/L)					
Bis(2-ethylhexyl)phthalate	None	<0.011R	<0.011U	<0.012U	**0.0021J***
VOCs (mg/L)					
Acetone	None	0.0081R	<0.005U	<0.0031UJ	<0.0047UJ
Carbon disulfide	None	<0.001UJ	**0.0017***	<0.001U	<0.001U
Chloroform	None	<0.001U	<0.001U	**0.002***	<0.001U
Methylene chloride	None	0.00086R	<0.00089UJ	<0.00071UJ	<0.0013UJ

[a] Only detected SRCs are presented in the table.

[b] Background concentrations are published in the *Phase II Remedial Investigation Report for Winklepeck Burning Grounds* (USACE 2001b).

AOC = Area of concern

ID = Identification.

J = Estimated value less than reporting limits.

mg/L = Milligrams per liter.

PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.

RVAAP = Ravenna Army Ammunition Plant.

SVOC = Semi-volatile organic compound.

U = Not detected.

UJ = Not detected, reporting limit estimated.

VOC = Volatile organic compound.

*** = Result exceeds background criteria or no background criteria was available.**

< = Less than.

Table 4–4. Characterization of 14 AOCs Sample Locations

Characterization of 14 AOCs Sample Location	Sample Depth (ft bgs)	Analytes	Potential Sources or Areas for Investigation	Previous Use and/or Description	Documented Release	Potential Contaminants from Use
WSAss-001M	0–1	Metals, Explosives	Igloo WS-2A	1941–1945: Building WS-2A was a high explosive storage igloo used for mercury fulminate storage. Characterized surface soil at the former entrance to storage igloo.	None	Mercury fulminate
WSAss-002M	0–1	Metals, Explosives	Igloo WS-2	1941–1945: Building WS-2 was a high explosive storage igloo used for mercury fulminate storage. Characterized surface soil at the former entrance to storage igloo.	None	Mercury fulminate
WSAss-003M	0–1	Metals, Explosives	Igloo WS-1A	1941–1945: Building WS-1A was a high explosive storage igloo used for lead azide storage. Characterized surface soil at the former entrance to storage igloo.	None	Lead azide
WSAss-004D	0–1	VOCs	Igloo WS-1	1941–1945: Building WS-1 was a high explosive storage igloo used for lead azide storage. Characterized surface soil at the former entrance to storage igloo.	None	Lead azide
WSAss-004M	0–1	Full suite				
WSAss-005M	0–1	Metals, Explosives	Igloo WS-3	1941–1945: Building WS-3 was a high explosive storage igloo used for tetryl storage. Characterized two discontinuous drainage ditches along the access road to WS-3. QC sample collected.	None	Tetryl
WSAss-006M	0–1	Metals, Explosives	Igloo WS-3A	1941–1945: Building WS-3A was a high explosive storage igloo used for tetryl storage. Characterized two discontinuous drainage ditches along the access road to WS-3A.	None	Tetryl
WSAss-007M	0–1	Metals, Explosives	Igloo WS-2A	1941–1945: Building WS-2A was a high explosive storage igloo used for mercury fulminate storage. Characterized drainage ditch north of WS-2A.	None	Mercury fulminate
WSAss-008M	0–1	Metals, Explosives	Igloo WS-2A	1941–1945: Building WS-2A was a high explosive storage igloo used for mercury fulminate storage. Characterized drainage ditch south of WS-2A.	None	Mercury fulminate
WSAss-009M	0–1	Metals, Explosives	Igloo WS-2	1941–1945: Building WS-2 was a high explosive storage igloo used for mercury fulminate storage. Characterized drainage ditch north of WS-2.	None	Mercury fulminate
WSAss-010M	0–1	Metals, Explosives	Igloos WS-2 and WS-2A	1941–1945: Buildings WS-2 and WS-2A were two high explosive storage igloos used for mercury fulminate storage. Characterized drainage ditch between WS-2 and WS-2A.	None	Mercury fulminate
WSAss-011D	0–1	VOCs	Igloo WS-2A	1941–1945: Building WS-2A was a high explosive storage igloo used for mercury fulminate storage. Backside of mound. Characterized drainage ditch west of WS-2A (backside of earthen mound).	None	Mercury fulminate
WSAss-011M	0–1	Full suite				
WSAss-012M	0–1	Metals, Explosives	Igloo WS-2	1941–1945: Building WS-2 was a high explosive storage igloo used for mercury fulminate storage. Characterized drainage ditch west of WS-2 (backside of earthen mound).	None	Mercury fulminate
WSAss-013M	0–1	Metals, Explosives	Igloo WS-1A	1941–1945: Building WS-1A was a high explosive storage igloo used for lead azide storage. Characterized drainage ditch west of WS-1A (backside of earthen mound).	None	Lead azide
WSAss-014M	0–1	Metals, Explosives	Igloo WS-1A	1941–1945: Building WS-1A was a high explosive storage igloo used for lead azide storage. Characterized drainage ditch south of WS-1A. QC sample collected.	None	Lead azide
WSAss-015M	0–1	Metals, Explosives	Igloo WS-1	1941–1945: Building WS-1 was a high explosive storage igloo used for lead azide storage. Characterized drainage ditch north of WS-1.	None	Lead azide
WSAss-016M	0–1	Metals, Explosives	Igloos WS-1 and WS-1A	1941–1945: Building WS-1 and WS-1A were two high explosive storage igloos used for lead azide storage. Characterized drainage ditch between WS-1 and WS-1A. QA sampled collected.	None	Lead azide
WSAss-017M	0–1	Metals, Explosives	Igloo WS-1	1941–1945: Building WS-1 was a high explosive storage igloo used for lead azide storage. Characterized drainage ditch west of WS-1 (backside of earthen mound).	None	Lead azide
WSAss-020M	0–1	Metals, Explosives	Igloo WS-1A	1941–1945: Building WS-1A was a high explosive storage igloo used for lead azide storage. Characterized drainage ditch north of WS-1A. QC sample collected.	None	Lead azide

AOC = Area of concern.
bgs = Below ground surface.
ft = Feet.
QC= Quality control.

Table 4–5. Analytes Detected in Characterization of 14 AOCs ISM Surface Soil Samples

Aggregate	**Background Criteria**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAss-001M**	**WSAss-002M**	**WSAss-003M**	**WSAss-004D**	**WSAss-004M**	**WSAss-005M**	**WSAss-005M**	**WSAss-006M**	**WSAss-007M**	**WSAss-008M**
Sample ID		**WSAss-001M-SO**	**WSAss-002M-SO**	**WSAss-003M-SO**	**WSAss-004D-SO**	**WSAss-004M-SO**	**WSAss-005M-DUP**	**WSAss-005M-SO**	**WSAss-006M-SO**	**WSAss-007M-SO**	**WSAss-008M-SO**
Date		**10/27/04**	**10/26/04**	**10/26/04**	**10/26/04**	**10/26/04**	**10/27/04**	**10/27/04**	**10/27/04**	**10/27/04**	**10/29/04**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed		**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**VOCs**	**TAL Metals, Explosives, Pesticides/PCBs, SVOCs**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**
Analyte											
Metals (mg/kg)											
Aluminum	17700	13000	12000	11000	NR	10000	13000	16000	12000	13000	10000
Antimony	0.96	<1.4U	<1.2U	<1.3U	NR	<1.4U	<1.4U	<1.5U	<1.4U	<1.5U	0.52
Arsenic	15.4	**18***	**19***	**16***	NR	15	**16***	11	15	**18***	14
Barium	88.4	54	56	65	NR	52	74	**110***	67	52	56
Beryllium	0.88	0.74	0.79	0.77	NR	0.7	0.81	**1***	0.79	0.81	0.69
Calcium	15800	4100	5400	5900	NR	2400	2300	5100	4000	1200	1300
Chromium	17.4	**22***	**25***	**26***	NR	**20***	**20***	**23***	**21***	**24***	**18***
Cobalt	10.4	10	**12***	**12***	NR	10	**11***	**11***	**11***	**12***	**11***
Copper	17.7	**21***	**20***	**18***	NR	**20***	**20***	**20***	**20***	**20***	**19***
Iron	23100	**30000***	**30000***	**27000***	NR	**26000***	**26000***	**27000***	**25000***	**29000***	**26000***
Lead	26.1	**69***	**97***	19	NR	15	16	16	15	22	**40***
Magnesium	3030	**3400***	**3400***	**3100***	NR	2900	**3200***	**3900***	**3700***	**3200***	3000
Manganese	1450	400	400	400	NR	310	340	410	410	300	290
Mercury	0.036	0.03	**0.7***	0.02	NR	**0.14***	0.03	**0.09***	**0.04***	0.03	**2***
Nickel	21.1	**23***	**29***	**29***	NR	**25***	**26***	**27***	**27***	**26***	**25***
Potassium	927	**1300***	**1000***	**1100***	NR	920	1600*	**1900***	**1600***	**1200***	**1200***
Selenium	1.4	0.42	<1.4U	<1.5U	NR	<1.4U	<1.5U	<1.5U	<1.4U	<1.7U	<1.4U
Sodium	123	**320***	**310***	**280***	NR	**280***	**390***	**430***	**390***	**340***	**260***
Thallium	0	<0.59U	<0.54U	<0.55U	NR	<0.59U	**0.26***	**0.26***	<0.6U	**0.31***	<0.58U
Vanadium	31.1	21	18	18	NR	16	21	28	19	20	17
Zinc	61.8	**71***	**140***	**64***	NR	**63***	**65***	**71***	**67***	**68***	**82***
Explosives and Propellants (mg/kg)											
3-Nitrotoluene	None	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Nitrocellulose	None	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SVOCs (mg/kg)											
2-Methylnaphthalene	None	NR	NR	NR	NR	**0.058***	NR	NR	NR	NR	NR
Acenaphthene	None	NR	NR	NR	NR	**1.5***	NR	NR	NR	NR	NR
Acenaphthylene	None	NR	NR	NR	NR	**0.016J***	NR	NR	NR	NR	NR
Anthracene	None	NR	NR	NR	NR	**2.9***	NR	NR	NR	NR	NR
Benz(a)anthracene	None	NR	NR	NR	NR	**8.2***	NR	NR	NR	NR	NR
Benzenemethanol	None	NR	NR	NR	NR	**0.62J***	NR	NR	NR	NR	NR
Benzo(a)pyrene	None	NR	NR	NR	NR	**5.5***	NR	NR	NR	NR	NR
Benzo(b)fluoranthene	None	NR	NR	NR	NR	**7.3***	NR	NR	NR	NR	NR
Benzo(ghi)perylene	None	NR	NR	NR	NR	**3.7***	NR	NR	NR	NR	NR

Table 4–5. Analytes Detected in Characterization of 14 AOCs ISM Surface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAss-001M**	**WSAss-002M**	**WSAss-003M**	**WSAss-004D**	**WSAss-004M**	**WSAss-005M**	**WSAss-005M**	**WSAss-006M**	**WSAss-007M**	**WSAss-008M**
Sample ID		**WSAss-001M-SO**	**WSAss-002M-SO**	**WSAss-003M-SO**	**WSAss-004D-SO**	**WSAss-004M-SO**	**WSAss-005M-DUP**	**WSAss-005M-SO**	**WSAss-006M-SO**	**WSAss-007M-SO**	**WSAss-008M-SO**
Date		**10/27/04**	**10/26/04**	**10/26/04**	**10/26/04**	**10/26/04**	**10/27/04**	**10/27/04**	**10/27/04**	**10/27/04**	**10/29/04**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed											
Analyte	**Background Criteria**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**VOCs**	**TAL Metals, Explosives, Pesticides/PCBs, SVOCs**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**
SVOCs (mg/kg)(continued)											
Benzo(k)fluoranthene	None	NR	NR	NR	NR	**3.2***	NR	NR	NR	NR	NR
Carbazole	None	NR	NR	NR	NR	**1.4***	NR	NR	NR	NR	NR
Chrysene	None	NR	NR	NR	NR	**7.8***	NR	NR	NR	NR	NR
Dibenz(a,h)anthracene	None	NR	NR	NR	NR	**0.94***	NR	NR	NR	NR	NR
Dibenzofuran	None	NR	NR	NR	NR	**0.54***	NR	NR	NR	NR	NR
Fluoranthene	None	NR	NR	NR	NR	**18***	NR	NR	NR	NR	NR
Fluorene	None	NR	NR	NR	NR	**1.3***	NR	NR	NR	NR	NR
Indeno(1,2,3-cd)pyrene	None	NR	NR	NR	NR	**3.4***	NR	NR	NR	NR	NR
Naphthalene	None	NR	NR	NR	NR	**0.081***	NR	NR	NR	NR	NR
Phenanthrene	None	NR	NR	NR	NR	**12***	NR	NR	NR	NR	NR
Phenol	None	NR	NR	NR	NR	**0.028J***	NR	NR	NR	NR	NR
Pyrene	None	NR	NR	NR	NR	**17***	NR	NR	NR	NR	NR
Pesticides/PCBs (mg/kg)											
beta-BHC	None	NR	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR

Table 4–5. Analytes Detected in Characterization of 14 AOCs ISM Surface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAss-009M**	**WSAss-010M**	**WSAss-011D**	**WSAss-011M**	**WSAss-012M**	**WSAss-013M**	**WSAss-014M**	**WSAss-014M**	**WSAss-015M**	**WSAss-016M**
Sample ID		**WSAss-009M-SO**	**WSAss-010M-SO**	**WSAss-011D-SO**	**WSAss-011M-SO**	**WSAss-012M-SO**	**WSAss-013M-SO**	**WSAss-014M-DUP**	**WSAss-014M-SO**	**WSAss-015M-SO**	**WSAss-016M-SO**
Date		**10/29/04**	**10/28/04**	**11/01/04**	**11/01/04**	**10/29/04**	**10/29/04**	**10/27/04**	**10/27/04**	**10/27/04**	**10/27/04**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed **Analyte**	**Background Criteria**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**VOCs**	**TAL Metals, Explosives, Pesticides/PCBs, SVOCs**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**
Metals (mg/kg)											
Aluminum	17700	11000	9500	NR	12000	8400	12000	12000	11000	11000	11000
Antimony	0.96	<1.3U	<1.3U	NR	<1.4U	<1.3U	<1.4U	<1.4U	<1.4U	<1.4U	<1.3U
Arsenic	15.4	**16***	14	NR	14	11	**17***	**16***	15	15	16*
Barium	88.4	55	51	NR	48	45	45	57	54	48	51
Beryllium	0.88	0.71	0.61	NR	0.62	0.5	0.64	0.7	0.66	0.63	0.68
Calcium	15800	1300	1600	NR	750	1300	830	1100	1100	1100	1300
Chromium	17.4	**18***	16	NR	**19***	**18***	**19***	**21***	20*	26*	21*
Cobalt	10.4	**12***	9.6	NR	8.9	6.6	10	**11***	10	9.9	10
Copper	17.7	**18***	**19***	NR	16	16	**21***	**20***	19*	19*	20*
Iron	23100	**27000***	23000	NR	23000	17000	**27000***	**26000***	24000*	25000*	26000*
Lead	26.1	**46***	**50***	NR	18	17	14	14	14	17	17
Magnesium	3030	**3100***	2600	NR	2400	1800	2900	**3200***	2900	2800	2800
Manganese	1450	350	320	NR	390	330	290	330	330	290	350
Mercury	0.036	**1.4***	**2.1***	NR	**0.04***	**0.05***	0.02	0.02	0.03	1.4*	2*
Nickel	21.1	**26***	**23***	NR	19	18	**22***	**26***	25*	26*	25*
Potassium	927	**1100***	**1100***	NR	**1200***	740	**1300***	**1400***	1200*	1100*	1300*
Selenium	1.4	<1.5U	<1.4U	NR	<1.4U	<1.3U	<1.4U	<1.5U	<1.6U	<1.4U	<1.5U
Sodium	123	**260***	**250***	NR	**280***	**200***	**290***	**380***	340*	370*	380*
Thallium	0	<0.54U	<0.56U	NR	<0.61U	<0.57U	<0.59U	<0.61U	0.26*	0.25*	<0.57U
Vanadium	31.1	18	16	NR	20	15	19	19	17	18	18
Zinc	61.8	**95***	**99***	NR	57	56	61	61	57	60	64*
Explosives and Propellants (mg/kg)											
3-Nitrotoluene	None	**0.08J***	<0.2U	<0.2U	NR	<0.2U	<0.2U	<0.2U	<0.19U	<0.2U	<0.2U
Nitrocellulose	None	NR	NR	NR	NR	**0.73J***	NR	NR	NR	NR	NR
SVOCs (mg/kg)											
2-Methylnaphthalene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Acenaphthene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Acenaphthylene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Anthracene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Benz(a)anthracene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Benzenemethanol	None	NR	NR	NR	<0.69U	NR	NR	NR	NR	NR	NR
Benzo(a)pyrene	None	NR	NR	NR	**0.012J***	NR	NR	NR	NR	NR	NR
Benzo(b)fluoranthene	None	NR	NR	NR	**0.019J***	NR	NR	NR	NR	NR	NR
Benzo(ghi)perylene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR

Table 4–5. Analytes Detected in Characterization of 14 AOCs ISM Surface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAss-009M**	**WSAss-010M**	**WSAss-011D**	**WSAss-011M**	**WSAss-012M**	**WSAss-013M**	**WSAss-014M**	**WSAss-014M**	**WSAss-015M**	**WSAss-016M**
Sample ID		**WSAss-009M-SO**	**WSAss-010M-SO**	**WSAss-011D-SO**	**WSAss-011M-SO**	**WSAss-012M-SO**	**WSAss-013M-SO**	**WSAss-014M-DUP**	**WSAss-014M-SO**	**WSAss-015M-SO**	**WSAss-016M-SO**
Date		**10/29/04**	**10/28/04**	**11/01/04**	**11/01/04**	**10/29/04**	**10/29/04**	**10/27/04**	**10/27/04**	**10/27/04**	**10/27/04**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed **Analyte**	**Background Criteria**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**VOCs**	**TAL Metals, Explosives, Pesticides/PCBs, SVOCs**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**
SVOCs (mg/kg)(continued)											
Benzo(k)fluoranthene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Carbazole	None	NR	NR	NR	<0.17U	NR	NR	NR	NR	NR	NR
Chrysene	None	NR	NR	NR	**0.015J***	NR	NR	NR	NR	NR	NR
Dibenz(a,h)anthracene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Dibenzofuran	None	NR	NR	NR	<0.069U	NR	NR	NR	NR	NR	NR
Fluoranthene	None	NR	NR	NR	**0.024J***	NR	NR	NR	NR	NR	NR
Fluorene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Indeno(1,2,3-cd)pyrene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Naphthalene	None	NR	NR	NR	<0.034U	NR	NR	NR	NR	NR	NR
Phenanthrene	None	NR	NR	NR	<0.052U	NR	NR	NR	NR	NR	NR
Phenol	None	NR	NR	NR	<0.17U	NR	NR	NR	NR	NR	NR
Pyrene	None	NR	NR	NR	**0.016J***	NR	NR	NR	NR	NR	NR
Pesticides/PCBs (mg/kg)											
beta-BHC	None	NR	NR	NR	**0.0034***	NR	NR	NR	NR	NR	NR

Table 4–5. Analytes Detected in Characterization of 14 AOCs ISM Surface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAss-016M**	**WSAss-017M**	**WSAss-020M**	**WSAss-020M**
Sample ID		**WSAss-016M-QA**	**WSAss-017M-SO**	**WSAss-020M-DUP**	**WSAss-020M-SO**
Date		**10/27/04**	**10/27/04**	**12/03/04**	**12/03/04**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed					
Analyte	**Background Criteria**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**
Metals (mg/kg)					
Aluminum	17700	11000	13000	12000	12000
Antimony	0.96	<1.5U	<1.4U	0.51J	<1.3U
Arsenic	15.4	15	14	**20***	**21***
Barium	88.4	52	60	51	52
Beryllium	0.88	0.68	0.66	0.77	0.79
Calcium	15800	1400	1100	1800	1800
Chromium	17.4	**22***	**22***	**19***	**20***
Cobalt	10.4	9.9	10	**14***	**14***
Copper	17.7	**22***	15	**22***	**21***
Iron	23100	**25000***	**25000***	**31000***	**32000***
Lead	26.1	17	14	15	16
Magnesium	3030	2700	2600	**3800***	**3900***
Manganese	1450	330	800	410	420
Mercury	0.036	**0.84***	**0.04***	0.03	0.03
Nickel	21.1	**24***	20	**31***	**32***
Potassium	927	**1200***	**1100***	**1500***	**1400***
Selenium	1.4	<1.5U	<1.4U	0.74	0.85
Sodium	123	**370***	**350***	**430***	**430***
Thallium	0	<0.63U	<0.59U	<0.59UJ	<0.57U
Vanadium	31.1	19	22	20	20
Zinc	61.8	**66***	58	**68***	**69***
Explosives and Propellants (mg/kg)					
3-Nitrotoluene	None	<0.2U	<0.2U	<0.2U	<0.2U
Nitrocellulose	None	NR	NR	NR	NR
SVOCs (mg/kg)					
2-Methylnaphthalene	None	NR	NR	NR	NR
Acenaphthene	None	NR	NR	NR	NR
Acenaphthylene	None	NR	NR	NR	NR
Anthracene	None	NR	NR	NR	NR
Benz(a)anthracene	None	NR	NR	NR	NR
Benzenemethanol	None	NR	NR	NR	NR
Benzo(a)pyrene	None	NR	NR	NR	NR
Benzo(b)fluoranthene	None	NR	NR	NR	NR
Benzo(ghi)perylene	None	NR	NR	NR	NR

Table 4–5. Analytes Detected in Characterization of 14 AOCs ISM Surface Soil Samples (continued)

Aggregate		AOC	AOC	AOC	AOC
Station		**WSAss-016M**	**WSAss-017M**	**WSAss-020M**	**WSAss-020M**
Sample ID		**WSAss-016M-QA**	**WSAss-017M-SO**	**WSAss-020M-DUP**	**WSAss-020M-SO**
Date		**10/27/04**	**10/27/04**	**12/03/04**	**12/03/04**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed					
Analyte	**Background Criteria**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**	**TAL Metals, Explosives**
SVOCs (mg/kg)(continued)					
Benzo(k)fluoranthene	None	NR	NR	NR	NR
Carbazole	None	NR	NR	NR	NR
Chrysene	None	NR	NR	NR	NR
Dibenz(a,h)anthracene	None	NR	NR	NR	NR
Dibenzofuran	None	NR	NR	NR	NR
Fluoranthene	None	NR	NR	NR	NR
Fluorene	None	NR	NR	NR	NR
Indeno(1,2,3-cd)pyrene	None	NR	NR	NR	NR
Naphthalene	None	NR	NR	NR	NR
Phenanthrene	None	NR	NR	NR	NR
Phenol	None	NR	NR	NR	NR
Pyrene	None	NR	NR	NR	NR
Pesticides/PCBs (mg/kg)					
beta-BHC	None	NR	NR	NR	NR

AOC = Area of concern.
BHC = Hexachlorocyclohexane.
ft = Feet.
ID = Identification.
ISM = Incremental sampling methodology.
J = Estimated value less than reporting limits.
mg/kg = Milligrams per kilogram.
NR = Not reported/not analyzed.
PCB = Polychlorinated biphenyl.
SVOC = Semi-volatile organic compound.
TAL = Target analyte list.
U = Not detected.
UJ = Not detected, reporting limit estimated.
VOC = Volatile organic compound.
*** = Result exceeds background criteria or no background criteria was available.**
< = Less than.

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Table 4–6. Human Health Chemicals of Potential Concern per the Characterization of 14 AOCs Report

Soil[a]	Sediment	Surface Water	Groundwater
Arsenic Iron 2-Methylnaphthalene Acenaphthylene Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(ghi)perylene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Phenanthrene Nitrocellulose	Not evaluated	Not evaluated	Not evaluated – no monitoring wells present at the AOC at time of investigation.

Adapted from Table WSA-7, Characterization of 14 AOCs at the Ravenna Army Ammunition Plant (MKM 2007).
AOC = Area of concern.

Table 4–7. Chemicals Exceeding ESVs per the Characterization of 14 AOCs Report

Soil	Sediment	Surface Water	Groundwater
Arsenic Chromium Iron Lead Mercury Nickel Zinc Beta-BHC Benz(a)anthracene Benzo(a)pyrene Carbazole Chrysene Dibenzofuran 3-Nitrotoluene Nitrocellulose	Not evaluated	Not evaluated	Not evaluated – no monitoring wells present at the AOC at time of investigation.

Adapted from Table WSA-8, Characterization of 14 AOCs at the Ravenna Army Ammunition Plant (MKM 2007).
AOC = Area of concern.
BHC = Hexachlorocyclohexane.

Table 4–8. Chemicals Detected at Concentrations above Screening Criteria in Previous Investigations

Surface Soil	Subsurface Soil	Sediment	Surface Water
Arsenic Chromium Cobalt Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene	Not previously sampled	Not previously sampled	Not previously sampled

Note: This table was generated using data from the Characterization of 14 AOCs at the Ravenna Army Ammunition Plant (MKM 2007).

Table 4–9. PBA08 RI Surface Soil Samples and Rationales

PBA08 RI Station	Targeted Area	Purpose	Analyses Performed				
			Metals	Explosives	VOCs	Pesticides/ PCBs	SVOC
WSAss-033M	ISM area around igloos WS-2 and WS-2A, and drainage ditches	Delineate lateral extent of previously identified surface soil contamination	Y	Y	N	N	PAH
WSAss-034M	ISM area around igloo WS-3A and drainage ditches	Delineate lateral extent of previously identified surface soil contamination	Y	Y	N	N	PAH
		QA/QC	Y	Y	N	N	PAH
			Y	Y	N	N	PAH
WSAss-035M	Drainage ditch downstream of igloo WS-3A and Building PS-7	Delineate lateral extent of previously identified surface soil contamination	Y	Y	N	N	PAH
WSAss-036M	ISM area around igloos WS-1 and WS-1A, and associated drainage ditches	Delineate lateral extent of previously identified surface soil contamination, analyzed for RVAAP full-suite analytes	Y	Y	Y	Y	Y

PAH = Polycyclic aromatic hydrocarbon.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
PCB = Polychlorinated biphenyl.
ISM = Incremental sampling methodology.
QA = Quality assurance.
QC = Quality control.
RVAAP = Ravenna Army Ammunition Plant.
SVOC = Semi-volatile organic compound.
VOC = Volatile organic compound.

Table 4–10. Analytes Detected in PBA08 RI ISM Surface Soil Samples

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAss-033M**	**WSAss-034M**	**WSAss-034M**	**WSAss-035M**	**WSAss-036M**
Sample ID		**WSAss-033M-5645-SO**	**WSAss-034M-6195-FD**	**WSAss-034M-5646-SO**	**WSAss-035M-5648-SO**	**WSAss-036M-5647-SO**
Date		**03/24/10**	**03/24/10**	**03/24/10**	**03/24/10**	**03/24/10**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed [a]		**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**
Analyte	**Background Criteria** [b]					
Metals (mg/kg)						
Aluminum	17700	**27100J***	12200J	12500J	11800J	12900J
Antimony	0.96	0.1J	0.13J	0.12J	0.11J	0.11J
Arsenic	15.4	**15.5J***	14.4J	14J	13.2J	14.8J
Barium	88.4	60.3	59.9	61.2	70.4	57
Beryllium	0.88	**1.3***	0.5	0.5	0.66	0.49
Cadmium	0	**0.11J***	**0.12J***	**0.12J***	**0.19J***	**0.11J***
Calcium	15800	2080J	1210J	1330J	2400J	787J
Chromium	17.4	**19.4***	**29.9***	**20.4***	**21.6***	**20***
Cobalt	10.4	**12.2***	**11.7***	9.9	9.6	**11***
Copper	17.7	16.4	16.5	16.3	17.3	17
Iron	23100	**30700***	**29800***	**28100***	**27300***	**29500***
Lead	26.1	17.2J	16.4J	16.2J	19.2J	17.4J
Magnesium	3030	**3130J***	2740J	2820J	2870J	2950J
Manganese	1450	1130	529	451	327	537
Mercury	0.036	0.018J	0.023J	0.019J	0.025J	0.036J
Nickel	21.1	**23J***	**25.5J***	**21.7J***	**23.3J***	**22.9J***
Potassium	927	**2230J***	**979J***	**989J***	**951J***	**974J***
Selenium	1.4	**1.4***	1.2	1.2	**1.4***	1.2
Silver	0	<0.024UJ	<0.026UJ	<0.028UJ	**0.035J***	<0.023UJ
Sodium	123	37.7J	40.4J	37.2J	44J	35.4J
Thallium	0	**0.16J***	**0.15J***	**0.16J***	**0.15J***	**0.16J***
Vanadium	31.1	22.7	21.8	21.9	21.4	21.9
Zinc	61.8	56.3	51.2	56	61.1	58
SVOCs (mg/kg)						
2-Methylnaphthalene	None	NR	NR	NR	NR	**0.009J***
Acenaphthene	None	**0.032J***	**0.025***	**0.011***	<0.0068U	<0.051U
Anthracene	None	**0.051J***	**0.057***	**0.023***	<0.0068U	**0.0068J***
Benz(a)anthracene	None	**0.11J***	**0.15***	**0.074***	**0.034***	**0.023J***
Benzo(a)pyrene	None	**0.097J***	**0.13***	**0.071***	**0.039***	**0.022J***
Benzo(b)fluoranthene	None	**0.13J***	**0.17***	**0.082***	**0.063***	**0.033J***
Benzo(ghi)perylene	None	**0.075J***	**0.097***	**0.051***	**0.034***	**0.016J***
Benzo(k)fluoranthene	None	**0.061J***	**0.085***	**0.053***	**0.024***	**0.012J***
Chrysene	None	**0.12J***	**0.16***	**0.078***	**0.047***	**0.023J***
Dibenz(a,h)anthracene	None	**0.02J***	**0.023***	**0.014***	**0.0084***	<0.051U
Fluoranthene	None	**0.33J***	**0.35***	**0.17***	**0.085***	**0.051***

Table 4–10. Analytes Detected in PBA08 RI ISM Surface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAss-033M**	**WSAss-034M**	**WSAss-034M**	**WSAss-035M**	**WSAss-036M**
Sample ID		**WSAss-033M-5645-SO**	**WSAss-034M-6195-FD**	**WSAss-034M-5646-SO**	**WSAss-035M-5648-SO**	**WSAss-036M-5647-SO**
Date		**03/24/10**	**03/24/10**	**03/24/10**	**03/24/10**	**03/24/10**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed [a]						
Analyte	**Background Criteria** [b]	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**
SVOCs (mg/kg), continued						
Fluorene	None	**0.032J***	**0.026***	**0.012***	**0.0076***	<0.051U
Indeno(1,2,3-cd)pyrene	None	**0.064J***	**0.08***	**0.044***	**0.03***	**0.015J***
Naphthalene	None	**0.014J***	**0.013***	**0.011***	**0.014***	**0.0075J***
Phenanthrene	None	**0.24J***	**0.22***	**0.099***	**0.037***	**0.031J***
Pyrene	None	**0.24J***	**0.26***	**0.13***	**0.061***	**0.037J***
Pesticides/PCBs (mg/kg)						
4,4'-DDE	None	NR	NR	NR	NR	**0.0004J***
Endosulfan sulfate	None	NR	NR	NR	NR	**0.0026J***
Endrin	None	NR	NR	NR	NR	**0.00069J***
alpha-Chlordane	None	NR	NR	NR	NR	**0.0021J***

[a] Only detected SRCs are presented in the table.

[b] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).

AOC = Area of concern.
DDE = Dichlorodiphenyldichloroethylene.
ft = Feet.
ID = Identification.
ISM = Incremental sampling methodology.
J = Estimated value less than reporting limits.
mg/kg = Milligrams per kilogram.
NR = Not reported/not analyzed.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
PCB = Polychlorinated biphenyl.
RVAAP = Ravenna Army Ammunition Plant.
SVOC = Semi-volatile organic compound.
TAL = Target analyte list.
U = Non-detectable concentration.
UJ = Not detected, reporting limit estimated.* = Result exceeds background criteria or no background criteria was available.
< = Less than.

Table 4–11. Analytes Detected in PBA08 RI Discrete Surface Soil Samples

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAsb-021**	**WSAsb-022**	**WSAsb-023**	**WSAsb-024**	**WSAsb-026**	**WSAsb-027**	**WSAsb-028**	**WSAsb-029**	**WSAss-030**
Sample ID		**WSAsb-021-5611-SO**	**WSAsb-022-5615-SO**	**WSAsb-023-5619-SO**	**WSAsb-024-5623-SO**	**WSAsb-026-5629-SO**	**WSAsb-027-5633-SO**	**WSAsb-028-5637-SO**	**WSAsb-029-5641-SO**	**WSAss-030-5653-SO**
Date		**03/23/10**	**03/23/10**	**03/23/10**	**03/24/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/24/10**	**03/24/10**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed[a]	**Background Criteria**[b]	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**Chromium Speciation**
Analyte										
Metals (mg/kg)										
Aluminum	17700	7880	9390	12000	10800	11700	10800	9020	10300	NR
Antimony	0.96	0.19J	0.098J	0.081J	0.09J	<0.68UJ	0.079J	0.1J	0.088J	NR
Arsenic	15.4	10.8	**16.2***	**15.5***	12.4	**21.5***	14.8	15.1	**16.2***	NR
Barium	88.4	75.4J	59.5J	**89.8J***	60.3J	36.7J	45J	51J	28.5J	NR
Beryllium	0.88	0.55	0.62	0.7	0.57	0.61	0.56	0.57	0.46	NR
Cadmium	0	**0.5***	**0.12J***	**0.064J***	**0.28***	**0.058J***	**0.099J***	**0.26J***	**0.1J***	NR
Calcium	15800	3860	2360	1830	2430	1500	1330	2290	695	NR
Chromium	17.4	14J	14J	**18.7J***	13.4J	17J	15.8J	13.3J	13.7J	**21.8***
Chromium, hexavalent	None	NR	NR	NR	NR	NR	NR	NR	NR	<1U
Cobalt	10.4	8.8	10.2	**11.3***	**11.6***	**12.2***	9.3	**11.6***	8.8	NR
Copper	17.7	**19.4***	**20.3***	**20.4***	15.1	**22***	16.3	17.4	**22.1***	NR
Iron	23100	20200J	**25500J***	**30400J***	**23600J***	**33600J***	**24200J***	**25700J***	**26700J***	NR
Lead	26.1	**47.7***	12.9	15.4	**27.4***	13.8	15.1	23	13.8	NR
Magnesium	3030	2220J	2490J	**3760J***	2320J	**3820J***	2830J	2470J	2480J	NR
Manganese	1450	383	330	224	812	260	235	299	216	NR
Mercury	0.036	**0.076J***	<0.12U	<0.12U	**0.16***	<0.14U	<0.12U	**0.73***	0.027J	NR
Nickel	21.1	19.8J	21.1J	**28.9J***	18.9J	**30J***	20.4J	**21.8J***	20J	NR
Potassium	927	**934J***	**1050J***	**1090J***	814J	884J	**1080J***	680J	781J	NR
Selenium	1.4	1.1	1	1.2	0.92	1.2	0.9	1.1	0.73	NR
Sodium	123	29.7J	33J	45.1J	35.8J	38.6J	37.7J	29.1J	32.9J	NR
Thallium	0	**0.18J***	**0.14J***	**0.18J***	**0.15J***	**0.17J***	**0.16J***	**0.13J***	**0.15J***	NR
Vanadium	31.1	15.2J	15.7J	19.3J	18.5J	17.6J	18.9J	15.5J	15.8J	NR
Zinc	61.8	**114***	**64.1***	61.6	**106***	**65.9***	56.7	**62.6***	56.9	NR
Explosives (mg/kg)										
Tetryl	None	<0.25U	<0.24U	<0.25U	<0.25U	<0.25U	<0.25U	0.026J*	<0.25U	NR
SVOCs (mg/kg)										
2-Methylnaphthalene	None	NR	**0.022J***	NR	NR	NR	NR	<2.3U	NR	NR
Acenaphthene	None	<0.021U	**0.22***	<0.0083U	**0.77***	<0.0091U	**0.077***	**0.68***	<0.0089U	NR
Anthracene	None	<0.021U	**0.45***	**0.0083***	**2.1***	<0.0091U	**0.18J***	**1.4***	<0.0089U	NR
Benz(a)anthracene	None	**0.073***	**1.3***	**0.033***	**3.9***	<0.0091U	**0.34J***	**2.6***	<0.0089U	NR
Benzo(a)pyrene	None	**0.072***	**1.1***	**0.033***	**3.6***	<0.0091U	**0.3J***	**2.1***	<0.0089U	NR
Benzo(b)fluoranthene	None	**0.11***	**1.3***	**0.039***	**4***	<0.0091U	**0.36J***	**2.6***	<0.0089U	NR
Benzo(ghi)perylene	None	**0.06***	**0.67***	**0.021***	**2.2***	<0.0091U	**0.21J***	**1.3***	<0.0089U	NR
Benzo(k)fluoranthene	None	**0.045***	**0.66***	**0.021***	**2.2***	<0.0091U	**0.19J***	**1.1***	<0.0089U	NR
Bis(2-ethylhexyl)phthalate	None	NR	**0.084J***	NR	NR	NR	NR	<2.3U	NR	NR
Carbazole	None	NR	**0.2***	NR	NR	NR	NR	**0.65***	NR	NR

Table 4–11. Analytes Detected in PBA08 RI Discrete Surface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAsb-021**	**WSAsb-022**	**WSAsb-023**	**WSAsb-024**	**WSAsb-026**	**WSAsb-027**	**WSAsb-028**	**WSAsb-029**	**WSAss-030**
Sample ID		**WSAsb-021-5611-SO**	**WSAsb-022-5615-SO**	**WSAsb-023-5619-SO**	**WSAsb-024-5623-SO**	**WSAsb-026-5629-SO**	**WSAsb-027-5633-SO**	**WSAsb-028-5637-SO**	**WSAsb-029-5641-SO**	**WSAss-030-5653-SO**
Date		**03/23/10**	**03/23/10**	**03/23/10**	**03/24/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/24/10**	**03/24/10**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed [a] **Analyte**	**Background Criteria [b]**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**Chromium Speciation**
SVOCs (mg/kg), continued										
Chrysene	None	**0.096***	**1.3***	**0.031***	**3.5***	<0.0091U	**0.32J***	**2.4***	<0.0089U	NR
Dibenz(a,h)anthracene	None	<0.021U	**0.19***	<0.0083U	**0.49***	<0.0091U	**0.051***	**0.24J***	<0.0089U	NR
Dibenzofuran	None	NR	**0.07J***	NR	NR	NR	NR	**0.19J***	NR	NR
Fluoranthene	None	**0.21***	**3***	**0.07***	**11***	**0.012***	**0.97J***	**7.9***	<0.0089U	NR
Fluorene	None	<0.021U	0.17*	<0.0083U	0.73*	<0.0091U	**0.068***	**0.55***	<0.0089U	NR
Indeno(1,2,3-cd)pyrene	None	**0.052***	**0.6***	**0.019***	**1.9***	<0.0091U	**0.17J***	**1.2***	<0.0089U	NR
Naphthalene	None	<0.021U	**0.039J***	<0.0083U	<0.085U	<0.0091U	<0.0083U	<0.34U	<0.0089U	NR
Phenanthrene	None	**0.089***	**1.6***	**0.032***	**7.5***	<0.0091U	**0.67J***	**5.5***	<0.0089U	NR
Pyrene	None	**0.16***	**2.4***	**0.055***	**8.1***	**0.0094***	**0.71J***	**5.6***	<0.0089U	NR

Table 4–11. Analytes Detected in PBA08 RI Discrete Surface Soil Samples (continued)

Aggregate		AOC	AOC
Station		WSAss-031	WSAss-032
Sample ID		WSAss-031-5654-SO	WSAss-032-5655-SO
Date		03/24/10	03/24/10
Depth (ft)		0.0 - 1.0	0.0 - 1.0
Parameters Analyzed [a]	Background	Chromium	Chromium
Analyte	Criteria [b]	Speciation	Speciation
Metals (mg/kg)			
Aluminum	17700	NR	NR
Antimony	0.96	NR	NR
Arsenic	15.4	NR	NR
Barium	88.4	NR	NR
Beryllium	0.88	NR	NR
Cadmium	0	NR	NR
Calcium	15800	NR	NR
Chromium	17.4	16.5	**20.6***
Chromium, hexavalent	None	**0.52J***	<1.1U
Cobalt	10.4	NR	NR
Copper	17.7	NR	NR
Iron	23100	NR	NR
Lead	26.1	NR	NR
Magnesium	3030	NR	NR
Manganese	1450	NR	NR
Mercury	0.036	NR	NR
Nickel	21.1	NR	NR
Potassium	927	NR	NR
Selenium	1.4	NR	NR
Sodium	123	NR	NR
Thallium	0	NR	NR
Vanadium	31.1	NR	NR
Zinc	61.8	NR	NR
Explosives (mg/kg)			
Tetryl	None	NR	NR
SVOCs (mg/kg)			
2-Methylnaphthalene	None	NR	NR
Acenaphthene	None	NR	NR
Anthracene	None	NR	NR
Benz(a)anthracene	None	NR	NR
Benzo(a)pyrene	None	NR	NR
Benzo(b)fluoranthene	None	NR	NR
Benzo(ghi)perylene	None	NR	NR
Benzo(k)fluoranthene	None	NR	NR
Bis(2-ethylhexyl)phthalate	None	NR	NR
Carbazole	None	NR	NR

Table 4–11. Analytes Detected in PBA08 RI Discrete Surface Soil Samples (continued)

Aggregate		**AOC**	**AOC**
Station		**WSAss-031**	**WSAss-032**
Sample ID		**WSAss-031-5654-SO**	**WSAss-032-5655-SO**
Date		**03/24/10**	**03/24/10**
Depth (ft)		**0.0 - 1.0**	**0.0 - 1.0**
Parameters Analyzed [a]	**Background Criteria [b]**	**Chromium Speciation**	**Chromium Speciation**
Analyte			
SVOCs (mg/kg), continued			
Chrysene	None	NR	NR
Dibenz(a,h)anthracene	None	NR	NR
Dibenzofuran	None	NR	NR
Fluoranthene	None	NR	NR
Fluorene	None	NR	NR
Indeno(1,2,3-cd)pyrene	None	NR	NR
Naphthalene	None	NR	NR
Phenanthrene	None	NR	NR
Pyrene	None	NR	NR

[a] Only detected SRCs are presented in the table.
[b] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).
AOC = Area of concern.
ft = Feet.
ID = Identification.
J = Estimated value less than reporting limits.
mg/kg = Milligrams per kilogram.
NR = Not reported/not analyzed.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
RVAAP = Ravenna Army Ammunition Plant.
SVOC = Semi-volatile organic compound.
TAL = Target analyte list.
U = Non-detectable concentration.
UJ = Not detected, reporting limit estimated.
* = Result exceeds background criteria or no background criteria was available.
< = Less than.

Table 4–12. Chromium Speciation Samples under PBA08 RI

PBA08 RI Location	Rationale for Sample Selection
WSAss-030	Discrete sample collected to assess chromium speciation at igloo WS-2A. Previous chromium result represents elevated chromium concentration (WSAss-001M at 22 mg/kg)
WSAss-031	Discrete sample collected to assess chromium speciation in drainage ditch between igloos WS-2 and WS-2A. Previous chromium result represents near background chromium concentration (WSAss-009M at 18 mg/kg)
WSAss-032	Discrete sample collected to assess chromium speciation at igloo WS-1A. Previous chromium result represents elevated chromium concentration (WSAss-003M at 26 mg/kg)

mg/kg = Milligrams per kilogram.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.

Table 4–13. Subsurface Soil Rationale and Analyses

PBA08 RI Location	Comments/Rationale	Sample Type	Depth (ft bgs)	Analyses Performed				
				Metals	Explosives	VOCs	Pesticides/ PCBs	SVOC
WSAsb-021	Delineate vertical extent of previously identified surface soil contamination	Discrete	0–1	Y	Y	N	N	PAH
		Discrete	1–4	Y	Y	N	N	PAH
		Discrete	4–7	Y	Y	N	N	PAH
		NA	7–13	Y	Y	N	N	N
	QA/QC	Discrete	4–7	Y	Y	N	N	PAH
		NA	7–13	Y	Y	N	N	PAH
		Discrete	4–7	Y	Y	N	N	PAH
		NA	7–13	N	N	N	N	N
WSAsb-022	Delineate vertical extent of previously identified surface soil contamination, analyzed for RVAAP full-suite analytes	Discrete	0–1	Y	Y	Y	Y	Y
		Discrete	1–4	Y	Y	Y	Y	Y
		Discrete	4–7	Y	Y	Y	Y	Y
		NA	7–13	N	N	N	N	N
	QA/QC	Discrete	1–4	Y	Y	N	N	PAH
		Discrete	1–4	Y	Y	N	N	PAH
WSAsb-023	Delineate vertical extent of previously identified surface soil contamination	Discrete	0–1	Y	Y	N	N	PAH
		Discrete[b]	1–4	Y	Y	N	N	PAH
		Discrete	4–7	Y	Y	N	N	PAH
		Discrete	7–13	Y	Y	N	N	PAH
WSAsb-024	Delineate vertical extent of previously identified surface soil contamination	Discrete	0–1	Y	Y	N	N	PAH
		Discrete	1–4	Y	Y	N	N	PAH
		Discrete	4–7	Y	Y	N	N	PAH
		Discrete	7–13	Y	Y	N	N	PAH
	QA/QC	Discrete	1–4	Y	Y	N	N	PAH
		Discrete[a]	1–4	Y	Y	N	N	PAH
WSAsb-025	Geotechnical	Discrete	4–5.2	Y	Y	N	N	PAH
		Discrete	12–13.1	Y	Y	N	N	PAH

Table 4–13. Subsurface Soil Rationale and Analyses (continued)

PBA08 RI Location	Comments/Rationale	Sample Type	Depth ft (bgs)	Analyses Performed Metals	Explosives	VOCs	Pesticides/ PCBs	SVOC
WSAsb-026	Delineate vertical extent of previously identified surface soil contamination	Discrete	0–1	Y	Y	N	N	PAH
		Discrete	1–4	Y	Y	N	N	PAH
		Discrete	4–7	Y	Y	N	N	PAH
		Discrete[a]	7–13	Y	Y	N	N	PAH
WSAsb-027	Delineate vertical extent of previously identified surface soil contamination	Discrete	0–1	Y	Y	N	N	PAH
		Discrete	1–4	Y	Y	N	N	PAH
		Discrete	4–7	Y	Y	N	N	PAH
		NA	7–13	N	N	N	N	N
WSAsb-028	Delineate vertical extent of previously identified surface soil contamination, analyzed for RVAAP full-suite analytes	Discrete	0–1	Y	Y	Y	Y	Y
		Discrete	1–4	Y	Y	Y	Y	Y
		Discrete	4–7	Y	Y	Y	Y	Y
		Discrete[b]	7–13	Y	Y	Y	Y	Y
WSAsb-029	Delineate vertical extent of previously identified surface soil contamination. Bedrock encountered at 7 ft	Discrete	0–1	Y	Y	N	N	PAH
		Discrete	1–4	Y	Y	N	N	PAH
		Discrete	4–7	Y	Y	N	N	PAH
		NS	7–13	N	N	N	N	N

[a] Sample analyzed by the laboratory based on exceedance of preliminary screening criteria of the 4–7 ft bgs sample interval.

[b] Two samples (10%) from 7–13 ft bgs were submitted for laboratory analysis to characterize subsurface soil to 13 ft bgs.

bgs = Below ground surface.
ft = Feet.
NA = Sample not analyzed by the laboratory based on preliminary screening criteria results of the 4–7 ft bgs sample interval.
NS = Not sampled due to refusal.
PAH = Polycyclic aromatic hydrocarbon.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
PCB = Polychlorinated biphenyl.
QA = Quality assurance.
QC = Quality control.
RVAAP = Ravenna Army and Ammunition Plant.
SVOC = Semi-volatile organic compound.
VOC = Volatile organic compound.

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Table 4–14. Analytes Detected in PBA08 RI Subsurface Soil Samples

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAsb-021**	**WSAsb-021**	**WSAsb-021**	**WSAsb-022**	**WSAsb-022**	**WSAsb-022**	**WSAsb-023**	**WSAsb-023**	**WSAsb-024**
Sample ID		**WSAsb-021-5612-SO**	**WSAsb-021-6201-FD**	**WSAsb-021-5613-SO**	**WSAsb-022-6200-FD**	**WSAsb-022-5616-SO**	**WSAsb-022-5617-SO**	**WSAsb-023-5620-SO**	**WSAsb-023-5621-SO**	**WSAsb-024-6203-FD**
Date		**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/24/10**
Depth (ft)		**1.0 - 4.0**	**4.0 - 7.0**	**4.0 - 7.0**	**1.0 - 4.0**	**1.0 - 4.0**	**4.0 - 7.0**	**1.0 - 4.0**	**4.0 - 7.0**	**1.0 - 4.0**
Parameters Analyzed[a] **Analyte**	**Background Criteria[b]**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**
Metals (mg/kg)										
Aluminum	19500	9650	12400	11300J	10700	9930	6680J	9950	6240J	10200J
Antimony	0.96	0.084J	0.093J	0.091J	0.079J	0.087J	0.1J	0.096J	<0.58UJ	0.088J
Arsenic	19.8	20.6*	17.7	13.9J	16.8	17.3	14.4J	16.4	13J	19.1
Barium	124	45.9J	36.5J	34.3J	52.6J	64.9J	34.6J	65.5J	28.9J	37.2J
Beryllium	0.88	0.55	0.65	0.63	0.6	0.67	0.52	0.61	0.34	0.57
Cadmium	0	**0.071J***	**0.049J***	**0.045J***	**0.052J***	**0.062J***	**0.056J***	**0.05J***	**0.062J***	**0.052J***
Calcium	35500	1600	3860	5220	1190	1460	1580	939	1230	1020
Chromium	27.2	15.2J	18.5J	18.4	15.7J	15.3J	13.6	13.8J	10.6	16.7
Cobalt	23.2	13.2	13.6	14.3J	11.5	**25.8***	10.3J	16.3	8.4J	10.6
Copper	32.3	21.1	20.4	18.7	20.6	23.9	21.9	24.3	18.4	17.8J
Iron	35200	28700J	32600J	29700	27500J	29300J	22000	26400J	20000	29400J
Lead	19.1	11.9	11.9	12.3J	10.9	17.5	18.3J	17.1	9.8J	11.5
Magnesium	8790	3490J	4980J	5650	3400J	3380J	2680	3180J	2520	4020J
Manganese	3030	571	271	295	379	572	259	338	385	280
Mercury	0.044	<0.12U	<0.12U	0.032J	<0.12U	<0.12U	<0.12U	<0.12U	<0.12U	<0.13U
Nickel	60.7	30.1J	32.5J	31.8	28.6J	33.5J	23	27.3J	19.1	28.9J
Potassium	3350	1150J	1800J	1760J	1350J	1070J	1260J	867J	948J	1300J
Selenium	1.5	1	1.1	1.1J	0.92	1.4	0.91J	1	0.79J	1.1J
Silver	0	<0.016UJ	<0.033UJ	**0.026J***	<0.013UJ	<0.014UJ	**0.025J***	<0.013UJ	**0.016J***	**0.016J***
Sodium	145	49.8J	74.6J	77.4J	50.6J	44.9J	53.6J	42.5J	53.2J	62.7J
Thallium	0.91	0.17J	0.18J	0.18J	0.15J	0.17J	0.12J	0.17J	0.12J	0.17J
Vanadium	37.6	16J	19.1J	18.6	16.3J	16.3J	12.7	15.1J	11.7	16.1
Zinc	93.3	62.2	67.9	61.5	63.5	67.2	61.5	68.6	50.3	67.3
SVOCs (mg/kg)										
Acenaphthene	None	<0.0083U	<0.0083U	<0.0082U	<0.059U	<0.062U	<0.06U	<0.008U	<0.0077U	<0.0086U
Anthracene	None	<0.0083U	<0.0083U	<0.0082U	<0.059U	<0.062U	<0.06U	<0.008U	<0.0077U	<0.0086U
Benz(a)anthracene	None	<0.0083U	<0.0083U	<0.0082U	<0.059U	**0.01J***	<0.06U	<0.008U	<0.0077U	<0.0086U
Benzo(a)pyrene	None	<0.0083U	<0.0083U	<0.0082U	<0.059U	<0.062U	<0.06U	<0.008U	<0.0077U	<0.0086U
Benzo(b)fluoranthene	None	<0.0083U	<0.0083U	<0.0082U	**0.0084J***	**0.011J***	<0.06U	<0.008U	<0.0077U	<0.0086U
Benzo(ghi)perylene	None	<0.0083U	<0.0083U	<0.0082U	<0.059U	<0.062U	<0.06U	<0.008U	<0.0077U	<0.0086U
Benzo(k)fluoranthene	None	<0.0083U	<0.0083U	<0.0082U	<0.059U	<0.062U	<0.06U	<0.008U	<0.0077U	<0.0086U
Bis(2-ethylhexyl)phthalate	None	NR	NR	NR	<0.39U	<0.41U	**0.038J***	NR	NR	NR
Chrysene	None	<0.0083U	<0.0083U	<0.0082U	<0.059U	<0.062U	<0.06U	<0.008U	<0.0077U	<0.0086U
Di-n-butyl phthalate	None	NR	NR	NR	<0.39U	**0.022J***	**0.021J***	NR	NR	NR

Table 4–14. Analytes Detected in PBA08 RI Subsurface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAsb-021**	**WSAsb-021**	**WSAsb-021**	**WSAsb-022**	**WSAsb-022**	**WSAsb-022**	**WSAsb-023**	**WSAsb-023**	**WSAsb-024**
Sample ID		**WSAsb-021-5612-SO**	**WSAsb-021-6201-FD**	**WSAsb-021-5613-SO**	**WSAsb-022-6200-FD**	**WSAsb-022-5616-SO**	**WSAsb-022-5617-SO**	**WSAsb-023-5620-SO**	**WSAsb-023-5621-SO**	**WSAsb-024-6203-FD**
Date		**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/24/10**
Depth (ft)		**1.0 - 4.0**	**4.0 - 7.0**	**4.0 - 7.0**	**1.0 - 4.0**	**1.0 - 4.0**	**4.0 - 7.0**	**1.0 - 4.0**	**4.0 - 7.0**	**1.0 - 4.0**
Parameters Analyzed [a] **Analyte**	**Background Criteria** [b]	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**
SVOCs (mg/kg)(continued)										
Dibenz(a,h)anthracene	None	4760	8900J	8210J	10500	7280	6880	9320	6720	11700
Fluoranthene	None	<0.63UJ	<0.61UJ	<0.63UJ	0.092J	0.087J	0.078J	0.086J	0.077J	0.12J
Fluorene	None	11.5J	12J	15.5J	15.5	**24.7J***	14.1	16.6	15.1J	15.5J
Indeno(1,2,3-cd)pyrene	None	23.9	45.2	34.9	88.9J	32.4	25.4	70J	39.2	48.3J
Naphthalene	None	0.25	0.45	0.43	0.63	0.46	0.41	0.53	0.41	0.5
Phenanthrene	None	**0.065J***	**0.088J***	<0.049UJ	**0.13J***	**0.051J***	**0.039J***	**0.054J***	**0.059J***	**0.082J***
Pyrene	None	5850J	20400	6000	1340J	1140	4420	790J	1190	1720J
Pesticides/PCBs (mg/kg)										
4,4'-DDT	None	7.4	13.6	12.4	14.7	11.5	10.5	13.8	11.4	15
VOCs (mg/kg)										
Toluene	None	6.4	9.5	9.4	16.8	9.1	8.7	9.4	9.4	5.2

Table 4–14. Analytes Detected in PBA08 RI Subsurface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAsb-024**	**WSAsb-024**	**WSAsb-024**	**WSAsb-026**	**WSAsb-026**	**WSAsb-026**	**WSAsb-027**	**WSAsb-027**	**WSAsb-028**
Sample ID		**WSAsb-024-5624-SO**	**WSAsb-024-5625-SO**	**WSAsb-024-5626-SO**	**WSAsb-026-5630-SO**	**WSAsb-026-5631-SO**	**WSAsb-026-5632-SO**	**WSAsb-027-5634-SO**	**WSAsb-027-5635-SO**	**WSAsb-028-5638-SO**
Date		**03/24/10**	**03/24/10**	**03/24/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**
Depth (ft)		**1.0 - 4.0**	**4.0 - 7.0**	**7.0 - 13.0**	**1.0 - 4.0**	**4.0 - 7.0**	**7.0 - 13.0**	**1.0 - 4.0**	**4.0 - 7.0**	**1.0 - 4.0**
Parameters Analyzed [a] **Analyte**	**Background Criteria [b]**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**
Metals (mg/kg)										
Aluminum	19500	12600	6800J	7860	13800	10400J	8380	12800	11200J	11000
Antimony	0.96	0.083J	0.079J	<0.58UJ	<0.67UJ	0.083J	0.08J	0.091J	0.081J	<0.62UJ
Arsenic	19.8	**20.8***	14.8J	14.2	19.5	21.3J*	16J	18.2	17.6J	17
Barium	124	42.1J	30.8J	29.3J	46J	37.8J	34J	43J	38.2J	43.9J
Beryllium	0.88	0.68	0.39	0.4	0.68	0.58	0.44	0.66	0.6	0.54
Cadmium	0	<0.046UJ	**0.057J***	**0.067J***	<0.043UJ	**0.042J***	<0.046UJ	<0.048UJ	<0.04UJ	<0.039UJ
Calcium	35500	1110	1260	7900	2230	4510	6530J	1850	3190	1570
Chromium	27.2	19J	11.7	11.9J	20.9J	17.5	13.3	19.2J	18.3	15.7J
Cobalt	23.2	13.3	8.7J	9.3	13.5	15.6J	10.3	14.9	12.8J	14.2
Copper	32.3	21.1	19.1	19.5	22	19.9	19.7	20.4	19	23
Iron	35200	33600J	23600	22400J	32600J	35000	25600	34500J	31900	29900J
Lead	19.1	11.9	11.7J	10.6	11.8	13.9J	10.6	12.8	12.5J	12.2
Magnesium	8790	4310J	2610	4350J	4750J	5550	4630J	4590J	4640	3700J
Manganese	3030	254	295	331	293	392	324	404	295	436
Mercury	0.044	<0.13U	<0.12U	<0.12U	<0.13U	<0.13U	<0.12U	<0.13U	<0.13U	0.025J
Nickel	60.7	31.5J	20.9	21.8J	32.3J	31.1	23.4	35J	30.5	29.4J
Potassium	3350	1580J	1100J	1210J	1650J	1590J	1400	1520J	1670J	963J
Selenium	1.5	1.1	0.84J	0.78	1.2	1.1J	0.76J	1.1	1.1J	1
Silver	0	<0.017UJ	<0.018UJ	<0.03UJ	<0.036UJ	**0.025J***	<0.03UJ	<0.019UJ	<0.023UJ	<0.013UJ
Sodium	145	59.2J	50.9J	60.3J	62.4J	75.2J	59.8J	59.7J	72.5J	49.8J
Thallium	0.91	0.17J	0.14J	0.12J	0.22J	0.17J	0.15J	0.2J	0.19J	0.17J
Vanadium	37.6	18.8J	12.4	12.5J	20.4J	17.8	13.3	19.6J	18.8	16.3J
Zinc	93.3	72.2	55.9	60.8	71.9	64.8	53.2J	65.4	60.3	67.3
SVOCs (mg/kg)										
Acenaphthene	None	**0.021***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Anthracene	None	**0.059***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Benz(a)anthracene	None	**0.13***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Benzo(a)pyrene	None	**0.12***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Benzo(b)fluoranthene	None	**0.14***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Benzo(ghi)perylene	None	**0.089***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Benzo(k)fluoranthene	None	**0.077***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Bis(2-ethylhexyl)phthalate	None	NR	NR	NR	NR	NR	NR	NR	NR	<0.41U
Chrysene	None	**0.12***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Di-n-butyl phthalate	None	NR	NR	NR	NR	NR	NR	NR	NR	<0.41U

Table 4–14. Analytes Detected in PBA08 RI Subsurface Soil Samples (continued)

Aggregate		AOC	AOC	AOC	AOC	AOC	AOC	AOC	AOC	AOC
Station		**WSAsb-021**	**WSAsb-021**	**WSAsb-021**	**WSAsb-022**	**WSAsb-022**	**WSAsb-022**	**WSAsb-023**	**WSAsb-023**	**WSAsb-024**
Sample ID		**WSAsb-021-5612-SO**	**WSAsb-021-6201-FD**	**WSAsb-021-5613-SO**	**WSAsb-022-6200-FD**	**WSAsb-022-5616-SO**	**WSAsb-022-5617-SO**	**WSAsb-023-5620-SO**	**WSAsb-023-5621-SO**	**WSAsb-024-6203-FD**
Date		**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/23/10**	**03/24/10**
Depth (ft)		**1.0 - 4.0**	**4.0 - 7.0**	**4.0 - 7.0**	**1.0 - 4.0**	**1.0 - 4.0**	**4.0 - 7.0**	**1.0 - 4.0**	**4.0 - 7.0**	**1.0 - 4.0**
Parameters Analyzed [a]	**Background Criteria** [b]	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**
Analyte										
SVOCs (mg/kg)(continued)										
Dibenz(a,h)anthracene	None	NR	NR	NR	NR	NR	NR	NR	NR	<0.41U
Fluoranthene	None	**0.019***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Fluorene	None	**0.37***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Indeno(1,2,3-cd)pyrene	None	**0.016***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Naphthalene	None	**0.067***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	<0.0078U	<0.0087U	<0.0087U	<0.062U
Phenanthrene	None	<0.0086U	<0.0079U	<0.0077U	<0.0089U	<0.0087U	**0.0081***	<0.0087U	<0.0087U	<0.062U
Pyrene	None	**0.2***	<0.0079U	<0.0077U	<0.0089U	<0.0087U	**0.017***	<0.0087U	<0.0087U	<0.062U
Pesticides/PCBs (mg/kg)										
4,4'-DDT	None	NR	NR	NR	NR	NR	NR	NR	NR	<0.0025U
VOCs (mg/kg)										
Toluene	None	NR	NR	NR	NR	NR	NR	NR	NR	**0.00034J***

Table 4–14. Analytes Detected in PBA08 RI Subsurface Soil Samples (continued)

Aggregate		AOC	AOC	AOC	AOC
Station		**WSAsb-028**	**WSAsb-028**	**WSAsb-029**	**WSAsb-029**
Sample ID		**WSAsb-028-5639-SO**	**WSAsb-028-5640-SO**	**WSAsb-029-5642-SO**	**WSAsb-029-5643-SO**
Date		**03/23/10**	**03/23/10**	**03/24/10**	**03/24/10**
Depth (ft)		**4.0 - 7.0**	**7.0 - 13.0**	**1.0 - 4.0**	**4.0 - 7.0**
Parameters Analyzed [a]	**Background Criteria [b]**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**
Analyte					
Metals (mg/kg)					
Aluminum	19500	8580J	6240	10600	7570J
Antimony	0.96	<0.61UJ	<0.57UJ	0.08J	<0.62UJ
Arsenic	19.8	15.4J	17.6	15.6	13.9J
Barium	124	34.1J	21.5J	36.4J	35.9J
Beryllium	0.88	0.48	0.33	0.5	0.4
Cadmium	0	<0.047UJ	**0.052J***	**0.05J***	<0.038UJ
Calcium	35500	1830	11600	269	347
Chromium	27.2	14.3	10J	13.7J	12
Cobalt	23.2	11.3J	7.4	10.9	9J
Copper	32.3	19.3	17.5	23.1	18.4
Iron	35200	28100	20000J	26700J	23200
Lead	19.1	11.6J	9.8	11.5	10.7J
Magnesium	8790	3420	3670J	2740J	2290
Manganese	3030	359	299	306	332
Mercury	0.044	<0.12U	<0.11U	<0.12U	<0.12U
Nickel	60.7	28.6	17.1J	24J	18.9
Potassium	3350	1260J	1050J	846J	689J
Selenium	1.5	0.95J	0.64	1	1J
Silver	0	<0.017UJ	<0.025UJ	<0.01UJ	<0.0056UJ
Sodium	145	54.4J	56.6J	37.2J	32.8J
Thallium	0.91	0.15J	0.1J	0.16J	0.12J
Vanadium	37.6	14.7	10.7J	15.5J	12.4
Zinc	93.3	56.6	54.4	61.2	52.2
SVOCs (mg/kg)					
Acenaphthene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Anthracene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Benz(a)anthracene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Benzo(a)pyrene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Benzo(b)fluoranthene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Benzo(ghi)perylene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Benzo(k)fluoranthene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Bis(2-ethylhexyl)phthalate	None	**0.024J***	<0.38U	NR	NR
Chrysene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Di-n-butyl phthalate	None	<0.4U	<0.38U	NR	NR

Table 4–14. Analytes Detected in PBA08 RI Subsurface Soil Samples (continued)

Aggregate		**AOC**	**AOC**	**AOC**	**AOC**
Station		**WSAsb-028**	**WSAsb-028**	**WSAsb-029**	**WSAsb-029**
Sample ID		**WSAsb-028-5639-SO**	**WSAsb-028-5640-SO**	**WSAsb-029-5642-SO**	**WSAsb-029-5643-SO**
Date		**03/23/10**	**03/23/10**	**03/24/10**	**03/24/10**
Depth (ft)		**4.0 - 7.0**	**7.0 - 13.0**	**1.0 - 4.0**	**4.0 - 7.0**
Parameters Analyzed [a]	**Background Criteria** [b]	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**
Analyte					
SVOCs (mg/kg)(continued)					
Dibenz(a,h)anthracene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Fluoranthene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Fluorene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Indeno(1,2,3-cd)pyrene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Naphthalene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Phenanthrene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Pyrene	None	<0.061U	<0.057U	<0.0083U	<0.0083U
Pesticides/PCBs (mg/kg)					
4,4'-DDT	None	<0.0024UJ	**0.00085J***	NR	NR
VOCs (mg/kg)					
Toluene	None	<0.0061UJ	<0.0057UJ	NR	NR

[a] Only detected site-related contaminants are presented in the table.

[b] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).

AOC = Area of concern.
DDT = Dichlorodiphenyltrichloroethane.
ft = Feet.
ID = Identification.
J = Estimated value less than reporting limits.
mg/kg = Milligrams per kilogram.
NR = Not reported/not analyzed.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
PCB = Polychlorinated biphenyl.
RVAAP = Ravenna Army Ammunition Plant.
SVOC = Semi-volatile organic compound.
TAL = Target analyte list.
U = Not detected.
UJ = Not detected, reporting limit estimated.
VOC = Volatile organic compound.
*** = Result exceeds background criteria or no background criteria was available.**
< = Less than.

Table 4–15. PBA08 RI Surface Water and Sediment Samples and Rationales

					Analyses Performed				
PBA08 RI Location	**Targeted Area**	**Comments/Rationale**	**Sample Type**	**Depth (ft bgs)**	**Metals**	**Explosives**	**VOCs**	**Pesticides/ PCBs**	**SVOC**
WSAsd-037	Unnamed tributary to Sand Creek	Ingress of tributary on west side of AOC, analyzed for RVAAP full-suite analytes	Composite	0–0.5	Y	Y	Y	Y	Y
WSAsw-037			Grab	NA	Y	Y	Y	Y	Y
WSAsd-038	Unnamed tributary to Sand Creek	Egress of tributary on west side of AOC prior to confluence with Sand Creek	Composite	0–0.5	Y	Y	N	N	Y
WSAsw-038			Grab	NA	Y	Y	Y	Y	Y
WSAsd-039	Sand Creek upstream of AOC	Sand Creek upstream of confluence with tributary near DA2sd/sw-102.	Composite	0–0.5	Y	Y	N	N	Y
WSAsw-039			Grab	NA	Y	Y	Y	Y	Y
WSAsd-040	Sand Creek downstream of AOC	Sand Creek east of George Road downstream of confluence with tributary	Composite	0–0.5	Y	Y	N	N	Y
WSAsw-040			Grab	NA	Y	Y	Y	Y	Y
		QA/QC	Grab	NA	Y	Y	Y	Y	Y
			Grab	NA	Y	Y	Y	Y	Y

AOC = Area of concern.
bgs = Below ground surface.
ft = Feet.
NA = Not applicable.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
PCB = Polychlorinated biphenyl.
QA = Quality assurance.
QC = Quality control.
RVAAP = Ravenna Army Ammunition Plant.
SVOC= Semi-volatile organic compound.
VOC = Volatile organic compound.

Table 4–16. Analytes Detected in PBA08 RI Surface Water Samples

Aggregate		**Outside AOC**	**Outside AOC**	**Outside AOC**	**Stream**	**Stream**
Sample location		**WSAsw-039**	**WSAsw-040**	**WSAsw-040**	**WSAsw-037**	**WSAsw-038**
Sample ID		**WSAsw-039-5658-SW**	**WSAsw-040-6199-FD**	**WSAsw-040-5659-SW**	**WSAsw-037-5656-SW**	**WSAsw-038-5657-SW**
Date		**03/23/10**	**03/30/10**	**03/30/10**	**03/23/10**	**03/23/10**
Parameters Analyzed [a]						
Analyte	**Background Criteria** [b]	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**	**RVAAP Full-suite analytes**
Metals (mg/L)						
Aluminum	3.37	0.672	0.354	0.347	0.272	0.289
Antimony	0	<0.005U	<0.005U	<0.005U	<0.005U	**0.00028J***
Arsenic	0.0032	0.00082J	0.00055J	0.00078J	0.00051J	0.00058J
Barium	0.0475	0.0161	0.0153	0.0154	0.0197	0.0193
Calcium	41.4	14.8	21.1	20.7	22.3	21.7
Chromium	0	**0.00076J***	<0.005U	<0.005U	<0.005U	<0.005U
Cobalt	0	<0.00022UJ	**0.00012J***	**0.00012J***	<0.00016UJ	<0.00016UJ
Copper	0.0079	0.0018J	<0.005U	<0.005U	<0.005U	<0.005U
Iron	2.56	0.83	0.638	0.566	0.686	0.721
Lead	0	**0.00046J***	**0.00028J***	**0.00027J***	**0.00025J***	**0.00026J***
Magnesium	10.8	4	5.53	5.43	6.45	6.28
Manganese	0.391	0.0468	0.0572	0.0565	0.0949	0.0887
Nickel	0	**0.0013J***	**0.00098J***	**0.0009J***	**0.0008J***	**0.00085J***
Potassium	3.17	1.25	1.18	1.16	1.1	1.08
Selenium	0	**0.00026J***	<0.005U	<0.005U	<0.005U	**0.00022J***
Sodium	21.3	2.9	4.02	3.96	3.52	3.45
Vanadium	0	**0.001J***	**0.00073J***	**0.00066J***	<0.01U	**0.00063J***
SVOCs (mg/L)						
Bis(2-ethylhexyl)phthalate	None	<0.01UJ	**0.002J***	<0.01U	<0.01UJ	<0.01UJ
VOCs (mg/L)						
Acetone	None	<0.01UJ	**0.0027J***	**0.0023J***	<0.01UJ	<0.01U

[a] Only detected SRCs are presented in the table.

[b] Background concentrations are published in the *Phase II Remedial Investigation Report for Winklepeck Burning Grounds* (USACE 2001b).

AOC = Area of concern
ID = Identification.
J = Estimated value less than reporting limits.
mg/L = Milligrams per liter.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
RVAAP = Ravenna Army Ammunition Plant.
SVOC = Semi-volatile organic compound.
U = Not detected.
UJ = Not detected, reporting limit estimated.
VOC = Volatile organic compound.
*** = Result exceeds background criteria or no background criteria was available.**

Table 4–17. Analytes Detected in PBA08 RI Sediment Samples

Aggregate		**Outside AOC**	**Outside AOC**	**Stream**	**Stream**
Sample location		**WSAsd-039**	**WSAsd-040**	**WSAsd-037**	**WSAsd-038**
Sample ID		**WSAsd-039-5651-SD**	**WSAsd-040-5652-SD**	**WSAsd-037-5649-SD**	**WSAsd-038-5650-SD**
Date		**03/23/10**	**03/30/10**	**03/23/10**	**03/23/10**
Depth (ft)		**0.0 - 0.5**	**0.0 - 0.5**	**0.0 - 0.5**	**0.0 - 0.5**
Parameters Analyzed[a]		**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**
Analyte	**Background Criteria**[b]				
		Metals (mg/kg)			
Aluminum	13900	4050J	2800	4540J	4600J
Antimony	0	<0.63UJ	<0.58UJ	**0.095J***	<0.58UJ
Arsenic	19.5	6.7	6.5	7.1	7.3
Barium	123	56.3J	20.7	78.2J	78.5
Beryllium	0.38	**0.48***	0.38	**0.42***	0.37
Cadmium	0	**0.54***	**0.097J***	**0.15J***	**0.11J***
Calcium	5510	614	465	2260	956
Chromium	18.1	6	5.4	8	9
Cobalt	9.1	6.6	4.7	8.7	7.3
Copper	27.6	10J	9.3J	14.1J	13.2J
Iron	28200	13600	14600	21900	26700
Lead	27.4	8.4	6.5J	11.1	8.6
Magnesium	2760	980J	787J	1650J	1570J
Manganese	1950	869	494	**2230***	1750
Mercury	0.059	0.045J	<0.12U	<0.15U	<0.12U
Nickel	17.7	**27.4J***	8.7J	15.5J	16.1J
Potassium	1950	417J	409	458J	518J
Selenium	1.7	0.73J	0.51J	0.68J	0.46J
Silver	0	**0.017J***	<0.003UJ	**0.027J***	**0.012J***
Sodium	112	23.9J	26J	35.7J	28.8J
Thallium	0.89	0.1J	<0.23U	<0.3U	0.078J
Vanadium	26.1	7.3	5.5	9.3	9
Zinc	532	55	38.1	58.9	55.1
		SVOCs (mg/kg)			
2-Methylnaphthalene	None	<0.41U	<0.38U	**0.08J***	**0.0084J***
Acenaphthylene	None	<0.063U	<0.058U	**0.011J***	<0.058U
Anthracene	None	<0.063U	<0.058U	**0.031J***	<0.058U
Benz(a)anthracene	None	<0.063U	<0.058U	**0.12***	**0.012J***
Benzo(a)pyrene	None	<0.063U	<0.058U	**0.092***	**0.012J***
Benzo(b)fluoranthene	None	<0.063U	<0.058U	**0.14***	**0.02J***
Benzo(ghi)perylene	None	<0.063U	<0.058U	**0.064J***	**0.012J***
Benzo(k)fluoranthene	None	<0.063U	<0.058U	**0.064J***	<0.058U
Bis(2-ethylhexyl)phthalate	None	<0.41U	**0.034J***	<0.49U	<0.38U
Chrysene	None	<0.063U	<0.058U	**0.12***	**0.014J***
Fluoranthene	None	<0.063U	<0.058U	**0.28***	**0.022J***
Indeno(1,2,3-cd)pyrene	None	<0.063U	<0.058U	**0.057J***	**0.009J***
Naphthalene	None	<0.063U	<0.058U	**0.068J***	<0.058U
Phenanthrene	None	<0.063U	<0.058U	**0.078***	**0.01J***
Pyrene	None	<0.063U	<0.058U	**0.19***	**0.018J***

Table 4–17. Analytes Detected in PBA08RI Sediment Samples (continued)

Aggregate		**Outside AOC**	**Outside AOC**	**Stream**	**Stream**
Sample location		**WSAsd-039**	**WSAsd-040**	**WSAsd-037**	**WSAsd-038**
Sample ID		**WSAsd-039-5651-SD**	**WSAsd-040-5652-SD**	**WSAsd-037-5649-SD**	**WSAsd-038-5650-SD**
Date		**03/23/10**	**03/30/10**	**03/23/10**	**03/23/10**
Depth (ft)		**0.0 - 0.5**	**0.0 - 0.5**	**0.0 - 0.5**	**0.0 - 0.5**
Parameters Analyzed[a]					
Analyte	**Background Criteria**[b]	**TAL Metals, Explosives, SVOCs**	**TAL Metals, Explosives, SVOCs**	**RVAAP Full-suite analytes**	**TAL Metals, Explosives, SVOCs**
VOCs (mg/kg)					
2-Butanone	None	NR	NR	**0.0021J***	NR

[a] Only detected site-related contaminants are presented in the table.

[b] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).

AOC = Area of concern.
ft = Feet.
ID = Identification.
J = Estimated value less than reporting limits.
mg/kg = Milligrams per kilogram.
NR = Not reported/not analyzed.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
RVAAP = Ravenna Army Ammunition Plant.
SVOC= Semi-volatile organic compound.
TAL = Target analyte list.
U = Not detected.
UJ = Not detected, reporting limit estimated.
VOC = Volatile organic compound.
* = Result exceeds background criteria or no background criteria was available.
< = Less than.

Table 4–18. Changes from the PBA08 SAP

Location	Affected Sample	Date Sampled	Change/Rationale
WSAsw-038	WSASW-038-5657-SW	3/23/2010	The original sample location was moved to collect a sample downgradient of the unnamed tributary bifurcation.
WSAsb-021	WSASB-021-5611-SO	3/23/2010	Sample location moved to the center of a ditch in an attempt to capture potential contaminants accumulated in the ditch.
	WSASB-021-5612-SO	3/23/2010	
	WSASB-021-5613-SO	3/23/2010	
	WSASB-021-5614-SO	3/23/2010	
	WSASB-021-6205-QA	3/23/2010	
	WSASB-021-6206-QA	3/23/2010	
	WSASB-021-6201-FD	3/23/2010	
	WSASB-021-6202-FD	3/23/2010	
WSAsb-022	WSASB-022-5615-SO	3/23/2010	Sample location moved to the center of a ditch in an attempt to capture potential contaminants accumulated in the ditch
	WSASB-022-5616-SO	3/23/2010	
	WSASB-022-5617-SO	3/23/2010	
	WSASB-022-5618-SO	3/23/2010	
	WSASB-022-6204-QA	3/23/2010	
	WSASB-022-6200-FD	3/23/2010	
WSAsb-027	WSASB-027-5633-SO	3/23/2010	Original location on steep slope; relocated approximately 20 ft north to allow access with drilling equipment.
	WSASB-027-5634-SO	3/23/2010	
	WSASB-027-5635-SO	3/23/2010	
	WSASB-027-5636-SO	3/23/2010	

ft = Feet.

PBA08 SAP = Performance-based Acquisition 2008 Supplemental Investigation Sampling and Analysis Plan Addendum No. 1.

Table 4–19. RVAAP Background Concentrations

Chemical	Surface Soil (mg/kg)	Subsurface soil (mg/kg)	Sediment (mg/kg)	Surface Water (mg/L)	Groundwater-Unconsolidated (mg/L)		Groundwater-Bedrock (mg/L)	
					Filtered	**Unfiltered**	**Filtered**	**Unfiltered**
Aluminum	17700	19500	13900	3.37	NA	48	NA	9.41
Antimony	0.96	0.96	0	0	0	0.0043	0	0
Arsenic	15.4	19.8	19.5	0.0032	0.0117	0.215	0	0.0191
Barium	88.4	124	123	0.0475	0.0821	0.327	0.256	0.241
Beryllium	0.88	0.88	0.38	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0
Calcium	15800	35500	5510	41.4	115	194	53.1	48.2
Chromium	17.4	27.2	18.1	0	0.0073	0.0852	0	0.0195
Cobalt	10.4	23.2	9.1	0	0	0.0463	0	0
Copper	17.7	32.3	27.6	0.0079	0	0.289	0	0.017
Cyanide	0	0	0	0	0	0	0	0
Iron	23100	35200	28200	2.56	0.279	195	1.43	21.5
Lead	26.1	19.1	27.4	0	0	0.183	0	0.023
Magnesium	3030	8790	2760	10.8	43.3	58.4	15	13.7
Manganese	1450	3030	1950	0.391	1.02	2.86	1.34	1.26
Mercury	0.036	0.044	0.059	0	0	0.00025	0	0
Nickel	21.1	60.7	17.7	0	0	0.117	0.0834	0.0853
Potassium	927	3350	1950	3.17	2.89	7.48	5.77	6.06
Selenium	1.4	1.5	1.7	0	0	0.0057	0	0
Silver	0	0	0	0	0	0	0	0
Sodium	123	145	112	21.3	45.7	44.7	51.4	49.7
Thallium	0	0.91	0.89	0	0	0.0024	0	0
Vanadium	31.1	37.6	26.1	0	0	0.0981	0	0.0155
Zinc	61.8	93.3	532	0.042	0.0609	0.888	0.0523	0.193

Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).
mg/kg = Milligrams per kilogram.
mg/L = Milligrams per liter.
NA = Not available. Aluminum results were rejected in validation.
RVAAP = Ravenna Army Ammunition Plant.

Table 4–20. Recommended Dietary Allowances/Reference Daily Intake Values

Essential Human Nutrient	USDA RDA/RDI[a] Value
Calcium	1000 mg/d
Chloride[b]	3400 mg/d
Iodine	150 µg/d
Iron	8 mg/d
Magnesium	400 mg/d
Potassium[b]	4700 mg/d
Phosphorous	700 mg/d
Sodium[b]	2300 mg/d

[a] Dietary reference intakes vary by gender and age, values present are for life stage group: Males 19-30 years.

[b] Adequate intake value.

mg/d = Milligram per day.

RDA= Recommended dietary allowance.

RDI= Reference daily intake.

µg/d = Micrograms per day.

USDA = U.S. Department of Agriculture.

Source = Values were obtained from http://fnic.nal.usda.gov charts.

Table 4–21. SRC Screening Summary for Surface Soil

Analyte	CAS Number	Freq. of Detect	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average Result (mg/kg)	Background Criteria[a] (mg/kg)	SRC? (yes/no)	SRC Justification
Metals								
Aluminum	**7429-90-5**	**22/ 22**	**8400**	**27100**	**12400**	**17700**	**Yes**	**Exceeds background**
Antimony	7440-36-0	5/ 22	0.1	0.52	0.571	0.96	No	Below background
Arsenic	**7440-38-2**	**22/ 22**	**11**	**21**	**15.3**	**15.4**	**Yes**	**Exceeds background**
Barium	**7440-39-3**	**22/ 22**	**45**	**110**	**57.7**	**88.4**	**Yes**	**Exceeds background**
Beryllium	**7440-41-7**	**22/ 22**	**0.49**	**1.3**	**0.715**	**0.88**	**Yes**	**Exceeds background**
Cadmium	**7440-43-9**	**4/ 22**	**0.11**	**0.19**	**0.185**	**0**	**Yes**	**Exceeds background**
Calcium	7440-70-2	22/ 22	750	5900	2190	15800	No	Essential nutrient
Chromium	**7440-47-3**	**22/ 22**	**16**	**26**	**20.9**	**17.4**	**Yes**	**Exceeds background**
Cobalt	**7440-48-4**	**22/ 22**	**6.6**	**14**	**10.6**	**10.4**	**Yes**	**Exceeds background**
Copper	**7440-50-8**	**22/ 22**	**15**	**21**	**18.6**	**17.7**	**Yes**	**Exceeds background**
Iron	7439-89-6	22/ 22	17000	32000	26600	23100	No	Essential nutrient
Lead	**7439-92-1**	**22/ 22**	**14**	**97**	**26.6**	**26.1**	**Yes**	**Exceeds background**
Magnesium	7439-95-4	22/ 22	1800	3900	3010	3030	No	Essential nutrient
Manganese	7439-96-5	22/ 22	290	1130	420	1450	No	Below background
Mercury	**7439-97-6**	**22/ 22**	**0.018**	**2.1**	**0.466**	**0.036**	**Yes**	**Exceeds background**
Nickel	**7440-02-0**	**22/ 22**	**18**	**32**	**24.5**	**21.1**	**Yes**	**Exceeds background**
Potassium	7440-09-7	22/ 22	740	2230	1220	927	No	Essential nutrient
Selenium	**7782-49-2**	**6/ 22**	**0.42**	**1.4**	**0.821**	**1.4**	**Yes**	**Exceeds background**
Silver	7440-22-4	1/ 22	0.035	0.035	0.398	0	No	<5% Detected
Sodium	7440-23-5	22/ 22	35.4	430	269	123	No	Essential nutrient
Thallium	**7440-28-0**	**8/ 22**	**0.15**	**0.31**	**0.261**	**0**	**Yes**	**Exceeds background**
Vanadium	7440-62-2	22/ 22	15	28	19.5	31.1	No	Below background
Zinc	**7440-66-6**	**22/ 22**	**56**	**140**	**69.7**	**61.8**	**Yes**	**Exceeds background**
Explosives and Propellants								
3-Nitrotoluene	**99-08-1**	**1/ 22**	**0.08**	**0.08**	**0.103**	**None**	**Yes**	**Detected organic**
Nitrocellulose	**9004-70-0**	**2/3**	**0.73**	**1.1**	**1.46**	**None**	**Yes**	**Detected organic**
SVOCs								
2-Methylnaphthalene	**91-57-6**	**2/ 3**	**0.009**	**0.058**	**0.028**	**None**	**Yes**	**Detected organic**
Acenaphthene	**83-32-9**	**3/ 6**	**0.011**	**1.5**	**0.265**	**None**	**Yes**	**Detected organic**
Acenaphthylene	**208-96-8**	**1/ 6**	**0.016**	**0.016**	**0.0115**	**None**	**Yes**	**Detected organic**
Anthracene	**120-12-7**	**4/ 6**	**0.0068**	**2.9**	**0.5**	**None**	**Yes**	**Detected organic**
Benz(a)anthracene	**56-55-3**	**5/ 6**	**0.023**	**8.2**	**1.41**	**None**	**Yes**	**Detected organic**
Benzenemethanol	**100-51-6**	**1/ 3**	**0.62**	**0.62**	**0.378**	**None**	**Yes**	**Detected organic**

Table 4–21. SRC Screening Summary for Surface Soil (continued)

Analyte	CAS Number	Freq. of Detect	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average Result (mg/kg)	Background Criteria[a] (mg/kg)	SRC? (yes/no)	SRC Justification
Benzo(a)pyrene	**50-32-8**	**6/ 6**	**0.012**	**5.5**	**0.957**	**None**	**Yes**	**Detected organic**
Benzo(b)fluoranthene	**205-99-2**	**6/ 6**	**0.019**	**7.3**	**1.27**	**None**	**Yes**	**Detected organic**
Benzo(ghi)perylene	**191-24-2**	**5/ 6**	**0.016**	**3.7**	**0.649**	**None**	**Yes**	**Detected organic**
Benzo(k)fluoranthene	**207-08-9**	**5/ 6**	**0.012**	**3.2**	**0.561**	**None**	**Yes**	**Detected organic**
Carbazole	**86-74-8**	**1/ 3**	**1.4**	**1.4**	**0.504**	**None**	**Yes**	**Detected organic**
Chrysene	**218-01-9**	**6/ 6**	**0.015**	**7.8**	**1.35**	**None**	**Yes**	**Detected organic**
Dibenz(a,h)anthracene	**53-70-3**	**4/ 6**	**0.0084**	**0.94**	**0.171**	**None**	**Yes**	**Detected organic**
Dibenzofuran	**132-64-9**	**1/ 3**	**0.54**	**0.54**	**0.248**	**None**	**Yes**	**Detected organic**
Fluoranthene	**206-44-0**	**6/ 6**	**0.024**	**18**	**3.11**	**None**	**Yes**	**Detected organic**
Fluorene	**86-73-7**	**4/ 6**	**0.0076**	**1.3**	**0.232**	**None**	**Yes**	**Detected organic**
Indeno(1,2,3-cd)pyrene	**193-39-5**	**5/ 6**	**0.015**	**3.4**	**0.595**	**None**	**Yes**	**Detected organic**
Naphthalene	**91-20-3**	**5/ 6**	**0.0075**	**0.081**	**0.0241**	**None**	**Yes**	**Detected organic**
Phenanthrene	**85-01-8**	**5/ 6**	**0.031**	**12**	**2.07**	**None**	**Yes**	**Detected organic**
Phenol	**108-95-2**	**1/ 3**	**0.028**	**0.028**	**0.0943**	**None**	**Yes**	**Detected organic**
Pyrene	**129-00-0**	**6/ 6**	**0.016**	**17**	**2.91**	**None**	**Yes**	**Detected organic**
Pesticides/PCBs								
4,4'-DDE	**72-55-9**	**1/ 3**	**0.0004**	**0.0004**	**0.00713**	**None**	**Yes**	**Detected organic**
Endosulfan sulfate	**1031-07-8**	**1/ 3**	**0.0026**	**0.0026**	**0.00682**	**None**	**Yes**	**Detected organic**
Endrin	**72-20-8**	**1/ 3**	**0.00069**	**0.00069**	**0.00618**	**None**	**Yes**	**Detected organic**
alpha-Chlordane	**5103-71-9**	**1/ 3**	**0.0021**	**0.0021**	**0.00665**	**None**	**Yes**	**Detected organic**
beta-BHC	**319-85-7**	**1/ 3**	**0.0034**	**0.0034**	**0.0074**	**None**	**Yes**	**Detected organic**

[a] Background concentrations are published in the *Phase II Remedial Investigation Report for Winklepeck Burning Grounds* (USACE 2001b). Site-related contaminant screening tables include all available and appropriate data as presented in Section 4.4.4.

BHC = Hexachlorocyclohexane.
CAS = Chemical Abstract Service.
DDE = Dichlorodiphenyldichloroethylene.
ISM = Incremental sampling methodology.
mg/kg = Milligrams per kilogram.
PCB = Polychlorinated biphenyl.
SRC = Site-related contaminant.
SVOC= Semi-volatile organic compound
Bold indicates analyte identified as an SRC.
< = Less than

Table 4–22. SRC Screening Summary for Subsurface Soil

Analyte	CAS Number	Freq of Detect	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average Result (mg/kg)	Background Criteria[a] (mg/kg)	SRC? yes/no	SRC Justification
Metals								
Aluminum	7429-90-5	19/ 19	6240	13800	9560	19500	No	Below background
Antimony	7440-36-0	12/ 19	0.079	0.1	0.166	0.96	No	Below background
Arsenic	**7440-38-2**	**19/ 19**	**13**	**21.3**	**16.7**	**19.8**	**Yes**	**Exceeds background**
Barium	7440-39-3	19/ 19	21.5	65.5	39.3	124	No	Below background
Beryllium	7440-41-7	19/ 19	0.33	0.68	0.526	0.88	No	Below background
Cadmium	**7440-43-9**	**11/ 19**	**0.042**	**0.071**	**0.0414**	**0**	**Yes**	**Exceeds background**
Calcium	7440-70-2	19/ 19	269	11600	2960	35500	No	Essential nutrient
Chromium	7440-47-3	19/ 19	10	20.9	15	27.2	No	Below background
Cobalt	**7440-48-4**	**19/ 19**	**7.4**	**25.8**	**12.6**	**23.2**	**Yes**	**Exceeds background**
Copper	7440-50-8	19/ 19	17.5	24.3	20.5	32.3	No	Below background
Iron	7439-89-6	19/ 19	20000	35000	27500	35200	No	Essential nutrient
Lead	7439-92-1	19/ 19	9.8	18.3	12.6	19.1	No	Below background
Magnesium	7439-95-4	19/ 19	2290	5650	3800	8790	No	Essential nutrient
Manganese	7439-96-5	19/ 19	254	572	355	3030	No	Below background
Mercury	7439-97-6	2/ 19	0.025	0.032	0.0577	0.044	No	Below background
Nickel	7440-02-0	19/ 19	17.1	35	26.8	60.7	No	Below background
Potassium	7440-09-7	19/ 19	689	1760	1240	3350	No	Essential nutrient
Selenium	7782-49-2	19/ 19	0.64	1.4	0.988	1.5	No	Below background
Silver	**7440-22-4**	**4/ 19**	**0.016**	**0.026**	**0.0124**	**0**	**Yes**	**Exceeds background**
Sodium	7440-23-5	19/ 19	32.8	77.4	55.4	145	No	Essential nutrient
Thallium	7440-28-0	19/ 19	0.1	0.22	0.157	0.91	No	Below background
Vanadium	7440-62-2	19/ 19	10.7	20.4	15.5	37.6	No	Below background
Zinc	7440-66-6	19/ 19	50.3	72.2	61.4	93.3	No	Below background

Table 4–22. SRC Screening Summary for Subsurface Soil (continued)

Analyte	CAS Number	Freq of Detect	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average Result (mg/kg)	Background Criteria[a] (mg/kg)	SRC? yes/no	SRC Justification
Metals								
Acenaphthene	83-32-9	1/ 19	0.021	0.021	0.0119	None	Yes	Detected organic
Anthracene	120-12-7	1/ 19	0.059	0.059	0.0139	None	Yes	Detected organic
Benz(a)anthracene	56-55-3	2/ 19	0.01	0.13	0.0165	None	Yes	Detected organic
Benzo(a)pyrene	50-32-8	1/ 19	0.12	0.12	0.0171	None	Yes	Detected organic
Benzo(b)fluoranthene	205-99-2	2/ 19	0.011	0.14	0.0171	None	Yes	Detected organic
Benzo(ghi)perylene	191-24-2	1/ 19	0.089	0.089	0.0155	None	Yes	Detected organic
Benzo(k)fluoranthene	207-08-9	1/ 19	0.077	0.077	0.0148	None	Yes	Detected organic
Bis(2-ethylhexyl)phthalate	117-81-7	2/ 5	0.024	0.038	0.132	None	Yes	Detected organic
Chrysene	218-01-9	1/ 19	0.12	0.12	0.0171	None	Yes	Detected organic
Di-n-butyl phthalate	84-74-2	2/ 5	0.021	0.022	0.128	None	Yes	Detected organic
Dibenz(a,h)anthracene	53-70-3	1/ 19	0.019	0.019	0.0118	None	Yes	Detected organic
Fluoranthene	206-44-0	3/ 19	0.01	0.37	0.0299	None	Yes	Detected organic
Fluorene	86-73-7	1/ 19	0.016	0.016	0.0116	None	Yes	Detected organic
Indeno(1,2,3-cd)pyrene	193-39-5	1/ 19	0.067	0.067	0.0143	None	Yes	Detected organic
Naphthalene	91-20-3	1/ 19	0.0081	0.0081	0.0112	None	Yes	Detected organic
Phenanthrene	85-01-8	3/ 19	0.01	0.2	0.0209	None	Yes	Detected organic
Pyrene	129-00-0	2/ 19	0.015	0.27	0.0241	None	Yes	Detected organic
Pesticide/PCB								
4,4'-DDT	50-29-3	1/ 5	0.00085	0.00085	0.00115	None	Yes	Detected organic
VOCs								
Toluene	108-88-3	1/ 5	0.00034	0.00034	0.00247	None	Yes	Detected organic

[a] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).

SRC screening tables include all available and appropriate data as presented in Section 4.4.4.

CAS = Chemical Abstract Service.

mg/kg = Milligrams per kilogram.

PCB = Polychlorinated biphenyl.

SRC = Site-related contaminant.

VOC = Volatile organic compound.

Bold indicates analyte identified as an SRC.

Table 4–23. SRC Screening Summary for Sediment

Analyte	CAS Number	Freq of Detect	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average Result (mg/kg)	Background Criteria[a] (mg/kg)	SRC? yes/no	SRC Justification
Metals								
Aluminum	7429-90-5	2/ 2	4540	4600	4570	13900	No	Below background
Antimony	**7440-36-0**	**1/ 2**	**0.095**	**0.095**	**0.193**	**0**	**Yes**	**Exceeds background**
Arsenic	7440-38-2	2/ 2	7.1	7.3	7.2	19.5	No	Below background
Barium	7440-39-3	2/ 2	78.2	78.5	78.4	123	No	Below background
Beryllium	**7440-41-7**	**2/ 2**	**0.37**	**0.42**	**0.395**	**0.38**	**Yes**	**Exceeds background**
Cadmium	**7440-43-9**	**2/ 2**	**0.11**	**0.15**	**0.13**	**0**	**Yes**	**Exceeds background**
Calcium	7440-70-2	2/ 2	956	2260	1610	5510	No	Essential nutrient
Chromium	7440-47-3	2/ 2	8	9	8.5	18.1	No	Below background
Cobalt	7440-48-4	2/ 2	7.3	8.7	8	9.1	No	Below background
Copper	7440-50-8	2/ 2	13.2	14.1	13.7	27.6	No	Below background
Iron	7439-89-6	2/ 2	21900	26700	24300	28200	No	Essential Nutrient
Lead	7439-92-1	2/ 2	8.6	11.1	9.85	27.4	No	Below background
Magnesium	7439-95-4	2/ 2	1570	1650	1610	2760	No	Essential nutrient
Manganese	**7439-96-5**	**2/ 2**	**1750**	**2230**	**1990**	**1950**	**Yes**	**Exceeds background**
Nickel	7440-02-0	2/ 2	15.5	16.1	15.8	17.7	No	Below background
Potassium	7440-09-7	2/ 2	458	518	488	1950	No	Essential nutrient
Selenium	7782-49-2	2/ 2	0.46	0.68	0.57	1.7	No	Below background
Silver	**7440-22-4**	**2/ 2**	**0.012**	**0.027**	**0.0195**	**0**	**Yes**	**Exceeds background**
Sodium	7440-23-5	2/ 2	28.8	35.7	32.3	112	No	Essential nutrient
Thallium	7440-28-0	1/ 2	0.078	0.078	0.114	0.89	No	Below background
Vanadium	7440-62-2	2/ 2	9	9.3	9.15	26.1	No	Below background
Zinc	7440-66-6	2/ 2	55.1	58.9	57	532	No	Below background
SVOCs								
2-Methylnaphthalene	**91-57-6**	**2/ 2**	**0.0084**	**0.08**	**0.0442**	**None**	**Yes**	**Detected organic**
Acenaphthylene	**208-96-8**	**1/ 2**	**0.011**	**0.011**	**0.02**	**None**	**Yes**	**Detected organic**
Anthracene	**120-12-7**	**1/ 2**	**0.031**	**0.031**	**0.03**	**None**	**Yes**	**Detected organic**
Benz(a)anthracene	**56-55-3**	**2/ 2**	**0.012**	**0.12**	**0.066**	**None**	**Yes**	**Detected organic**
Benzo(a)pyrene	**50-32-8**	**2/ 2**	**0.012**	**0.092**	**0.052**	**None**	**Yes**	**Detected organic**
Benzo(b)fluoranthene	**205-99-2**	**2/ 2**	**0.02**	**0.14**	**0.08**	**None**	**Yes**	**Detected organic**
Benzo(ghi)perylene	**191-24-2**	**2/ 2**	**0.012**	**0.064**	**0.038**	**None**	**Yes**	**Detected organic**
Benzo(k)fluoranthene	**207-08-9**	**1/ 2**	**0.064**	**0.064**	**0.0465**	**None**	**Yes**	**Detected organic**
Chrysene	**218-01-9**	**2/ 2**	**0.014**	**0.12**	**0.067**	**None**	**Yes**	**Detected organic**
Fluoranthene	**206-44-0**	**2/ 2**	**0.022**	**0.28**	**0.151**	**None**	**Yes**	**Detected organic**

Table 4–23. SRC Screening Summary for Sediment (continued)

Analyte	CAS Number	Freq of Detect	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average Result (mg/kg)	Background Criteria[a] (mg/kg)	SRC? yes/no	SRC Justification
SVOCs (continued)								
Indeno(1,2,3-cd)pyrene	**193-39-5**	**2/ 2**	**0.009**	**0.057**	**0.033**	**None**	**Yes**	**Detected organic**
Naphthalene	**91-20-3**	**1/ 2**	**0.068**	**0.068**	**0.0485**	**None**	**Yes**	**Detected organic**
Phenanthrene	**85-01-8**	**2/ 2**	**0.01**	**0.078**	**0.044**	**None**	**Yes**	**Detected organic**
Pyrene	**129-00-0**	**2/ 2**	**0.018**	**0.19**	**0.104**	**None**	**Yes**	**Detected organic**
VOCs								
2-Butanone	**78-93-3**	**1/ 1**	**0.0021**	**0.0021**	**0.0021**	**None**	**Yes**	**Detected organic**

[a] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).

SRC screening tables include all available and appropriate data as presented in Section 4.4.4.

CAS = Chemical Abstract Service.

mg/kg = Milligrams per kilogram.

SRC = Site-related contaminant.

SVOC= Semi-volatile organic compound.

VOC = Volatile organic compound.

Bold indicates analyte identified as an SRC**.**

Table 4–24. SRC Screening for Surface Water

Analyte	CAS Number	Freq of Detect	Minimum Detect	Maximum Detect	Average Result	Background Criteria[a]	SRC? (yes/no)	SRC Justification
Metals (mg/L)								
Aluminum	7429-90-5	2/2	0.272	0.289	0.281	3.37	No	Below background
Antimony	**7440-36-0**	**1/2**	**0.00028**	**0.00028**	**0.00139**	**0**	**Yes**	**Exceeds background**
Arsenic	7440-38-2	2/2	0.00051	0.00058	0.000545	0.0032	No	Below background
Barium	7440-39-3	2/2	0.0193	0.0197	0.0195	0.0475	No	Below background
Calcium	7440-70-2	2/2	21.7	22.3	22	41.4	No	Essential nutrient
Iron	7439-89-6	2/2	0.686	0.721	0.704	2.56	No	Essential nutrient
Lead	**7439-92-1**	**2/2**	**0.00025**	**0.00026**	**0.000255**	**0**	**Yes**	**Exceeds background**
Magnesium	7439-95-4	2/2	6.28	6.45	6.37	10.8	No	Essential nutrient
Manganese	7439-96-5	2/2	0.0887	0.0949	0.0918	0.391	No	Below background
Nickel	**7440-02-0**	**2/2**	**0.0008**	**0.00085**	**0.000825**	**0**	**Yes**	**Exceeds background**
Potassium	7440-09-7	2/2	1.08	1.1	1.09	3.17	No	Essential nutrient
Selenium	**7782-49-2**	**1/2**	**0.00022**	**0.00022**	**0.00136**	**0**	**Yes**	**Exceeds background**
Sodium	7440-23-5	2/2	3.45	3.52	3.49	21.3	No	Essential nutrient
Vanadium	**7440-62-2**	**1/2**	**0.00063**	**0.00063**	**0.00282**	**0**	**Yes**	**Exceeds background**

[a] Background concentrations are published in the Phase II Remedial Investigation Report for Winklepeck Burning Grounds (USACE 2001b).

CAS = Chemical Abstract Service.

mg/L = Milligrams per liter.

SRC = Site-related Contaminant.

Bold indicates analyte identified as an SRC.

Table 4–25. Data Summary and Designated Use for RI

Sample ID	Type	Date	Depth (ft)	Sampling Event	QC	N&E	F&T	HHRA	ERA	Comments
Surface and Subsurface Soil										
RV-451	D	10/19/98	0–0.5	RRSE 1998	--	--	--	--	--	Used for initial evaluation of site.
RV-452	D	10/19/98	0–0.5	RRSE 1998	--	--	--	--	--	Used for initial evaluation of site.
RV-453	D	10/19/98	0–0.5	RRSE 1998	--	--	--	--	--	Used for initial evaluation of site.
RV-454	D	10/19/98	0–0.5	RRSE 1998	--	--	--	--	--	Used for initial evaluation of site.
RV-455	D	10/19/98	0–0.5	RRSE 1998	--	--	--	--	--	Used for initial evaluation of site.
WS1-001-CONF	D	06/24/04	0–1	Igloo Demolition 2004	--	--	--	--	--	Lead confirmation sample after slab removal used qualitatively.
WS1-002-CONF	D	06/24/04	0–1	Igloo Demolition 2004	--	--	--	--	--	Lead confirmation sample after slab removal used qualitatively.
WS1A-001-CONF	D	06/24/04	0–1	Igloo Demolition 2004	--	--	--	--	--	Lead confirmation sample after slab removal used qualitatively.
WS1A-002-CONF	D	06/24/04	0–1	Igloo Demolition 2004	--	--	--	--	--	Lead confirmation sample after slab removal used qualitatively.
WS2-001-CONF	D	06/24/04	0–1	Igloo Demolition 2004	--	--	--	--	--	Mercury confirmation sample after slab removal used qualitatively.
WS2-002-CONF	D	06/24/04	0–1	Igloo Demolition 2004	--	--	--	--	--	Mercury confirmation sample after slab removal used qualitatively.
WS2A-001-CONF	D	06/24/04	0–1	Igloo Demolition 2004	--	--	--	--	--	Mercury confirmation sample after slab removal used qualitatively.
WS2A-002-CONF	D	06/24/04	0–1	Igloo Demolition 2004	--	--	--	--	--	Mercury confirmation sample after slab removal used qualitatively.
WSAsb-021-5611-SO	D	03/23/10	0–1	PBA08 RI	--	X	--	X	--	
WSAsb-021-5612-SO	D	03/23/10	1–4	PBA08 RI	--	X	X	X	--	

Table 4–25. Data Summary and Designated Use for RI (continued)

Sample ID	Type	Date	Depth (ft)	Sampling Event	QC	N&E	F&T	HHRA	ERA	Comments
WSAsb-021-5613-SO	D	03/23/10	4–7	PBA08 RI	--	X	X	X	--	
WSAsb-021-6201-FD	D	03/23/10	4–7	PBA08 RI	X	--	--	--	--	Field duplicate.
WSAsb-022-5615-SO	D	03/23/10	0–1	PBA08 RI	--	X	--	X	--	
WSAsb-022-5616-SO	D	03/23/10	1–4	PBA08 RI	--	X	X	X	--	
WSAsb-022-5617-SO	D	03/23/10	4–7	PBA08 RI	--	X	X	X	--	
WSAsb-022-6200-FD	D	03/23/10	1–4	PBA08 RI	X	--	--	--	--	Field duplicate.
WSAsb-023-5619-SO	D	03/23/10	0–1	PBA08 RI	--	X	--	X	--	
WSAsb-023-5620-SO	D	03/23/10	1–4	PBA08 RI	--	X	X	X	--	
WSAsb-023-5621-SO	D	03/23/10	4–7	PBA08 RI	--	X	X	X	--	
WSAsb-024-5623-SO	D	03/24/10	0–1	PBA08 RI	--	X	--	X	--	
WSAsb-024-5624-SO	D	03/24/10	1–4	PBA08 RI	--	X	X	X	--	
WSAsb-024-5625-SO	D	03/24/10	4–7	PBA08 RI	--	X	X	X	--	
WSAsb-024-5626-SO	D	03/24/10	7–13	PBA08 RI	--	X	X	X	--	
WSAsb-024-6203-FD	D	03/24/10	1–4	PBA08 RI	X	--	--	--	--	Field duplicate.
WSAsb-026-5629-SO	D	03/23/10	0–1	PBA08 RI	--	X	--	X	--	
WSAsb-026-5630-SO	D	03/23/10	1–4	PBA08 RI	--	X	X	X	--	
WSAsb-026-5631-SO	D	03/23/10	4–7	PBA08 RI	--	X	X	X	--	
WSAsb-026-5632-SO	D	03/23/10	7–13	PBA08 RI	--	X	X	X	--	
WSAsb-027-5633-SO	D	03/23/10	0–1	PBA08 RI	--	X	--	X	--	
WSAsb-027-5634-SO	D	03/23/10	1–4	PBA08 RI	--	X	X	X	--	
WSAsb-027-5635-SO	D	03/23/10	4–7	PBA08 RI	--	X	X	X	--	
WSAsb-028-5637-SO	D	03/23/10	0–1	PBA08 RI	--	X	--	X	--	
WSAsb-028-5638-SO	D	03/23/10	1–4	PBA08 RI	--	X	X	X	--	
WSAsb-028-5639-SO	D	03/23/10	4–7	PBA08 RI	--	X	X	X	--	
WSAsb-028-5640-SO	D	03/23/10	7–13	PBA08 RI	--	X	X	X	--	
WSAsb-029-5641-SO	D	03/24/10	0–1	PBA08 RI	--	X	--	X	--	
WSAsb-029-5642-SO	D	03/24/10	1–4	PBA08 RI	--	X	X	X	--	
WSAsb-029-5643-SO	D	03/24/10	4–7	PBA08 RI	--	X	X	X	--	
WSAss-001M-SO	ISM	10/27/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-002M-SO	ISM	10/26/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-003M-SO	ISM	10/26/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-004D-SO	ISM	10/26/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-004M-SO	ISM	10/26/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-005M-DUP	ISM	10/27/04	0–1	14 AOCs	X	--	--	--	--	Field duplicate.
WSAss-005M-SO	ISM	10/27/04	0–1	14 AOCs	--	X	X	X	X	

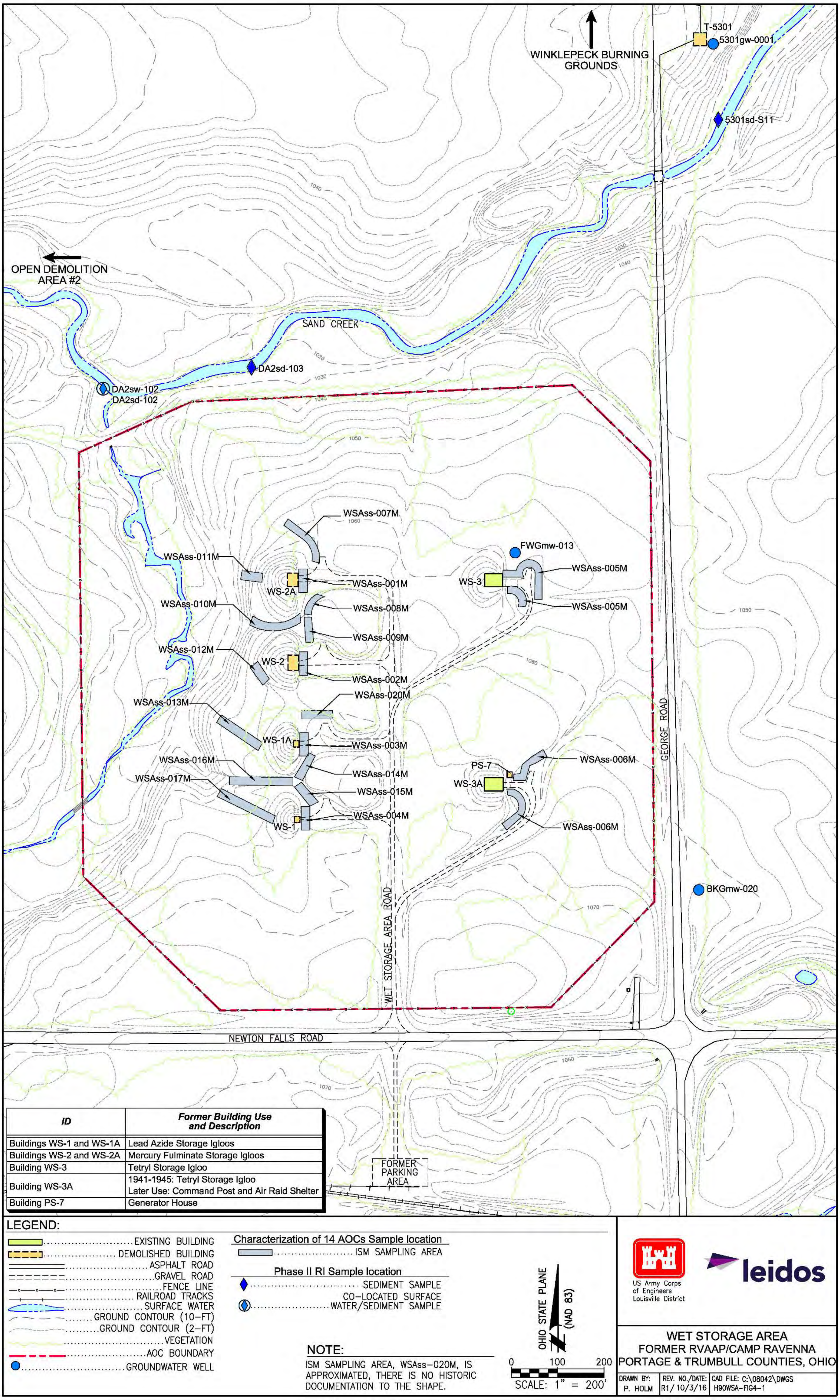
Table 4–25. Data Summary and Designated Use for RI (continued)

Sample ID	Type	Date	Depth (ft)	Sampling Event	QC	N&E	F&T	HHRA	ERA	Comments
WSAss-006M-SO	ISM	10/27/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-007M-SO	ISM	10/27/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-008M-SO	ISM	10/29/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-009M-SO	ISM	10/29/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-010M-SO	ISM	10/28/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-011D-SO	ISM	11/01/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-011M-SO	ISM	11/01/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-012M-SO	ISM	10/29/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-013M-SO	ISM	10/29/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-014M-DUP	ISM	10/27/04	0–1	14 AOCs	X	--	--	--	--	Field duplicate.
WSAss-014M-SO	ISM	10/27/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-015M-SO	ISM	10/27/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-016M-QA	ISM	10/27/04	0–1	14 AOCs	X	--	--	--	--	Field duplicate.
WSAss-016M-SO	ISM	10/27/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-017M-SO	ISM	10/27/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-020M-DUP	ISM	12/03/04	0–1	14 AOCs	X	--	--	--	--	Field duplicate.
WSAss-020M-SO	ISM	12/03/04	0–1	14 AOCs	--	X	X	X	X	
WSAss-030-5653-SO	D	03/24/10	0–1	PBA08 RI	--	X	--	X	--	Sample collected for chromium speciation analysis only.
WSAss-031-5654-SO	D	03/24/10	0–1	PBA08 RI	--	X	--	X	--	Sample collected for chromium speciation analysis only.
WSAss-032-5655-SO	D	03/24/10	0–1	PBA08 RI	--	X	--	X	--	Sample collected for chromium speciation analysis only.
WSAss-033M-5645-SO	ISM	03/24/10	0–1	PBA08 RI	--	X	X	X	X	
WSAss-034M-5646-SO	ISM	03/24/10	0–1	PBA08 RI	--	X	X	X	X	
WSAss-034M-6195-FD	ISM	03/24/10	0–1	PBA08 RI	X	--	--	--	--	Field duplicate.
WSAss-035M-5648-SO	ISM	03/24/10	0–1	PBA08 RI	--	X	X	X	X	
WSAss-036M-5647-SO	ISM	03/24/10	0–1	PBA08 RI	--	X	X	X	X	
Sediment										
5301ss-S11-0001-CS	D	05/01/00	0–0.5	B5301 IRA	--	X	--	--	--	Sample used for evaluation of contaminant transport.

Table 4–25. Data Summary and Designated Use for RI (continued)

Sample ID	Type	Date	Depth (ft)	Sampling Event	QC	N&E	F&T	HHRA	ERA	Comments
DA2sd-101-0776-SD	D	07/10/02	0–0.1	DA2 P2 RI	--	X	--	--	--	Sample used for evaluation of contaminant transport.
DA2sd-101-0849-SD	D	07/10/02	0–0.1	DA2 P2 RI	X	--	--	--	--	Field duplicate.
DA2sd-103-0778-SD	D	07/10/02	0–0.1	DA2 P2 RI	--	X	--	--	--	Sample used for evaluation of contaminant transport.
WSAsd-037-5649-SD	D	03/23/10	0–0.5	PBA08 RI	--	X	X	X	X	
WSAsd-038-5650-SD	D	03/23/10	0–0.5	PBA08 RI	--	X	X	X	X	
WSAsd-039-5651-SD	D	03/23/10	0–0.5	PBA08 RI	--	X	--	--	--	Sample used for evaluation of contaminant transport.
WSAsd-040-5652-SD	D	03/30/10	0–0.5	PBA08 RI	--	X	--	--	--	Sample used for evaluation of contaminant transport.
Surface Water										
DA2sw-102-0787-SW	D	07/09/02	0–0.1	DA2P2	--	X	--	--	--	Sample used for evaluation of contaminant transport.
DA2sw-102-0788-SW	D	09/09/02	0–0.1	DA2P2	--	X	--	--	--	Sample used for evaluation of contaminant transport.
DA2sw-102-0789-SW	D	11/26/02	0–0.1	DA2P2	--	X	--	--	--	Sample used for evaluation of contaminant transport.
DA2sw-102-0790-SW	D	04/03/03	0–0.1	DA2P2	--	X	--	--	--	Sample used for evaluation of contaminant transport.
WSAsw-037-5656-SW	D	03/23/10	-	PBA08 RI	--	X	X	X	X	
WSAsw-038-5657-SW	D	03/23/10	-	PBA08 RI	--	X	X	X	X	
WSAsw-039-5658-SW	D	03/23/10	-	PBA08 RI	--	X	--	--	--	Sample used for evaluation of contaminant transport.
WSAsw-040-5659-SW	D	03/30/10	-	PBA08 RI	--	X	--	--	--	Sample used for evaluation of contaminant transport.
WSAsw-040-6199-FD	D	03/30/10	-	PBA08 RI	X	--	--	--	--	Field duplicate.

AOC = Area of concern
D = Discrete.
ERA = Ecological risk assessment.
F&T = Fate and transport.
ft = Feet.
HHRA = Human health risk assessment.
ID = Identification.
ISM = Incremental sampling methodology.
IRA = Interim Removal Action.
N&E = Nature and extent.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
QC = Quality control.
RI = Remedial investigation.
RRSE = Relative Risk Site Evaluation.



ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

Figure 4–1. Characterization of 14 AOCs Sample Locations at Wet Storage Area

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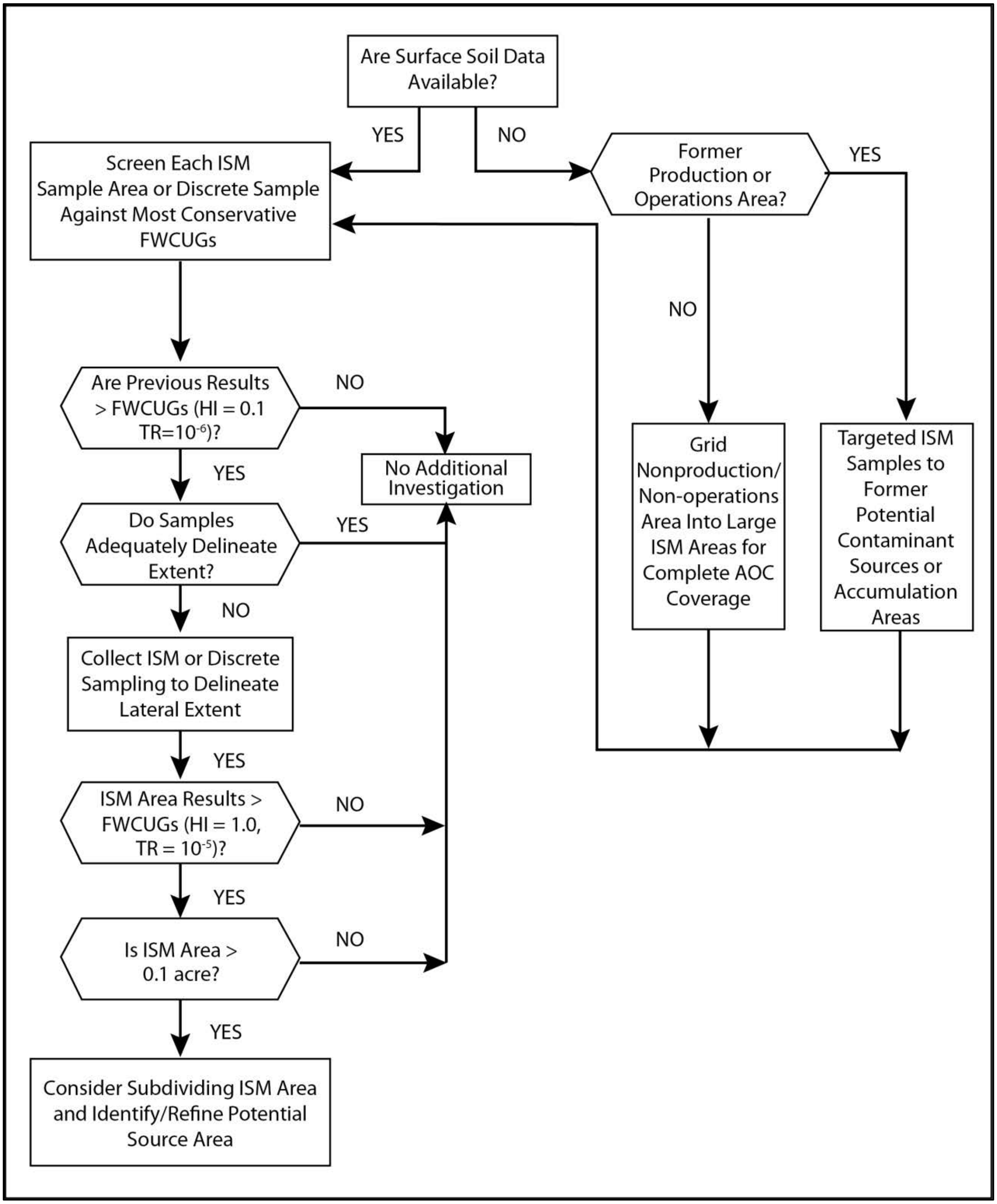


Figure 4–2. PBA08 RI Surface Soil Sampling

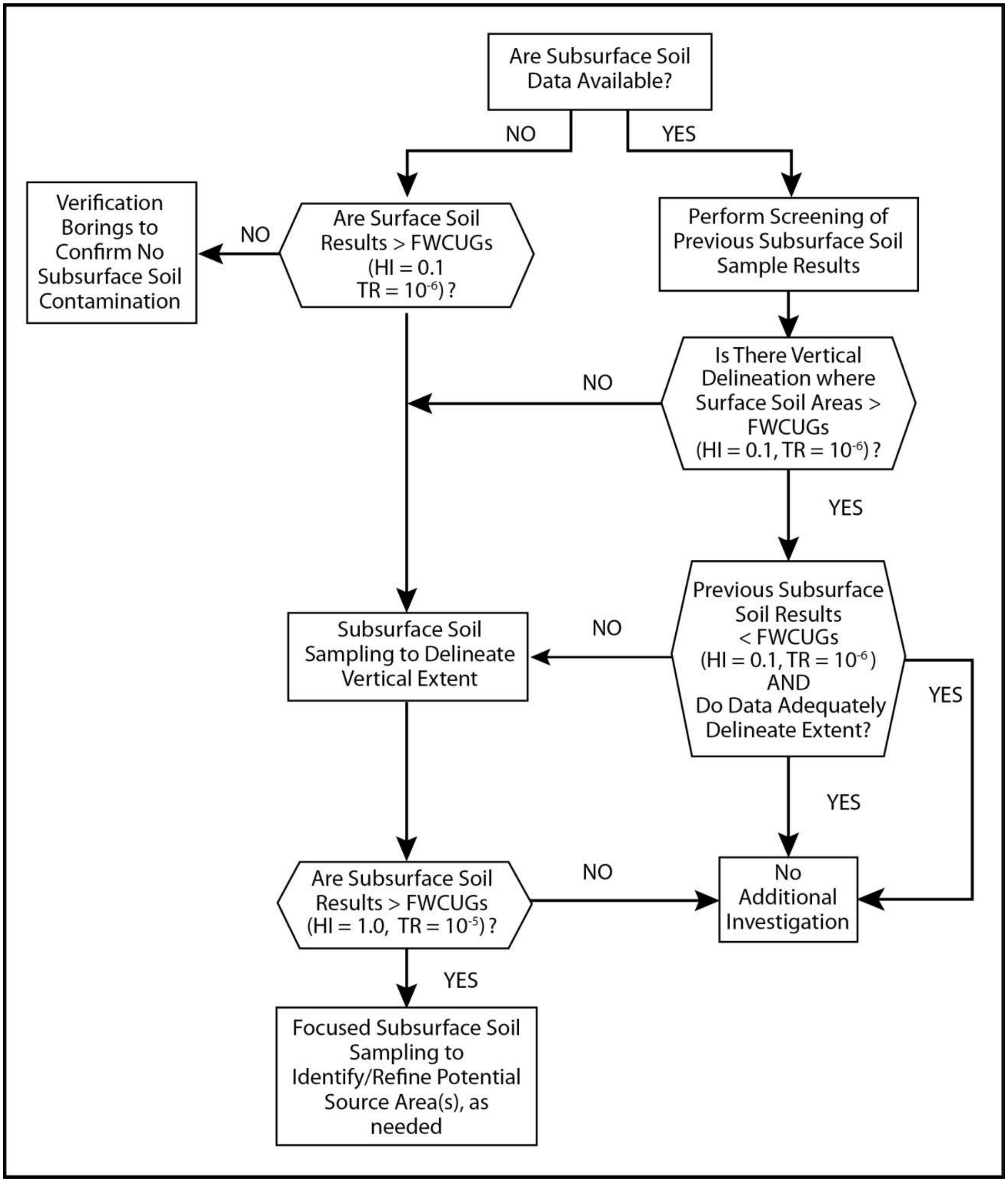
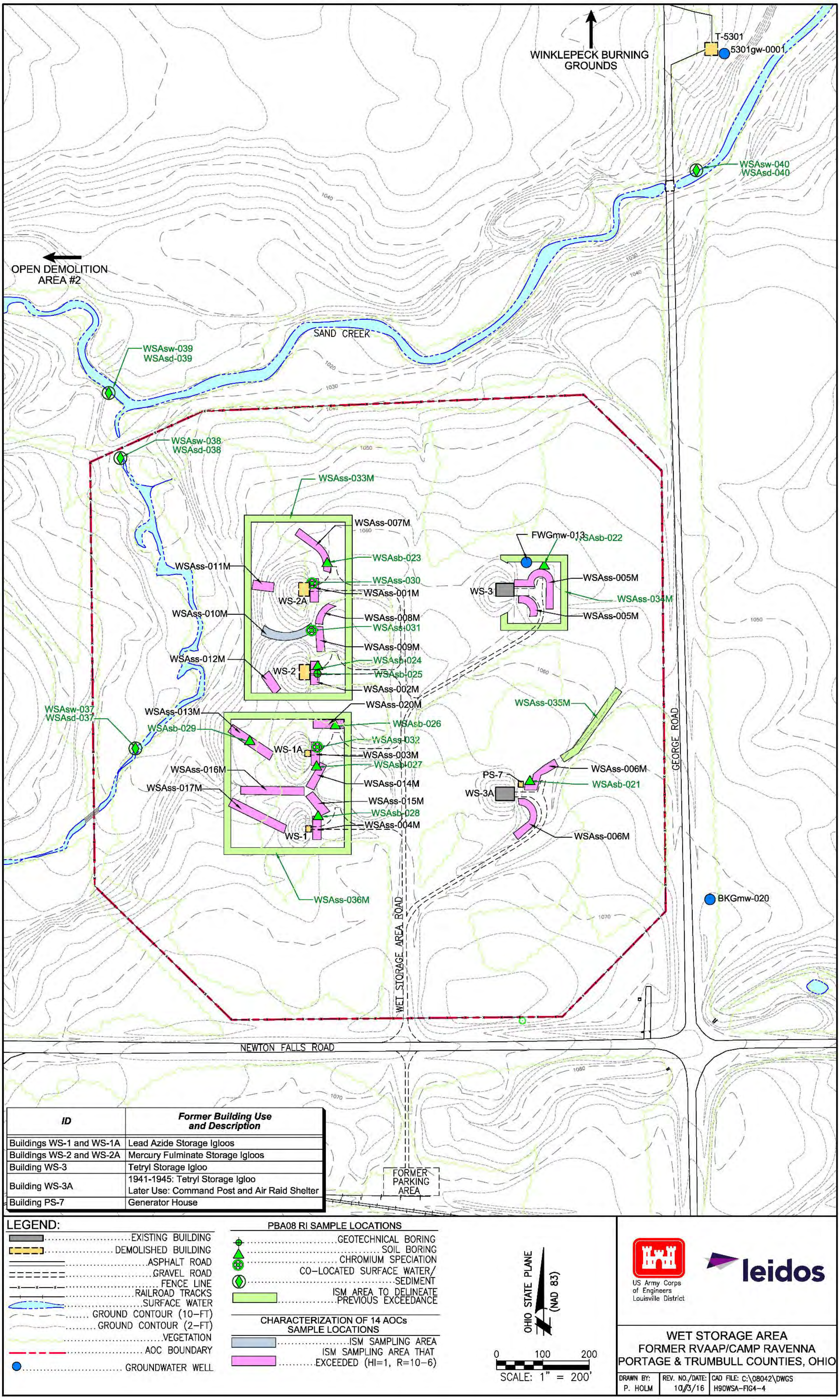


Figure 4–3. PBA08 RI Subsurface Soil Sampling



ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

Figure 4–4. 2010 PBA08 RI Sample Locations

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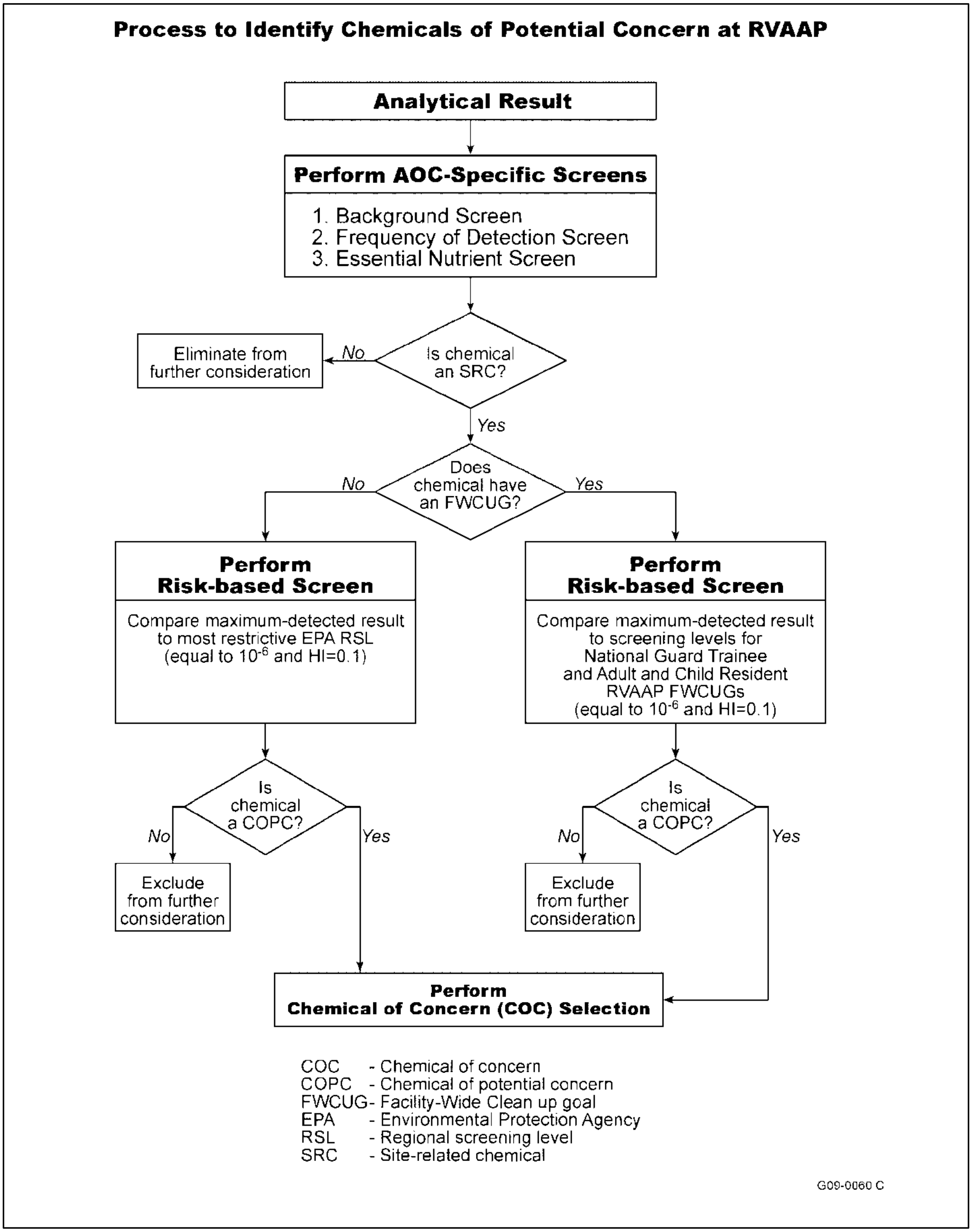

Figure 4–5. Process to Identify RVAAP COPCs in the HHRA (USACE 2010a)

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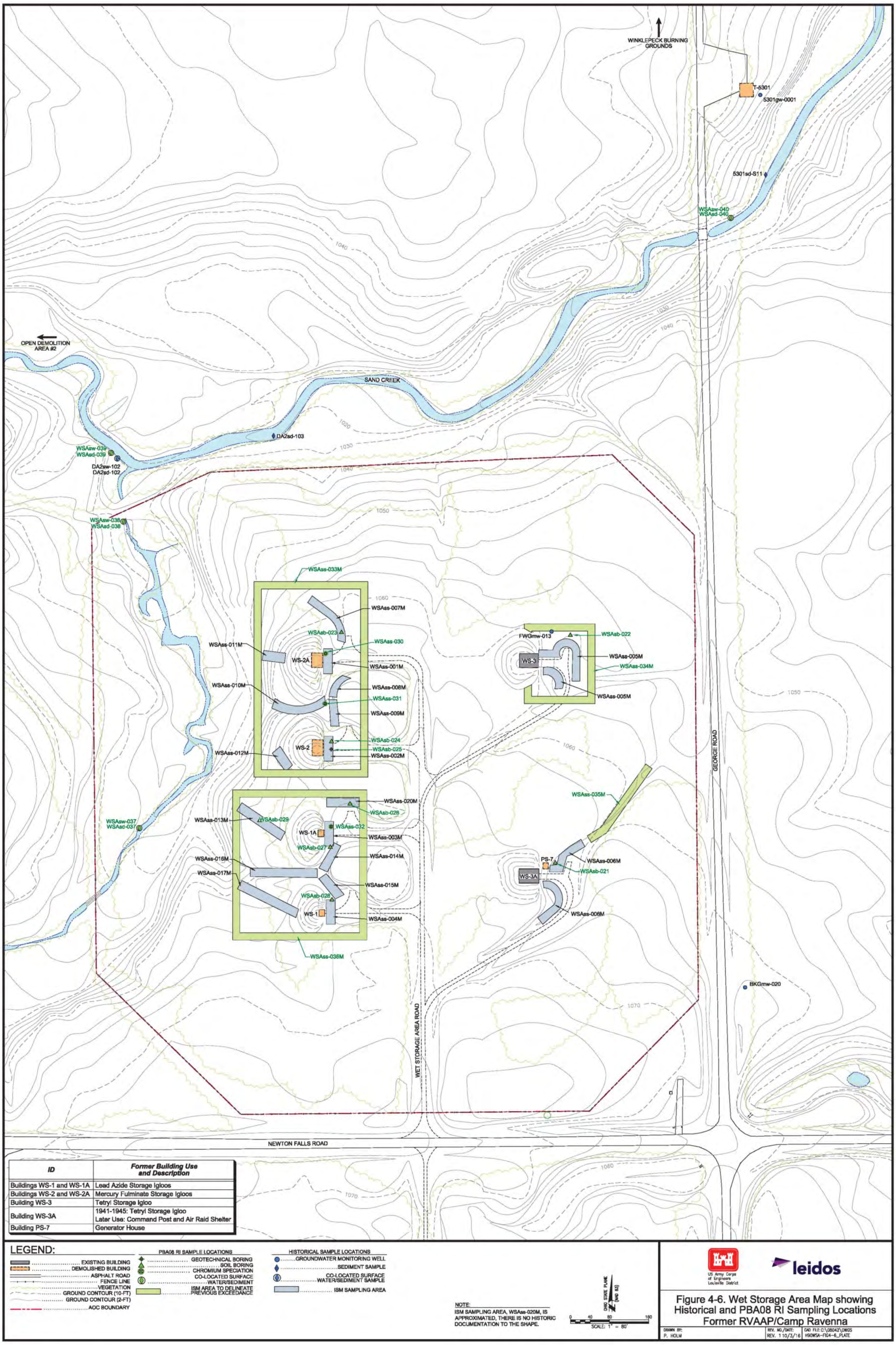

ID	*Former Building Use and Description*
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

NOTE:
ISM SAMPLING AREA, WSAss-020M, IS APPROXIMATED, THERE IS NO HISTORIC DOCUMENTATION TO THE SHAPE.

Figure 4-6. Wet Storage Area Map showing
Historical and PBA08 RI Sampling Locations
Former RVAAP/Camp Ravenna

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\08042\DWGS
P. HOLM	REV. 1 10/3/16	H90WSA-FIG4-6_PLATE

Figure 4–6. All Wet Storage Area RI Sample Locations

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5.0 NATURE AND EXTENT OF CONTAMINATION

This section evaluates the nature and extent of contamination at Wet Storage Area. This evaluation includes two types of chemicals: SRCs identified as being previously used during operational activities or that potentially were associated with operations, and SRCs that do not appear to have been used during historical operations but were analyzed during investigations. The evaluation discusses the nature and extent of SRCs in environmental media at Wet Storage Area, with a focus on chemicals previously used during operational activities, using analytical data results obtained from the 2004 Characterization of 14 AOCs and 2010 PBA08 RI. Surface water and sediment samples outside the AOC from the 2002 ODA2 Phase II RI and the 2000 Building T-5301 IRA were considered with respect to contaminant migration but were not used in the Wet Storage Area data screening process.

To support the evaluation of nature and extent of contamination, SRC concentrations were compared to SLs corresponding to the lowest FWCUG for the Resident Receptor (Adult and Child) and National Guard Trainee at a target HQ of 0.1 or TR of 1E-06, as presented in the FWCUG Report. The following figures in Section 5.0 illustrate the concentrations and distribution of SRCs that exceed SLs.

- Figure 5-1 – Detected Concentrations of Explosives and Propellants in Soil.
- Figure 5-2 – Exceedances of FWCUG (HQ of 0.1, TR of 1E-06) for Arsenic, Chromium, Lead, Mercury, Aluminum, and Cobalt in Soil.
- Figure 5-3 – PAH Exceedances of FWCUG (HQ of 0.1, TR of 1E-06) in Soil.
- Figure 5-4 – Detected Concentrations of VOCs, Pesticides, and PCBs in Soil.
- Figure 5-5 – Exceedances of FWCUG (HQ of 0.1, TR of 1E-06) for Arsenic, Chromium, Lead, Mercury, and Manganese in Surface Water and Sediment.
- Figure 5-6 – SVOC Exceedances of FWCUG (HQ of 0.1, TR of 1E-06) in Surface Water and Sediment.
- Figure 5-7 – Detected Concentrations of VOCs, Pesticides, and PCBs in Surface Water and Sediment.

As discussed in Section 4.0, data from all eligible samples were combined and screened to identify SRCs representing current conditions at Wet Storage Area. All validated Wet Storage Area data from previous studies (2000 Building T-5301 IRA, 2002 ODA2 Phase II RI, 2004 Characterization of 14 AOCs, and 2010 PBA08 RI) are included in Appendix D. Complete laboratory analytical data packages from the PBA08 RI are also included in Appendix D.

Contaminant nature and extent is presented below for each medium and class of analytes.

5.1 DATA EVALUATION

As discussed in Section 4.2, surface soil, surface water, and sediment samples were collected during prior investigations such as the Characterization of 14 AOCs. Surface soil, subsurface soil, sediment, and surface water samples were collected during the PBA08 RI. All available sample data were evaluated to determine suitability for use in the various key RI data screens and evaluations (nature and extent, fate and transport, risk assessment). Evaluation of data suitability for use in the PBA08 RI involved two primary considerations: representativeness with respect to current AOC conditions and sample collection methods (e.g., discrete vs. ISM).

Samples from prior historical investigations were evaluated to determine if conditions had changed substantively between earlier characterization efforts and PBA08 RI activities. Demolition and removal of headwalls, slabs, and foundations of storage igloos WS-1, WS-1A, WS-2, and WS-2A at Wet Storage Area were completed prior to the Characterization of 14 AOCs investigation in 2004; therefore, no surface soil samples were eliminated from evaluation on the basis of changed conditions. Only PBA08 RI data are available for subsurface soil, as the 2004 investigation did not include soil borings. Historical sediment and surface water samples were collected at the unnamed tributary to the west of Wet Storage Area and Sand Creek under sampling efforts for other nearby AOCs (i.e., ODA2 and Building T-5301) between 2000 and 2004. The previous sediment and surface water data do not represent current conditions. Although sediment and surface water samples were collected under the PBA08 RI, only those samples collected within Wet Storage Area were used to evaluate nature and extent, whereas those collected off-AOC were used to assess contaminant transport.

All previous surface soil samples from 2004 were collected using ISM sample methods, as were those collected under the PBA08 RI; therefore, data from both investigations were screened for SRCs and carried forward into the risk assessment. Discrete surface soil samples sourced from the 0–1 ft bgs interval from soil borings installed in 2010 were utilized for nature and extent evaluation only, as only the ISM samples were utilized for surface soil SRC screening. For subsurface soil, only discrete sample data from the PBA08 RI were available; therefore, they were screened for SRCs and COPCs and carried forward into the risk assessment. For sediment, only discrete samples were collected from the unnamed tributary on the west side of the AOC and Sand Creek in 2010 and under previous investigations conducted between 2000 and 2003 at other AOCs. Only two 2010 sediment and surface water samples collected within the unnamed tributary to the west were screened for SRCs, as these were considered representative of AOC conditions. All other sediment and surface water samples were not considered representative of current conditions on the AOC and were used only for evaluating contaminant nature and extent (e.g., temporal trends) and/or contaminant transport (i.e., to determine off-AOC migration).

5.2 SURFACE SOIL DISCRETE SAMPLE RESULTS FOR CHROMIUM SPECIATION

During the 2010 PBA08 RI, surface soil samples were collected from three discrete sample locations and analyzed for hexavalent chromium and total chromium. Two samples were collected from areas previously identified during the 2004 Characterization of 14 AOCs as having elevated total chromium concentrations (WSAss-030 and WSAss-032), and one sample was collected from an area previously identified as having a total chromium concentration near background concentrations (WSAss-031). This sampling determined the contribution of hexavalent chromium to total chromium over a range of concentrations in soil at Wet Storage Area for use in the HHRA (Section 7.2).

Chromium speciation results are shown in Table 5-1. Two of the three samples had a total chromium concentration above the facility-wide background concentration of 17.4 mg/kg. The range of hexavalent chromium concentrations was non-detectable to 0.52J mg/kg and did not appear to be correlative to total chromium values. A detailed assessment of the speciation results respective to the HHRA is presented in Section 7.2.4.1.

5.3 CONTAMINANT NATURE AND EXTENT IN SURFACE SOIL

Table 4-21 presents the results of the SRC screening for surface soil at Wet Storage Area. The following subsections discuss the concentration and distribution of ISM surface soil results.

5.3.1 Explosives and Propellants

Figure 5-1 presents the locations that had detectable concentrations of explosives and propellants. 3-Nitrotoluene and nitrocellulose were identified as SRCs and as potentially related to previous AOC operations. The igloos were evaluated for explosives and propellants during both of the investigations comprising the RI data set. Specifically, the soil samples around the igloos were analyzed during the 2004 Characterization of 14 AOCs and data gaps were assessed during the 2010 PBA08 RI.

The maximum concentrations of 3-nitrotoluene and nitrocellulose were all below their respective SLs and were not considered COPCs. 3-Nitrotoluene was detected in the 2004 ISM surface soil sample WSAss-001M immediately adjacent to one of the former igloos in the northwest portion of the AOC. PBA08 RI sample WSAss-033M was collected to delineate the extent of contamination at this former igloo location and no explosives were detected. Nitrocellulose was detected in 2004 ISM surface soil samples WSAss-011M and WSAss-004M as shown in Figure 5-1.

A PBA08 RI discrete soil sample collected from 0–1 ft bgs from soil boring WSAsb-028 contained the explosive tetryl at a concentration of 0.026J mg/kg. Soil boring WSAsb-028 was located adjacent to 2004 ISM surface soil sample WSAss-004M. Tetryl was not detected in any other 2004 or PBA08 RI ISM or discrete samples and was not classified as an SRC.

5.3.2 Inorganic Chemicals

Arsenic, chromium, lead, and mercury were identified as potential inorganic SRCs and as potentially related to previous site use. All four of these inorganic chemicals had a maximum detection above the background concentration, as summarized in the list below.

- Arsenic was detected above the background concentration (15.4 mg/kg) in 9 of 22 ISM samples, with a maximum concentration of 21 mg/kg at 2004 sample location WSAss-020M that evaluated surface soil near former Building WS-1A.
- Chromium was detected above the background concentration (17.4 mg/kg) in 21 of 22 ISM samples, with a maximum concentration of 26 mg/kg observed at 2004 sample location WSAss-003M that evaluated surface soil near former Building WS-1A.

- Lead was detected above the background concentration of 26.1 mg/kg in 5 of 22 ISM samples, with a maximum concentration of 97 mg/kg observed at 2004 sample location WSAss-002M that evaluated surface soil near former Building WS-2.
- Mercury was detected above the background concentration of 0.036 mg/kg in 12 of 22 ISM samples, with a maximum concentration of 2.1 mg/kg at 2004 sample location WSAss-010M that evaluated surface soil near former Buildings WS-2A and WS-2.

Figure 5-2 presents the locations with concentrations that exceeded SLs and background concentrations for these four chemicals. Of these four chemicals, lead and mercury had no detections above the SL, and were therefore not considered COPCs. Chromium exceeded the SL for hexavalent chromium (1.64 mg/kg), but did not exceed the SL for trivalent chromium (8,147 mg/kg) so it is not shown in Figure 5-1. The SL exceedances of arsenic do not appear to be concentrated in any particular area of the AOC.

Although not identified as previously used during historical operations, 10 additional inorganic chemicals were identified as SRCs from the RVAAP screening process, as presented in Table 4-21 and summarized below:

- Aluminum was detected above the background concentration of 17,700 mg/kg in one sample, with a concentration of 27,100 mg/kg observed at the 2010 PBA08 RI sample location WSAss-033M. Aluminum also exceeded its respective SL (3,496 mg/kg) and is considered a COPC.
- Barium was detected above the background concentration of 88.4 mg/kg in one sample, with a concentration of 110 mg/kg observed at 2004 sample location WSAss-005M.
- Beryllium was detected above the background concentration of 0.88 mg/kg in two samples, with a maximum concentration of 1.3 mg/kg observed at 2010 PBA08 RI sample location WSAss-033M.
- Cadmium does not have a background concentration. The inorganic chemical was detected in four samples, with a maximum concentration of 0.19 mg/kg observed at 2010 PBA08 RI sample location WSAss-035M.
- Cobalt was detected above the background concentration of 10.4 mg/kg in 10 samples, with a maximum concentration of 14 mg/kg observed at 2004 sample location WSAss-020M. Cobalt also exceeded its respective SL (7.03 mg/kg) and is considered a COPC.
- Copper was detected above the background concentration of 17.7 mg/kg in 15 samples, with a maximum concentration of 21 mg/kg observed at 2004 sample locations WSAss-001M, WSAss-013M, and WSAss-020M.
- Nickel was detected above the background concentration of 21.1 mg/kg in 19 samples, with a maximum concentration of 32 mg/kg observed at 2004 sample location WSAss-020M.
- Selenium was detected above the background concentration of 1.4 mg/kg in two samples, with a maximum concentration of 1.4 mg/kg observed at 2010 PBA08 RI sample locations WSAss-033M and WSAss-035M.

- Thallium does not have a background concentration. The inorganic chemical was detected in eight samples, with a maximum concentration of 0.31 mg/kg observed at 2004 sample location WSAss-007M.
- Zinc was detected above the background concentration of 61.8 mg/kg in 12 samples, with a maximum concentration of 140 mg/kg observed at 2004 sample location WSAss-002M.

5.3.3 Semi-volatile Organic Compounds

SVOCs do not have background concentrations for comparison purposes with chemical results; consequently, a large number of SVOCs were identified as SRCs. A total of 21 SVOC SRCs were identified by data screening; 6 PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] exceeded their SLs and were identified as COPCs. Figure 5-3 illustrates the distribution of PAHs exceeding their respective SLs in the surface soil at Wet Storage Area.

PAHs were identified as potential organic contaminants from previous site use at Generator House PS-7. Benzo(a)pyrene was detected above its respective SL in the 2010 PBA08 RI discrete surface soil sample WSAsb-021 and WSAss-035M.

Five of the six PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] that exceeded the SLs were detected at concentrations greater than their respective Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1 at one sample location from the 2004 Characterization of 14 AOCs: WSAss-004M. All other detected PAH concentrations at WSAss-004M were below their respective Resident Receptor (Adult and Child) at a TR of 1E-05, HQ of 1. A 2010 PBA08 RI sample, WSAss-036M, delineated the area containing WSAss-004M. The detected PAH concentrations were typically two orders of magnitude lower than those observed at WSAss-004M. Benzo(a)pyrene also exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1 at discrete PBA08 RI sample locations WSAsb-022 and WSAsb-027. Benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene also exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1 at discrete PBA08 RI sample locations WSA-024 and WSAsb-028.

5.3.4 Volatile Organic Compounds, Pesticides, and Polychlorinated Biphenyls

Five pesticides were identified as SRCs in surface soil at Wet Storage Area. The pesticides 4,4'-dichlorodiphenyldichloroethylene (DDE); endosulfan sulfate; endrin; and alpha-chlordane were detected in the 2010 PBA08 RI ISM sample WSAss-036M, which delineates the location of the two former igloos at the southwest portion of the AOC (Figure 5-4). Beta-hexachlorocyclohexane (BHC) was detected at WSAss-011M, located at the northwest portion of the AOC (Figure 5-4).

No VOCs or PCBs were detected in the surface soil at Wet Storage Area.

5.4 CONTAMINANT NATURE AND EXTENT IN SUBSURFACE SOIL

As discussed in Section 4.0, data from subsurface soil samples were screened to identify SRCs representing subsurface conditions at Wet Storage Area. Subsurface soil samples were not collected during historical investigations at Wet Storage Area; therefore, the SRC screening data set was comprised of 19 discrete samples collected during the 2010 PBA08 RI. Eight soil borings were completed at Wet Storage Area to define the vertical extent of contamination in subsurface soil. In five borings, either bedrock (two locations) or groundwater was encountered before the boring could be advanced to 13 ft bgs; therefore, only two discrete subsurface soil samples were collected from 1–4 and 4–7 ft bgs. Three borings were advanced to 13 ft bgs, and three discrete subsurface soil samples were collected from 7–13 ft bgs at each location. Six subsurface borings were analyzed for TAL metals, explosives, and PAHs; samples from two borings were analyzed for RVAAP full-suite analytes. Table 4-22 presents the results of the SRC screening for subsurface soil samples. Figures 5-1 through 5-4 illustrate the distribution of identified subsurface soil SRCs in all samples collected at Wet Storage Area.

5.4.1 Explosives and Propellants

No explosives or propellants were detected in the subsurface soil samples at Wet Storage Area.

5.4.2 Inorganic Chemicals

Arsenic, chromium, lead, and mercury were identified as potential inorganic SRCs and as potentially related to previous site use. One of these four inorganic chemicals (arsenic) had detections above the background concentration. Arsenic was detected above the background concentration (19.8 mg/kg) in 3 of 19 subsurface samples, with a maximum concentration of 21.3J mg/kg at 2010 PBA08 RI sample location WSAsb-026 in the 4–7 ft bgs interval. WSAsb-026 evaluated subsurface soil near former Building WS-1A. Arsenic was also detected above its background concentration at locations WSAsb-021 and WSAsb-024 in the 1–4 ft bgs interval at both locations. Arsenic concentrations in all three soil borings decreased below the background concentration in the next deeper sampling interval.

The arsenic concentrations detected at WSAsb-021, WSAsb-024, and WSAsb-026 were above the SL, and arsenic is considered to be a COPC. Figure 5-2 presents the locations with concentrations that exceeded SLs and background concentrations for arsenic. The SL exceedances of arsenic do not appear to be concentrated in any particular area of the AOC.

Although not identified as previously used during historical operations, three additional inorganic chemicals were identified as SRCs from the RVAAP screening process, as presented in Table 4-22 and as summarized below:

- Cadmium does not have a background concentration. The inorganic chemical was detected in 11 samples, with a maximum concentration of 0.071 mg/kg observed at 2010 PBA08 RI sample location WSAsb-021 in the 1–4 ft bgs interval.
- Cobalt was detected above the background concentration of 23.2 mg/kg in one sample, with a concentration of 25.8 mg/kg observed at 2010 PBA08 RI sample location WSAsb-0222 in the 1–4 ft bgs interval. Cobalt also exceeded its respective SL (7.03 mg/kg) and is considered a COPC.
- Silver does not have a background concentration. The inorganic chemical was detected in four samples, with a maximum concentration of 0.026 mg/kg observed at 2010 PBA08 RI sample location WSAss-021 in the 4i7 ft bgs interval.

5.4.3 Semi-volatile Organic Compounds

Seventeen SVOCs were detected and identified as SRCs in subsurface soil at Wet Storage Area. Except for bis(2-ethylhexyl)phthalate and di-n-butyl phthalate, all of the SVOCs were PAHs and were also identified as SRCs in surface soil. Benzo(a)pyrene was detected from the 1–4 ft bgs interval at PBA08 RI sample location WSAsb-024 at a concentration that exceeded its respective SL of 0.022 mg/kg; benzo(a)pyrene was identified as a COPC (Figure 5-3). The benzo(a)pyrene concentration was detected below the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. No SVOCs were detected from the 4–7 or 7–13 ft bgs intervals at WSAsb-024.

5.4.4 Volatile Organic Compounds, Pesticides, and Polychlorinated Biphenyls

One VOC (toluene) and one pesticide [4,4’-dichlorodiphenyltrichloroethane (DDT)] were detected at low, estimated concentrations (less than the laboratory reporting limit) in the PBA08 RI sample location WSAsb-028, which is located near the former southwest igloos. Toluene was detected from the 1–4 ft bgs interval, but was not observed in either the 4–7 or 7–13 ft bgs intervals. The pesticide, 4,4’-DDT, was detected in the 7–13 ft bgs interval but not in the two shallower samples collected at WSAsb-028. No PCBs were detected in subsurface soil at Wet Storage Area.

5.4.5 Geotechnical Subsurface Soil Sample

One soil boring was completed at Wet Storage Area to obtain geotechnical parameters to perform vadose zone soil leaching and groundwater transport modeling. Two samples were collected from this soil boring from the 4–5.2 and 12–13.1 ft bgs intervals. Soil boring WSAsb-025 was advanced to a depth of 28 ft bgs, with weathered shale encountered at 23.8 ft bgs. Groundwater was not encountered in this boring. Table 5-2 summarizes the results of the geotechnical characteristics of Wet Storage Area soil. Laboratory analytical data package results are presented in Appendix D.

5.5 CONTAMINANT NATURE AND EXTENT IN SEDIMENT

Four discrete sediment samples (0–0.5 ft bgs) were collected during the PBA08 RI; two were located within the unnamed tributary on the west side of Wet Storage Area, and two were located within Sand Creek. Three of the samples were analyzed for TAL metals, explosives, and PAHs, and one sample was analyzed for RVAAP full-suite analytes. Table 4-23 presents the results of the SRC screening for the PBA08 RI sediment samples, and Table 4-17 summarizes the analytical results for all detected analytes. Complete copies of analytical results are presented in Appendix D.

The population of sediment samples deemed representative for the purposes of SRC screening were the two PBA08 RI discrete sediment samples collected at the unnamed tributary, locations WSAsd-037 and WSAsd-038. The two PBA08 RI samples collected within Sand Creek are downstream of Wet Storage Area and were utilized for evaluating nature and extent and contaminant transport. Three discrete sediment samples collected in 2000 and 2002 within Sand Creek as part of investigations associated with other AOCs (e.g., ODA2 and Building T-5301) are incorporated for nature and extent purposes only (i.e., not for SRC screening).

5.5.1 Explosives and Propellants

No explosives or propellants were detected in sediment samples at Wet Storage Area.

5.5.2 Inorganic Chemicals

None of the four inorganic chemicals (i.e., arsenic chromium, lead, and mercury) that were identified as potential inorganic SRCS and as potentially related to previous site use were detected above their background concentrations.

Although not identified as previously used during historical operations, five inorganic chemicals were identified as SRCs from the RVAAP screening process, as presented in Table 4-23 and as summarized below:

- Antimony does not have a background concentration. The inorganic chemical was detected in one sample, with a concentration of 0.095J mg/kg observed at 2010 PBA08 RI sample location WSAsd-037.
- Beryllium was detected above the background concentration of 0.38 mg/kg in one sample, with a concentration of 0.42 mg/kg observed at 2010 PBA08 RI sample location WSAsd-037.
- Cadmium does not have a background concentration. The inorganic chemical was detected in both samples, with a maximum concentration of 0.15J mg/kg observed at 2010 PBA08 RI sample location WSAsd-037. The concentrations were below the laboratory reporting limit.

- Manganese was detected above the background concentration of 1,950 mg/kg in one sample, with a maximum concentration of 2,230 mg/kg observed at 2010 PBA08 RI sample location WSAsd-037. Manganese also exceeded its respective SL (35.1 mg/kg) and is considered a COPC.
- Silver does not have a background concentration. The inorganic chemical was detected in both samples, with a maximum concentration of 0.027J mg/kg observed at 2010 PBA08 RI sample location WSAsd-037. The concentrations were below the laboratory reporting limit.

All five inorganic SRCs were detected at higher concentrations at the most upstream location WSAsd-037, as compared to location WSAsd-038 which was located immediately upstream of the confluence with Sand Creek. The results for WSAsd-039 and WSAsd-040 also confirm this longitudinal trend with fewer inorganic SRC observations above background concentrations as the distance downstream increases.

5.5.3 Semi-volatile Organic Compounds

Fourteen SVOCs (all PAHs) were identified as SRCs in sediment. All of the PAHs were detected at concentrations below their respective SL except benzo(a)pyrene. Benzo(a)pyrene was detected at PBA08 RI sample location WSAsd-037 at a concentration (0.093 mg/kg) that exceeded its respective SL of 0.022 mg/kg, and benzo(a)pyrene was identified as a COPC (Figure 5-6). The concentration was detected below the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. No PAHs were detected in the two PBA08 RI sample locations in Sand Creek and downstream of the AOC, or in either of the historical sediment samples collected in 2000 and 2002.

PAHs in sediment reflect a clear longitudinal trend, exhibiting decreasing numbers and concentrations with downstream distance. However, location WSAsd-037, which exhibits the highest and most PAH detections, is in a location upstream relative to potential surface water contributions from Wet Storage Area; therefore, it is not influenced by runoff from the AOC.

5.5.4 Volatile Organic Compounds, Pesticides, and Polychlorinated Biphenyls

One VOC (2-butanone) was detected in PBA08 RI sample location WSAsd-037 at the most upstream location in the unnamed tributary below the laboratory reporting limit (Figure 5-7). The other three PBA08 RI discrete sediment samples were not analyzed for VOCs, as these were not RVAAP full-suite sample locations. 2-Butanone was not detected in either of the two 2002 sediment samples collected in Sand Creek that were associated with ODA2 (locations DA2sd-101 and DA2sd-103). The historical sample collected at DA2sd-103, located immediately downgradient of the confluence with Sand Creek, exhibited detections of the VOC chloromethane and the pesticide dieldrin; however, these two chemicals were not detected in sediment at Wet Storage Area.

5.6 NATURE AND EXTENT OF CONTAMINATION IN SURFACE WATER

Surface water at Wet Storage Area is present within the unnamed tributary on the west side of the AOC, which then enters into Sand Creek at the north. Within the former operational area at Wet Storage Area, surface water only occurs as storm water runoff either overland or within discontinuous ditch lines immediately adjacent to access roads. Four surface water samples were collected during the PBA08 RI; two were used to perform SRC screening and two were used to assess contaminant transport. Available historical surface water data were also evaluated, although they were not used in SRC screening. Table 4-24 summarizes the results of the surface water SRC screening. Complete copies of analytical results are presented in Appendix D.

5.6.1 Explosives and Propellants

No explosives or propellants were detected in surface water at Wet Storage Area.

5.6.2 Inorganic Chemicals

Lead and four inorganic chemicals (antimony, nickel, selenium, and vanadium) that were not identified as previously used during historical operations were identified as SRCs in surface water. No background concentrations are established for surface water for these inorganic chemicals, and all detections from the PBA08 RI samples were below the laboratory screening criteria. The maximum detections within the AOC of all five metals was at sample location WSAsd-038. Four of the five inorganic chemicals (lead, nickel, selenium, and vanadium) with higher concentrations occurred outside the AOC at PBA08 RI sample location WSAsd-039, located on Sand Creek upgradient of the confluence with the unnamed tributary. None of the inorganic SRCs were detected in historical surface water samples.

5.6.3 Semi-volatile Organic Compounds

No SVOCs were detected in surface water at Wet Storage Area. There was one detection below the SL of bis(2-ethylhexyl)phthalate at DA2sw-102 in 2003 outside the AOC in Sand Creek.

5.6.4 Volatile Organic Compounds, Pesticides, and Polychlorinated Biphenyls

No VOCs, pesticides, or PCBs were detected in surface water at Wet Storage Area. There was one detection each for carbon disulfide (0.0017 mg/L at DA2sw-102), chloroform (0.002 mg/L at DA2sw-102, and acetone (0.0023J mg/L at WSAsw-040) outside the AOC.

5.7 SUMMARY OF CONTAMINANT NATURE AND EXTENT

Data from the 2004 Characterization of 14 AOCs and 2010 PBA08 RI were used to identify SRCs at Wet Storage Area. This data effectively characterizes the nature and extent of contamination at the AOC. To support the evaluation of the nature and extent of contamination, SRC concentrations were compared to SLs corresponding to the lowest FWCUG for the Resident Receptor (Adult and Child) and the National Guard Trainee at a target HQ of 0.1 or TR of 1E-06, as presented in the FWCUG Report. If there was no FWCUG for a chemical, the USEPA RSL was used as the SL. Based on the information provided earlier in this section and as summarized below, it can be concluded that the vertical and horizontal extent of contamination is defined, and no further sampling is needed to evaluate Wet Storage Area.

5.7.1 Surface Soil

The predominant SRCs in surface soil at Wet Storage Area were inorganic chemicals and SVOCs, the majority of which were PAHs. Fourteen inorganic chemicals were identified as SRCs in surface soil. The maximum concentrations for inorganic SRCs were not concentrated in any one location, and two ISM samples with the most maximum detections for surface soil were WSAss-002M and WSAss-033M. The highest density of samples with inorganic chemicals above background concentrations was located in the vicinity of the former igloos in the northwestern portion of Wet Storage Area. Aluminum, arsenic, and cobalt concentrations exceeded their respective SLs and were considered COPCs; however, only arsenic concentrations at nine ISM locations exceeded the respective Resident Receptor (Adult and Child) at a TR of 1E-05, HQ of 1. The arsenic exceedance does not appear to be concentrated in any particular area of the AOC.

All 21 SVOC SRCs were detected at 2004 ISM sample location WSAss-004M, located adjacent to one of the southwestern igloos, with maximum detections for all 21 of the SVOC SRCs observed in this sample. Thirteen SVOCs were detected at WSAss-036M, which delineates the area containing WSAss-004M, at concentrations typically two orders of magnitude lower than those observed at WSAss-004M. Although SVOC detections in surface soil occur throughout the AOC, the samples with the highest concentrations generally occur adjacent to the former and extant igloo locations and are effectively delineated by the PBA08 RI data. Five of the six PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] that exceeded the SLs at WSAss-004M were detected at concentrations greater than their respective Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. Benzo(a)pyrene also exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1 at discrete PBA08 RI sample locations WSAsb-022, WSAsb-024, WSAsb-027, and WSAsb-028. Benz(a)anthracene, benzo(b)fluoranthene, and dibenz(a,h)anthracene also exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1 at discrete PBA08 RI sample locations WSAsb-024 and WSAsb-028.

An explosive (3-nitrotoluene), propellant (nitrocellulose), and five pesticides (4,4’-DDE; endosulfan sulfate; endrin; alpha-chlordane; and beta-BHC) were identified as SRCs in the surface soil at Wet Storage Area. None of the detected concentrations exceeded their respective SLs. VOCs and PCBs were not detected in the surface soil.

5.7.2 Subsurface Soil

Four inorganic chemicals (arsenic, cadmium, cobalt, and silver) were identified as SRCs, although no spatial or vertical trend is apparent for the distribution of inorganic chemicals in subsurface soil, and concentrations only marginally exceeded their applicable background concentrations. Seventeen SVOCs were identified as SRCs, with soil boring location WSAsb-024 (located adjacent to one of the former igloos in the northwest portion of the AOC) containing the greatest number and highest concentrations of SVOCs. Benzo(a)pyrene was detected from the 1–4 ft bgs interval at WSAsb-024 at a concentration that exceeded its respective SL of 0.022 mg/kg, and benzo(a)pyrene was identified as a COPC. The benzo(a)pyrene concentration was detected below the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. No SVOCs were detected from the 4–7 or 7–13 ft bgs intervals at WSAsb-024. The majority of SVOC SRCs were PAHs which were identified as SRCs in surface soil as well.

One VOC (toluene) and one pesticide (4,4'-DDT) were identified as SRCs, although they occurred at low, estimated concentrations in different depth intervals of soil boring WSAsb-028. Explosives, propellants, and PCBs were not detected in the subsurface soil.

5.7.3 Sediment

The greatest number and highest magnitude of the identified SRCs in sediment samples were detected in the most upstream location within the unnamed tributary to the west of Wet Storage Area. The predominant SRCs in sediment were inorganic chemicals and PAHs. SRC concentrations generally followed a clear longitudinal trend, exhibiting decreasing numbers and concentrations with downstream distance. However, location WSAsd-037, which exhibits the highest and most PAH and inorganic detections, is in a location that is upstream relative to potential surface water contributions from Wet Storage Area; therefore, it is not influenced by runoff from the AOC. Two of the inorganic chemicals (antimony and manganese) were not identified as SRCs in surface soil at Wet Storage Area and occurred in sediment at upstream location WSAsd-037 at concentrations twice or more of the maximum concentrations observed in surface soil at the AOC. Manganese concentrations at WSAsd-037 exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. One VOC (2-butanone) was detected in sediment sample WSAsd-037 upstream of the AOC. Chloromethane and the pesticide dieldrin were detected in sediment in one historical sample in Sand Creek, downstream of the AOC. Explosives, propellants, pesticides, and PCBs were not detected in sediment samples at Wet Storage Area.

5.7.4 Surface Water

Surface water at Wet Storage Area is present within the unnamed tributary on the west side of the AOC, which then enters into Sand Creek to the north. Within the former operational area at Wet Storage Area, surface water only occurs as storm water runoff either overland or within discontinuous ditch lines immediately adjacent to intra-AOC access roads. While five inorganic SRCs were identified in surface water, these inorganic chemicals did not have established background concentrations, and all detections were at concentrations below laboratory screening criteria. Explosives, propellants, SVOCs, pesticides, and PCBs were not detected in surface water samples at Wet Storage Area. Nitrocellulose, bis(2-ethylhexyl)phthalate, acetone, carbon disulfide, and chloroform were each detected once at locations outside the AOC.

Table 5–1. Chromium Speciation Results

Sample location	Hexavalent Chromium Concentration (mg/kg)	Total Chromium Concentration[a] (mg/kg)	Percent Hexavalent Chromium (%)
WSAss-030	< 1U	21.8*	NA
WSAss-031	0.52J	16.5	3.2
WSAss-032	< 1.1U	20.6*	NA

[a] Background concentration for total chromium = 17.4 mg/kg. No background concentration is available for hexavalent chromium.

J = Estimated value is less than reporting limits.
mg/kg = Milligrams per kilogram.
NA = Not applicable; hexavalent chromium was not detected in the sample.
U = Non-detectable concentration.
< = Less than.

Table 5–2. Summary of Geotechnical Parameters

Sample ID: Parameters	WSAsb-025-5627-SO	WSAsb-025-5628-SO
Depth	4–5.2 ft bgs	12–13.1 ft bgs
Porosity	37%	34.2%
Density	1.70 g/cm^3	1.78 g/cm^3
Moisture content	17.4%	16.9%
Total organic carbon	1,300 mg/kg	1,200 mg/kg
Size fraction analysis	0.5% gravel, 11.8 % sand, 55.6 % silt, 32.1 % clay	27.8% sand, 59.8% silt, 12.4% clay
Permeability (K)	1.1E-06 cm/sec	1.8E-06 cm/sec

bgs = Below ground surface.
cm/sec = Centimeters per second.
ft = Feet.
g/cm^3 = Grams per cubic centimeter.
ID = Identification.
mg/kg = Milligrams per kilogram.

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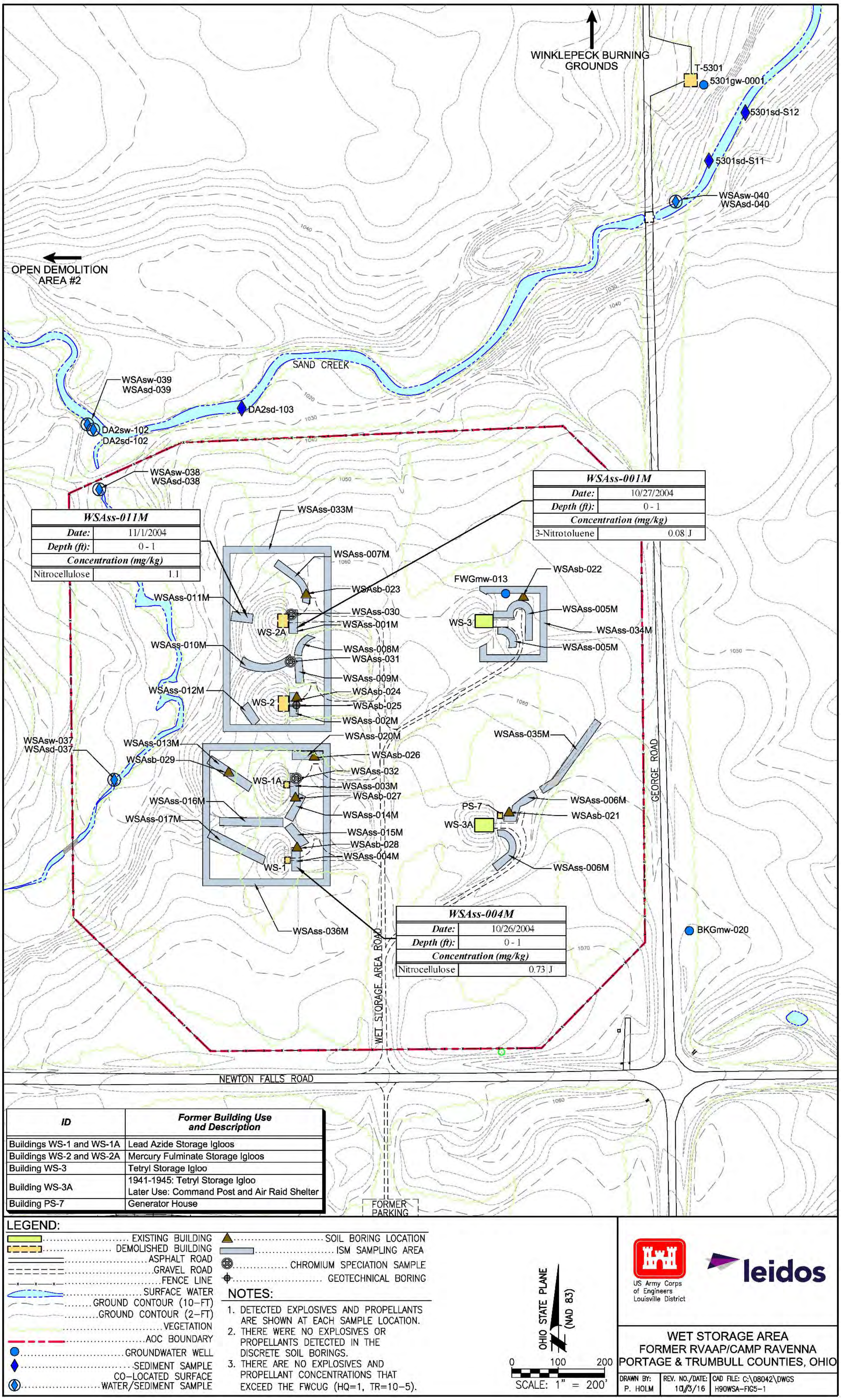


WSAss-011M	
Date:	11/1/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Nitrocellulose	1.1

WSAss-001M	
Date:	10/27/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
3-Nitrotoluene	0.08 J

WSAss-004M	
Date:	10/26/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Nitrocellulose	0.73 J

ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

LEGEND:

🟩	EXISTING BUILDING
▨	DEMOLISHED BUILDING
═	ASPHALT ROAD
┅	GRAVEL ROAD
—x—x—	FENCE LINE
	SURFACE WATER
	GROUND CONTOUR (10–FT)
	GROUND CONTOUR (2–FT)
	VEGETATION
	AOC BOUNDARY
●	GROUNDWATER WELL
◆	SEDIMENT SAMPLE
◈	CO–LOCATED SURFACE WATER/SEDIMENT SAMPLE
▲	SOIL BORING LOCATION
▭	ISM SAMPLING AREA
⊗	CHROMIUM SPECIATION SAMPLE
⊕	GEOTECHNICAL BORING

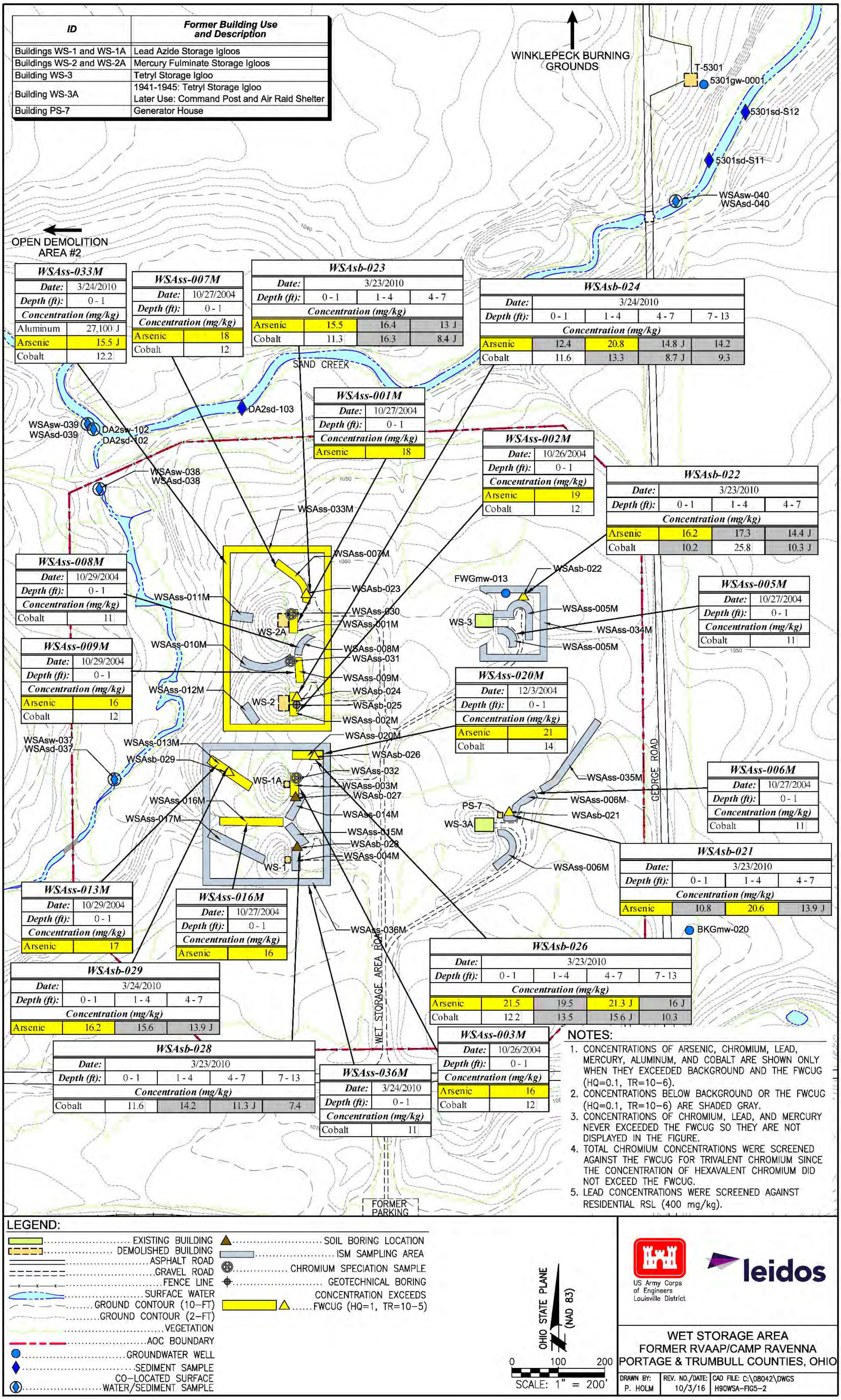
NOTES:

1. DETECTED EXPLOSIVES AND PROPELLANTS ARE SHOWN AT EACH SAMPLE LOCATION.
2. THERE WERE NO EXPLOSIVES OR PROPELLANTS DETECTED IN THE DISCRETE SOIL BORINGS.
3. THERE ARE NO EXPLOSIVES AND PROPELLANT CONCENTRATIONS THAT EXCEED THE FWCUG (HQ=1, TR=10–5).

WET STORAGE AREA
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\08042\DWGS
P. HOLM	10/3/16	H90WSA–FIG5–1

Figure 5–1. Detected Concentrations of Explosives and Propellants in Soil



ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

WSAss-033M

Date:	3/24/2010
Depth (ft):	0 - 1
Concentration (mg/kg)	
Aluminum	27,100 J
Arsenic	15.5 J
Cobalt	12.2

WSAss-007M

Date:	10/27/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Arsenic	18
Cobalt	12

WSAsb-023

Date:	3/23/2010		
Depth (ft):	0 - 1	1 - 4	4 - 7
Concentration (mg/kg)			
Arsenic	15.5	16.4	13 J
Cobalt	11.3	16.3	8.4 J

WSAsb-024

Date:	3/24/2010			
Depth (ft):	0 - 1	1 - 4	4 - 7	7 - 13
Concentration (mg/kg)				
Arsenic	12.4	20.8	14.8 J	14.2
Cobalt	11.6	13.3	8.7 J	9.3

WSAss-001M

Date:	10/27/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Arsenic	18

WSAss-002M

Date:	10/26/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Arsenic	19
Cobalt	12

WSAsb-022

Date:	3/23/2010		
Depth (ft):	0 - 1	1 - 4	4 - 7
Concentration (mg/kg)			
Arsenic	16.2	17.3	14.4 J
Cobalt	10.2	25.8	10.3 J

WSAss-008M

Date:	10/29/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Cobalt	11

WSAss-005M

Date:	10/27/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Cobalt	11

WSAss-009M

Date:	10/29/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Arsenic	16
Cobalt	12

WSAss-020M

Date:	12/3/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Arsenic	21
Cobalt	14

WSAss-006M

Date:	10/27/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Cobalt	11

WSAsb-021

Date:	3/23/2010		
Depth (ft):	0 - 1	1 - 4	4 - 7
Concentration (mg/kg)			
Arsenic	10.8	20.6	13.9 J

WSAss-013M

Date:	10/29/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Arsenic	17

WSAss-016M

Date:	10/27/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Arsenic	16

WSAsb-026

Date:	3/23/2010			
Depth (ft):	0 - 1	1 - 4	4 - 7	7 - 13
Concentration (mg/kg)				
Arsenic	21.5	19.5	21.3 J	16 J
Cobalt	12.2	13.5	15.6 J	10.3

WSAsb-029

Date:	3/24/2010		
Depth (ft):	0 - 1	1 - 4	4 - 7
Concentration (mg/kg)			
Arsenic	16.2	15.6	13.9 J

WSAsb-028

Date:	3/23/2010			
Depth (ft):	0 - 1	1 - 4	4 - 7	7 - 13
Concentration (mg/kg)				
Cobalt	11.6	14.2	11.3 J	7.4

WSAss-036M

Date:	3/24/2010
Depth (ft):	0 - 1
Concentration (mg/kg)	
Cobalt	11

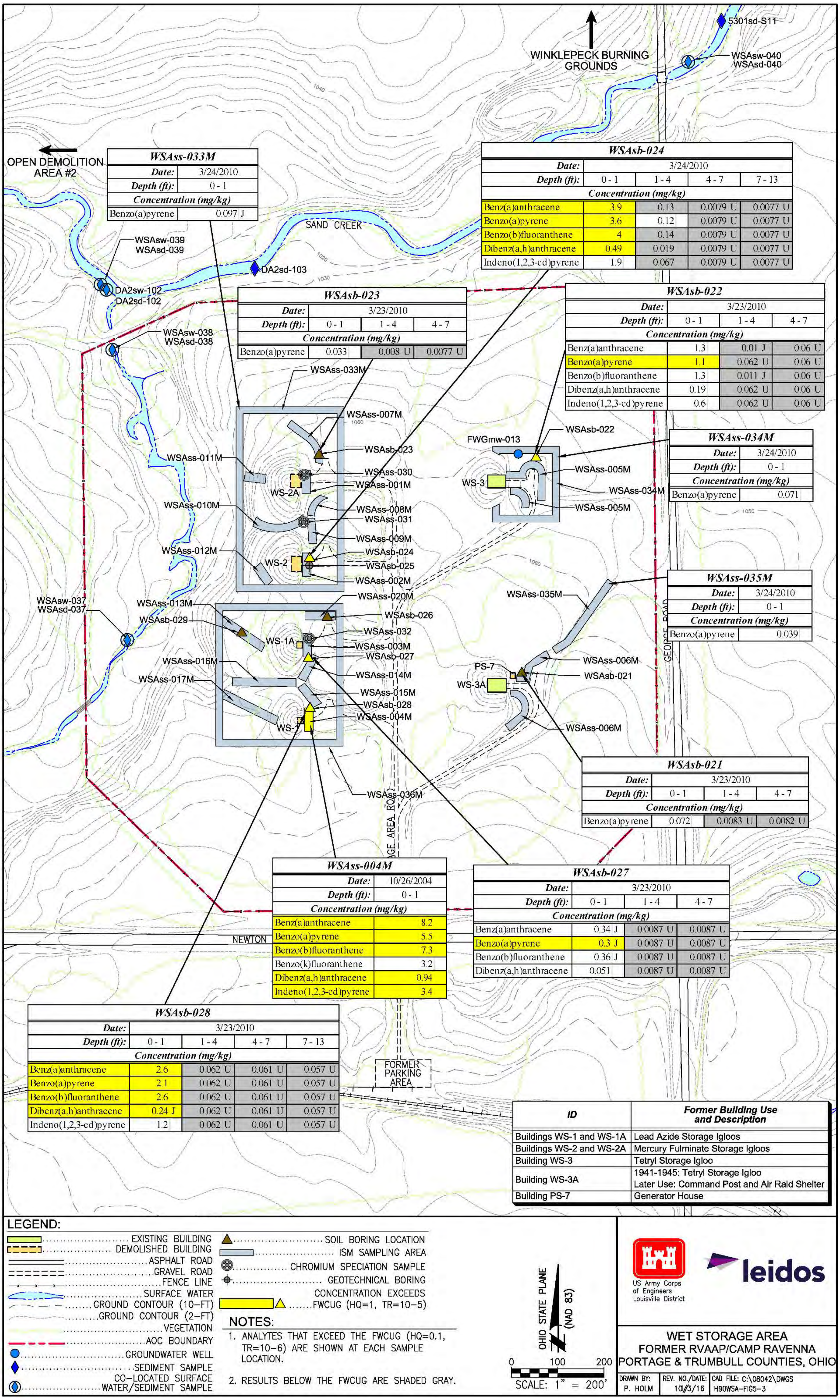
WSAss-003M

Date:	10/26/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Arsenic	16
Cobalt	12

NOTES:

1. CONCENTRATIONS OF ARSENIC, CHROMIUM, LEAD, MERCURY, ALUMINUM, AND COBALT ARE SHOWN ONLY WHEN THEY EXCEEDED BACKGROUND AND THE FWCUG (HQ=0.1, TR=10−6).
2. CONCENTRATIONS BELOW BACKGROUND OR THE FWCUG (HQ=0.1, TR=10−6) ARE SHADED GRAY.
3. CONCENTRATIONS OF CHROMIUM, LEAD, AND MERCURY NEVER EXCEEDED THE FWCUG SO THEY ARE NOT DISPLAYED IN THE FIGURE.
4. TOTAL CHROMIUM CONCENTRATIONS WERE SCREENED AGAINST THE FWCUG FOR TRIVALENT CHROMIUM SINCE THE CONCENTRATION OF HEXAVALENT CHROMIUM DID NOT EXCEED THE FWCUG.
5. LEAD CONCENTRATIONS WERE SCREENED AGAINST RESIDENTIAL RSL (400 mg/kg).

Figure 5–2. Exceedances of FWCUG (HQ of 0.1, TR of 1E-06) for Arsenic, Chromium, Lead, Mercury, Aluminum, and Cobalt in Soil



WSAss-033M

Date:	3/24/2010
Depth (ft):	0 - 1
Concentration (mg/kg)	
Benzo(a)pyrene	0.097 J

WSAsb-024

Date:	3/24/2010			
Depth (ft):	0 - 1	1 - 4	4 - 7	7 - 13
Concentration (mg/kg)				
Benz(a)anthracene	3.9	0.13	0.0079 U	0.0077 U
Benzo(a)pyrene	3.6	0.12	0.0079 U	0.0077 U
Benzo(b)fluoranthene	4	0.14	0.0079 U	0.0077 U
Dibenz(a,h)anthracene	0.49	0.019	0.0079 U	0.0077 U
Indeno(1,2,3-cd)pyrene	1.9	0.067	0.0079 U	0.0077 U

WSAsb-023

Date:	3/23/2010		
Depth (ft):	0 - 1	1 - 4	4 - 7
Concentration (mg/kg)			
Benzo(a)pyrene	0.033	0.008 U	0.0077 U

WSAsb-022

Date:	3/23/2010		
Depth (ft):	0 - 1	1 - 4	4 - 7
Concentration (mg/kg)			
Benz(a)anthracene	1.3	0.01 J	0.06 U
Benzo(a)pyrene	1.1	0.062 U	0.06 U
Benzo(b)fluoranthene	1.3	0.011 J	0.06 U
Dibenz(a,h)anthracene	0.19	0.062 U	0.06 U
Indeno(1,2,3-cd)pyrene	0.6	0.062 U	0.06 U

WSAss-034M

Date:	3/24/2010
Depth (ft):	0 - 1
Concentration (mg/kg)	
Benzo(a)pyrene	0.071

WSAss-035M

Date:	3/24/2010
Depth (ft):	0 - 1
Concentration (mg/kg)	
Benzo(a)pyrene	0.039

WSAsb-021

Date:	3/23/2010		
Depth (ft):	0 - 1	1 - 4	4 - 7
Concentration (mg/kg)			
Benzo(a)pyrene	0.072	0.0083 U	0.0082 U

WSAss-004M

Date:	10/26/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
Benz(a)anthracene	8.2
Benzo(a)pyrene	5.5
Benzo(b)fluoranthene	7.3
Benzo(k)fluoranthene	3.2
Dibenz(a,h)anthracene	0.94
Indeno(1,2,3-cd)pyrene	3.4

WSAsb-027

Date:	3/23/2010		
Depth (ft):	0 - 1	1 - 4	4 - 7
Concentration (mg/kg)			
Benz(a)anthracene	0.34 J	0.0087 U	0.0087 U
Benzo(a)pyrene	0.3 J	0.0087 U	0.0087 U
Benzo(b)fluoranthene	0.36 J	0.0087 U	0.0087 U
Dibenz(a,h)anthracene	0.051	0.0087 U	0.0087 U

WSAsb-028

Date:	3/23/2010			
Depth (ft):	0 - 1	1 - 4	4 - 7	7 - 13
Concentration (mg/kg)				
Benz(a)anthracene	2.6	0.062 U	0.061 U	0.057 U
Benzo(a)pyrene	2.1	0.062 U	0.061 U	0.057 U
Benzo(b)fluoranthene	2.6	0.062 U	0.061 U	0.057 U
Dibenz(a,h)anthracene	0.24 J	0.062 U	0.061 U	0.057 U
Indeno(1,2,3-cd)pyrene	1.2	0.062 U	0.061 U	0.057 U

ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

LEGEND:

🟩	EXISTING BUILDING
▭	DEMOLISHED BUILDING
═	ASPHALT ROAD
╌	GRAVEL ROAD
—x—x—	FENCE LINE
	SURFACE WATER
	GROUND CONTOUR (10-FT)
	GROUND CONTOUR (2-FT)
	VEGETATION
	AOC BOUNDARY
●	GROUNDWATER WELL
◆	SEDIMENT SAMPLE
	CO-LOCATED SURFACE WATER/SEDIMENT SAMPLE
▲	SOIL BORING LOCATION
▭	ISM SAMPLING AREA
⊗	CHROMIUM SPECIATION SAMPLE
⊕	GEOTECHNICAL BORING
🟨 △	CONCENTRATION EXCEEDS FWCUG (HQ=1, TR=10-5)

NOTES:

1. ANALYTES THAT EXCEED THE FWCUG (HQ=0.1, TR=10-6) ARE SHOWN AT EACH SAMPLE LOCATION.
2. RESULTS BELOW THE FWCUG ARE SHADED GRAY.

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WET STORAGE AREA
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

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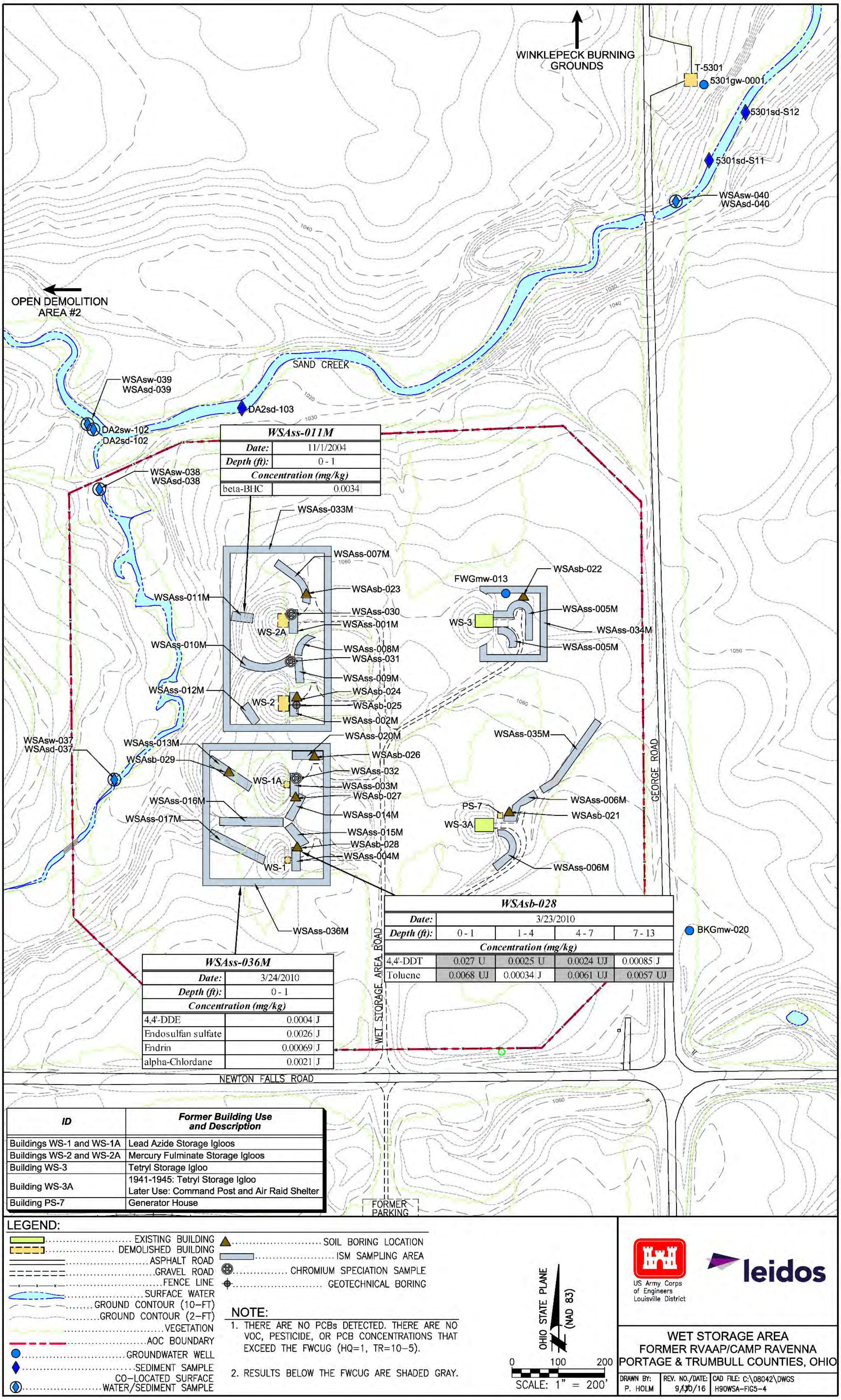
P. HOLM	10//3/16	H90WSA-FIG5-3

Figure 5–3. PAH Exceedances of FWCUG (HQ of 0.1, TR of 1E-06) in Soil



WSAss-011M	
Date:	11/1/2004
Depth (ft):	0 - 1
Concentration (mg/kg)	
beta-BHC	0.0034

WSAsb-028				
Date:	3/23/2010			
Depth (ft):	0 - 1	1 - 4	4 - 7	7 - 13
Concentration (mg/kg)				
4,4'-DDT	0.027 U	0.0025 U	0.0024 UJ	0.00085 J
Toluene	0.0068 UJ	0.00034 J	0.0061 UJ	0.0057 UJ

WSAss-036M		
Date:	3/24/2010	
Depth (ft):	0 - 1	
Concentration (mg/kg)		
4,4'-DDE	0.0004	J
Endosulfan sulfate	0.0026	J
Endrin	0.00069	J
alpha-Chlordane	0.0021	J

ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

LEGEND:

🟩	EXISTING BUILDING
▨	DEMOLISHED BUILDING
═	ASPHALT ROAD
╌	GRAVEL ROAD
—x—	FENCE LINE
~	SURFACE WATER
— —	GROUND CONTOUR (10–FT)
- - -	GROUND CONTOUR (2–FT)
—	VEGETATION
— —	AOC BOUNDARY
●	GROUNDWATER WELL
◆	SEDIMENT SAMPLE
◈	CO–LOCATED SURFACE WATER/SEDIMENT SAMPLE
▲	SOIL BORING LOCATION
▭	ISM SAMPLING AREA
⊗	CHROMIUM SPECIATION SAMPLE
⊕	GEOTECHNICAL BORING

NOTE:

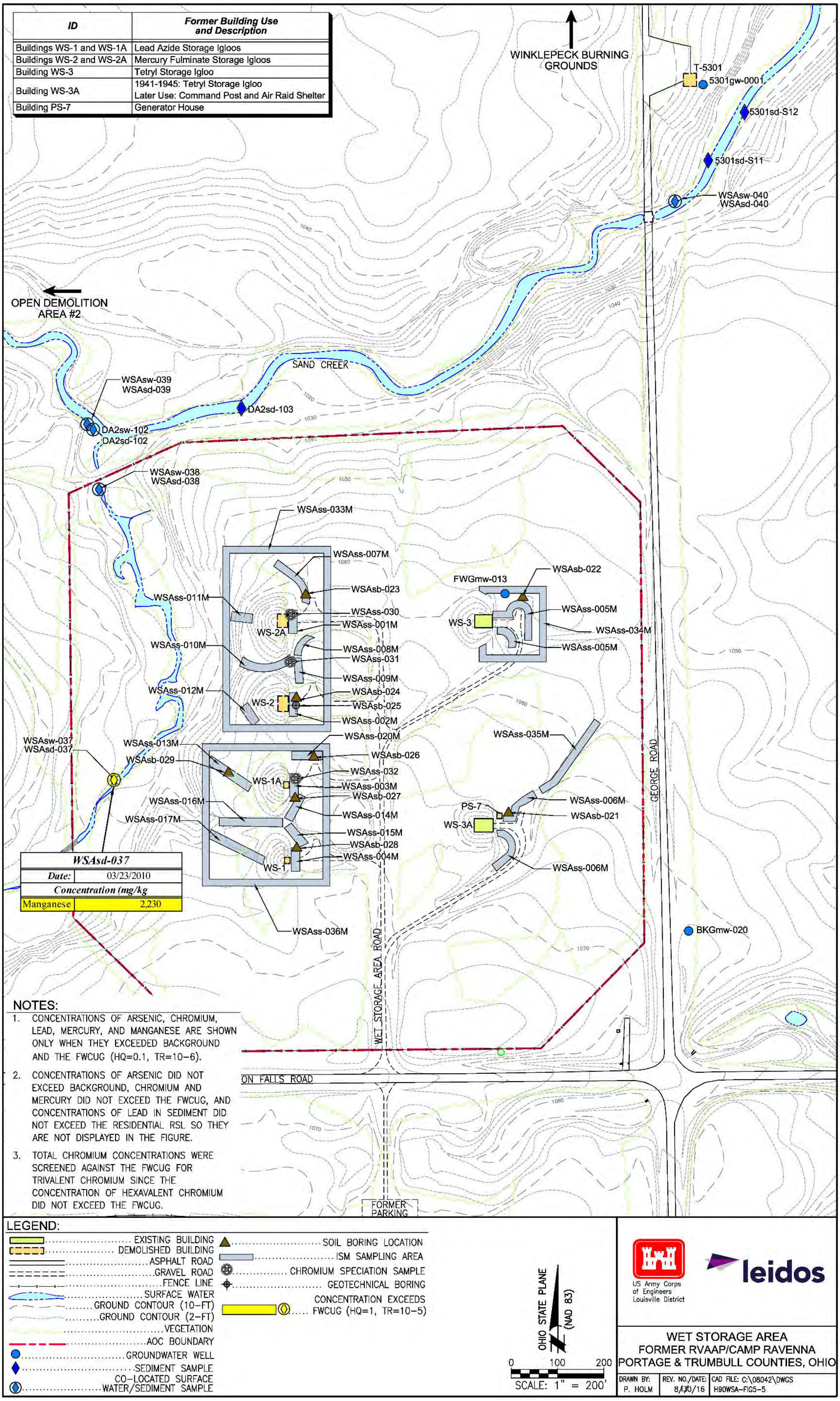
1. THERE ARE NO PCBs DETECTED. THERE ARE NO VOC, PESTICIDE, OR PCB CONCENTRATIONS THAT EXCEED THE FWCUG (HQ=1, TR=10–5).

2. RESULTS BELOW THE FWCUG ARE SHADED GRAY.

WET STORAGE AREA
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\08042\DWGS
P. HOLM	9/30/16	H90WSA–FIG5–4

Figure 5–4. Detected Concentrations of VOCs, Pesticides, and PCBs in Soil



ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

WSAsd-037	
Date:	03/23/2010
Concentration (mg/kg	
Manganese	2,230

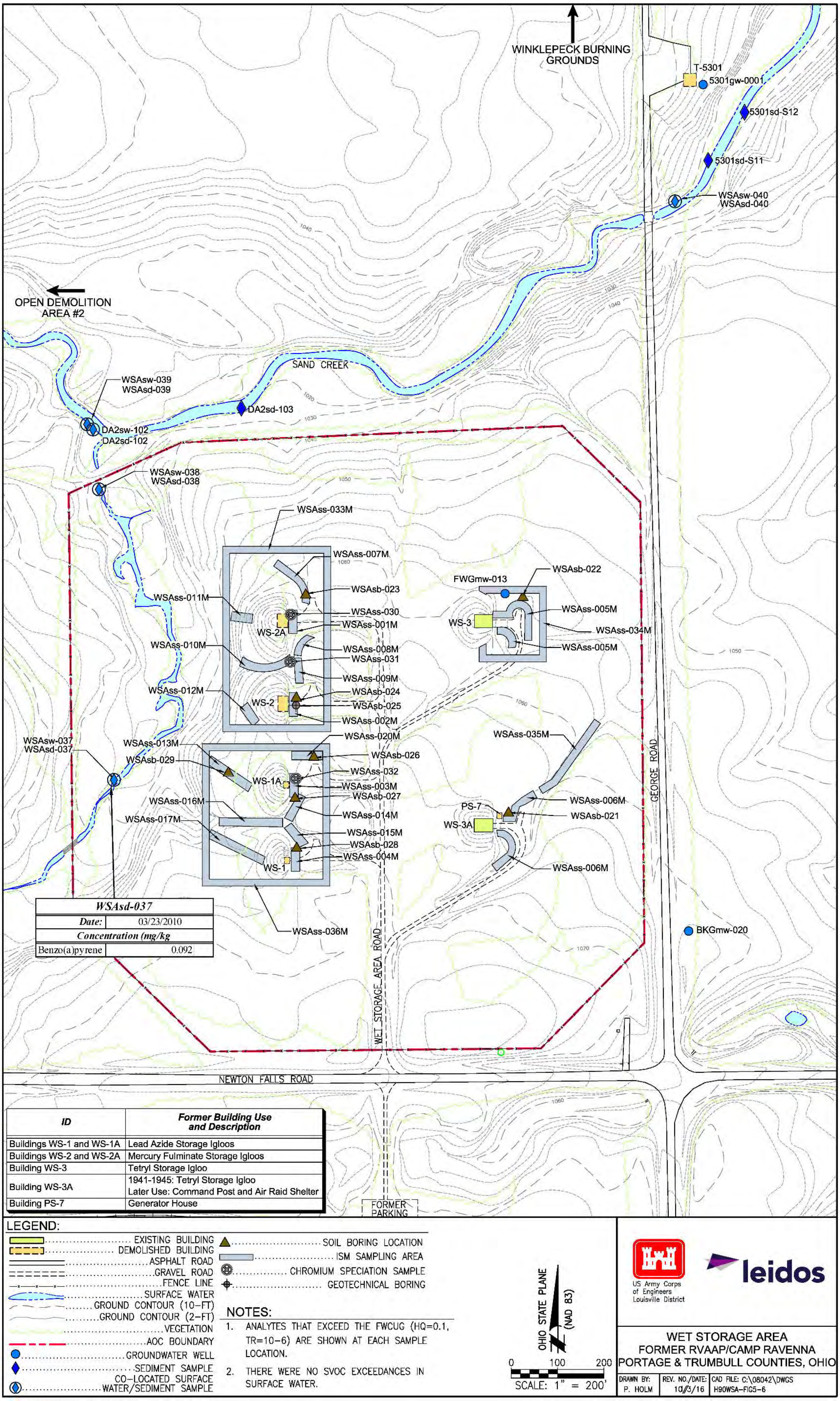
NOTES:

1. CONCENTRATIONS OF ARSENIC, CHROMIUM, LEAD, MERCURY, AND MANGANESE ARE SHOWN ONLY WHEN THEY EXCEEDED BACKGROUND AND THE FWCUG (HQ=0.1, TR=10–6).
2. CONCENTRATIONS OF ARSENIC DID NOT EXCEED BACKGROUND, CHROMIUM AND MERCURY DID NOT EXCEED THE FWCUG, AND CONCENTRATIONS OF LEAD IN SEDIMENT DID NOT EXCEED THE RESIDENTIAL RSL SO THEY ARE NOT DISPLAYED IN THE FIGURE.
3. TOTAL CHROMIUM CONCENTRATIONS WERE SCREENED AGAINST THE FWCUG FOR TRIVALENT CHROMIUM SINCE THE CONCENTRATION OF HEXAVALENT CHROMIUM DID NOT EXCEED THE FWCUG.

WET STORAGE AREA
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\08042\DWGS
P. HOLM	8/30/16	H90WSA–FIG5–5

Figure 5–5. Exceedances of FWCUG (HQ of 0.1, TR of 1E-06) for Arsenic, Chromium, Lead, Mercury, and Manganese in Surface Water and Sediment



WSAsd-037	
Date:	03/23/2010
Concentration (mg/kg	
Benzo(a)pyrene	0.092

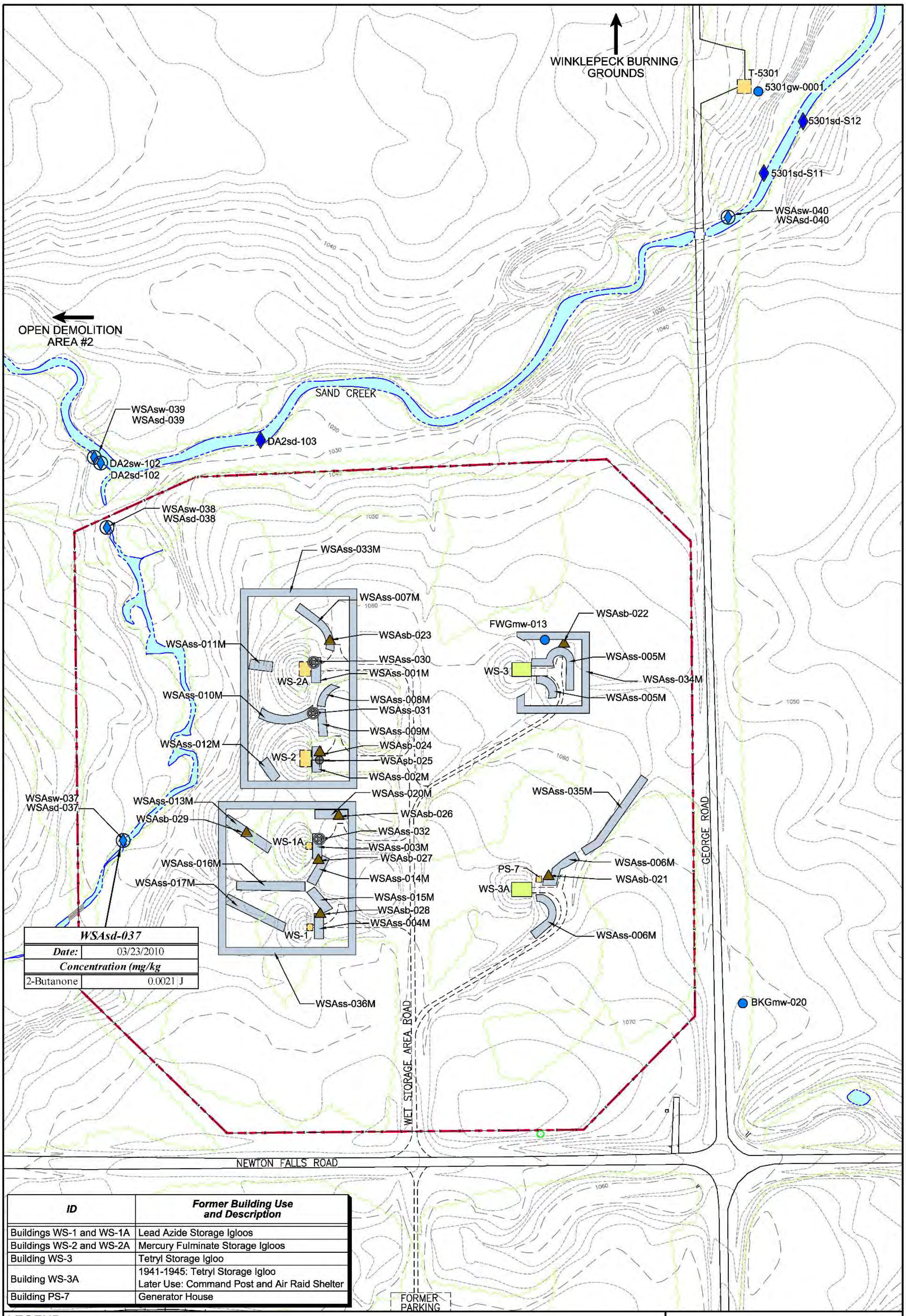
ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

NOTES:

1. ANALYTES THAT EXCEED THE FWCUG (HQ=0.1, TR=10-6) ARE SHOWN AT EACH SAMPLE LOCATION.
2. THERE WERE NO SVOC EXCEEDANCES IN SURFACE WATER.

WET STORAGE AREA
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

Figure 5–6. SVOC Exceedances of FWCUG (HQ of 0.1, TR of 1E-06) in Surface Water and Sediment



WSAsd-037	
Date:	03/23/2010
Concentration (mg/kg)	
2-Butanone	0.0021 J

ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

LEGEND:

🟩	EXISTING BUILDING
🟧	DEMOLISHED BUILDING
═	ASPHALT ROAD
╍	GRAVEL ROAD
—x—x—	FENCE LINE
▭	SURFACE WATER
— —	GROUND CONTOUR (10–FT)
- - -	GROUND CONTOUR (2–FT)
┈	VEGETATION
▬ ▬	AOC BOUNDARY
●	GROUNDWATER WELL
◆	SEDIMENT SAMPLE
◈	CO–LOCATED SURFACE WATER/SEDIMENT SAMPLE
▲	SOIL BORING LOCATION
▭	ISM SAMPLING AREA
⊗	CHROMIUM SPECIATION SAMPLE
⌖	GEOTECHNICAL BORING

NOTES:

1. THERE ARE NO PESTICIDES OR PCBs DETECTED. THERE ARE NO VOC, PESTICIDE, OR PCB CONCENTRATIONS THAT EXCEED THE FWCUG (HQ=1, TR=10–5).
2. THERE ARE NO VOC, PESTICIDE, OR PCB DETECTIONS IN SURFACE WATER.

OHIO STATE PLANE (NAD 83)

0 100 200

SCALE: 1" = 200'

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WET STORAGE AREA
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\08042\DWGS
P. HOLM	10/3/16	H90WSA–FIG5–7

Figure 5–7. Detected Concentrations of VOCs, Pesticides, and PCBs in Surface Water and Sediment

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6.0 CONTAMINANT FATE AND TRANSPORT

Contaminant fate and transport modeling assesses the potential for SRCs to leach from surface soil, subsurface soil, and sediment sources at Wet Storage Area and impact groundwater beneath the sources and downgradient receptor locations. Modeling results were included in the decision-making process to determine whether performing remedial actions may be necessary to protect groundwater resources. Surface water exposure pathways are evaluated in the HHRA and ERA presented in Sections 7.2 and 7.3, respectively. A summary of the principles of contaminant fate and transport are presented in this section along with the results of the modeling.

Section 6.1 describes physical and chemical properties of SRCs found in soil and sediment at the AOC. Section 6.2 presents a conceptual model for contaminant fate and transport that considers AOC topography, hydrogeology, contaminant sources, and release mechanisms. Section 6.3 presents a soil screening analysis, and Section 6.4 presents a sediment screening analysis to identify the SRCs with the potential to migrate from soil and sediment to groundwater as initial CMCOPCs. Section 6.5 describes fate and transport modeling of final CMCOPCs and presents CMCOCs. Section 6.6 provides an evaluation of the identified CMCOPCs to identify the final CMCOCs. Section 6.7 presents the summary and conclusions of this fate and transport analysis.

6.1 PHYSICAL AND CHEMICAL PROPERTIES OF SITE-RELATED CONTAMINANTS

The major contaminants of the former RVAAP are TNT, composition B, sulfates, nitrates, lead styphnate, and lead azide. Additional site-specific contaminants at Wet Storage Area include various explosives and propellants, heavy metals (arsenic, chromium, lead, and mercury), and PAHs from Generator House PS-7.

The evaluation of contaminant fate and transport not only includes chemicals identified as potential contaminants from previous use but also includes chemicals that were evaluated as part of the overall RI. The comprehensive list of surface and subsurface soil SRCs (15 inorganic chemicals and 32 organic chemicals) and sediment SRCs (5 inorganic chemicals and 15 organic chemicals) were detailed in Section 4.0 and are summarized below:

- Inorganic SRCs in surface and subsurface soil: aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc.
- Inorganic SRCs in sediment: antimony, beryllium, cadmium, manganese, and silver.
- Organic SRCs in surface and subsurface soil: 2-methylnaphthalene; acenaphthene; acenaphthylene; anthracene; benz(a)anthracene; benzenemethanol; benzo(a)pyrene; benzo(b)fluoranthene; benzo(ghi)perylene; benzo(k)fluoranthene; bis(2-ethylhexyl)phthalate; carbazole; chrysene; di-n-butyl phthalate; dibenz(a,h)anthracene; dibenzofuran; fluoranthene; fluorene; indeno(1,2,3-cd)pyrene; naphthalene; phenanthrene; phenol; pyrene; 3-nitrotoluene; nitrocellulose; toluene; 4,4'-DDE; 4,4'-DDT; endosulfan sulfate; endrin; alpha-chlordane; and beta-BHC.

- Organic SRCs in sediment: 2-methylnaphthalene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene, and 2-butanone.

Chemicals released into the environment are susceptible to several degradation pathways, including hydrolysis, oxidation, reduction, isomerization, photolysis, photo-oxidation, biotransformation, and biodegradation. Transformed products resulting from these processes may behave differently than their parent chemical in the environment.

The migration of chemicals is governed by their physical and chemical properties and the surface and subsurface media through which chemicals are transferred. In general, chemicals and structures with similar physical and chemical characteristics will show similar patterns of transformation, transport, or attenuation in the environment. Solubility, vapor pressure data, chemical partitioning coefficients, degradation rates, and Henry's Law Constant (HLC) provide information that can be used to evaluate contaminant mobility in the environment. Partitioning coefficients are used to assess relative affinities of chemicals for solution or solid phase adsorption. However, the synergistic effects of multiple migrating chemicals and complexity of soil/water interactions, including pH and oxidation-reduction potential, grain size, and clay mineral variability, are typically unknown.

The physical properties of the chemicals defined as SRCs in surface and subsurface soil and sediment are summarized in Appendix E, Tables E-1 and E-2. These properties are used to assess the anticipated behavior of each chemical under environmental conditions. The physical properties of the chemicals defined as SRCs detected in soil and sediment are summarized in Sections 6.1.1 through 6.1.5.

6.1.1 Chemical Factors Affecting Fate and Transport

The water solubility of a chemical is a measure of the saturated concentration of the chemical in water at a given temperature and pressure. The tendency for a chemical to be transported by groundwater is directly related to its solubility and inversely related to its tendencies to adsorb to soil and volatilize from water (OGE 1988). Chemicals with high water solubilities tend to desorb from soil, are less likely to volatilize from water, and are susceptible to biodegradation. The water solubility of a chemical varies with temperature, pH, and the presence of other dissolved chemicals (including organic carbon and humic acids).

The octanol-water partition coefficient (K_{ow}) can be used to estimate the tendency for a chemical to partition between environmental phases of different polarity. The K_{ow} is a laboratory-determined ratio of the concentration of a chemical in the n-octanol phase of a two-phase system to the concentration in the water phase. Chemicals with log K_{ow} values less than one are highly hydrophilic, while chemicals with log K_{ow} values greater than four will partition to soil particles (Lyman et al. 1990).

The water/organic carbon partition coefficient (K_{oc}) is a measure of the tendency of an organic chemical to partition between water and organic carbon in soil. The K_{oc} is defined as the ratio of the absorbed chemical per unit weight of organic carbon to the aqueous solute concentration. This coefficient can be used to estimate the degree to which an organic chemical will adsorb to soil and thus not migrate with groundwater. The higher the K_{oc} value, the greater is the tendency of the chemical to partition into soil (OGE 1988). The soil/water partitioning coefficient (K_d) is calculated by multiplying the K_{oc} value by the fraction of organic carbon in the soil.

Vapor pressure is a measure of the pressure at which a chemical and its vapor are in equilibrium. The value can be used to determine the extent to which a chemical would travel in air, as well as the rate of volatilization from soil and solution (OGE 1988). In general, chemicals with vapor pressures lower than 10^{-7} mm mercury will not be present in the atmosphere or air spaces in soil in significant amounts, while chemicals with vapor pressures higher than 10^{-2} mm mercury will exist primarily in the air (Dragun 1988).

The HLC value for a chemical is a measure of the ratio of the chemical's vapor pressure to its aqueous solubility. The HLC value can be used to make general predictions about a chemical's tendency to volatilize from water. Chemicals with HLC values less than 10^{-7} atm-m^3/mol will generally volatilize slowly, while chemicals with a HLC greater than 10^{-3} atm-m^3/mol will volatilize rapidly (Lyman et al. 1990).

6.1.2 Biodegradation

Organic chemicals with differing chemical structures will biodegrade at different rates. Primary biodegradation consists of any biologically induced structural change in an organic chemical. Complete biodegradation is the biologically mediated degradation of an organic chemical into carbon dioxide, water, oxygen, and other metabolic inorganic products (Dragun 1988). The first order biodegradation rate of an organic chemical is proportional to the concentration:

$$-dC/dt = kC \qquad \text{(Equation 6-1)}$$

Where:

C = concentration
t = time
k = biodegradation rate constant = ln 2 / $t_{1/2}$
$t_{1/2}$ = biodegradation half-life

The biodegradation half-life is the time necessary for half of the chemical to degrade. The biodegradation rate of an organic chemical generally depends on the presence and population size of soil microorganisms that are capable of degrading the chemical.

6.1.3 Inorganic Chemicals

Inorganic chemicals detected in soil and sediment samples are associated with the aqueous phase and leachable metal ions on soil particles. The transport of this material from unsaturated soil to the underlying water table is controlled by the physical processes of precipitation percolation, chemical interaction with the soil, and downward transport of metal ions by continued percolation. The chemistry of inorganic chemical interactions with percolating precipitation and varying soil conditions is complex and includes numerous chemical transformations that may result in altered oxidation states, including ion exchange, adsorption, precipitation, or complexation. The chemical reactions, which are affected by environmental conditions (i.e., pH, oxidation-reduction conditions, type and amount of organic matter, clay content, and the presence of hydrous oxides), may act to enhance or reduce the mobility and toxicity of metal ions. In general, these reactions are reversible and add to the variability commonly observed in distributions of inorganic chemicals in soil.

The chemical form of an inorganic chemical determines its solubility and mobility in the environment; however, chemical speciation is complex and difficult to delineate in routine laboratory analysis. Inorganic chemicals in soil are commonly found in several forms, including dissolved concentrations in soil pore water, metal ions occupying exchange sites on inorganic soil constituents (adsorbed to inorganic soil constituents), metal ions associated with insoluble organic matter, precipitated inorganic chemicals as pure or mixed solids, and metal ions present in the structure of primary or secondary minerals.

The dissolved (aqueous) fraction and its equilibrium sorbed fraction are important when considering the migration potential of inorganic chemicals through soil. Of the inorganic chemicals that are likely to form, chlorides, nitrates, and nitrites are commonly the most soluble. Sulfate, carbonate, and hydroxides generally have low to moderate solubility. Soluble chemicals are transported in aqueous forms subject to attenuation, whereas less soluble chemicals remain as a precipitate and limit the overall dissolution of metal ions. The solubility of the metal ions is also regulated by ambient chemical conditions, including pH and oxidation/reduction.

The attenuation of metal ions in the environment can be estimated numerically using the retardation factor (R), dispersion in higher flow systems (high conductivity environments), and diffusion in low conductivity environments. R defines the extent to which the velocity of the contaminant is slowed, which is largely derived from the K_d. R is calculated using the following equation:

$$R = 1 + (K_d \rho_b)/ \theta_w \qquad \text{(Equation 6-2)}$$

Where:

ρ_b = the soil bulk dry density (g/cm^3)
θ_w = soil moisture content (dimensionless)

Metal ion concentrations in the environment do not attenuate by natural or biological degradation because of low volatility and solubility of the ions. Inorganic chemicals may be biotransformed or bioconcentrated through microbial activity.

6.1.4 Organic Chemicals

Organic chemicals such as SVOCs or VOCs, may be transformed or degraded in the environment by processes including hydrolysis, oxidation/reduction, photolysis, volatilization, biodegradation, or biotransformation. The half-life of organic chemicals in transport media can vary from minutes to years, depending on environmental conditions and chemical structures. Some types of organic chemicals are very stable, and degradation rates can be very slow. Organic degradation may either enhance (by producing more toxic byproducts) or reduce (reducing concentrations) the toxicity of a chemical in the environment.

6.1.5 Explosives-Related Chemicals

Explosives-related chemicals 3-nitrotoluene and nitrocellulose were detected in soil at Wet Storage Area. Nitrocellulose is an aliphatic nitrate ester that will gelatinize when mixed together with nitroglycerin. Nitrocellulose occurs as a fibrous solid that can act as a sorbent that will dissolve in water under highly basic conditions with high temperatures. Nitrocellulose can undergo denitrification as a degradation pathway. Degradation of nitrocellulose to non-reactive nitrocellulose has been observed under methanogenic and fungus-mediated reducing conditions (USACE 2006). Although nitrotoluenes are much more resistant to biodegradation, 3-nitrotoluene can serve as a growth substrate for bacteria and is a good candidate for bioremediation. 3-Nitrotoluene was shown to transform in a stepwise reaction into 3-nitrobenzyl alcohol, 3-nitrobenzaldehyde, 3-nitrobenzoate, and finally, 3-nitrophenol (Sadat et al. 1995).

6.2 CONCEPTUAL MODEL FOR FATE AND TRANSPORT

The CSM, which defines the framework for fate and transport modeling, describes conditions at Wet Storage Area, including the contaminant sources, surficial and subsurface hydrogeologic conditions, contaminant migration and pathways, and contaminant release mechanisms.

AOC conditions described in Sections 2.0 through 5.0 include contaminant source information, the surrounding geologic and hydrologic conditions, and the magnitude of SRCs and their current spatial distribution. Information from Section 3.0 and the nature and extent evaluation in Section 5.0 were used to develop the CSM for fate and transport modeling by identifying SRCs and migration pathways. The CSM is based on information and data collected for historical investigations, this RI Report, and informed assumptions about the AOC. Assumptions contained in the CSM are reiterated throughout this section. The better the information and the greater the accuracy of the assumptions, the more accurately the CSM describes the AOC, and therefore, the more reliable the fate and transport modeling predictions can be. A summary of the salient elements of the CSM that apply to fate and transport modeling are summarized in the following sections.

6.2.1 Contaminant Sources

No primary contaminant sources are located on the AOC. Remnant infrastructure within the eastern part of Wet Storage Area consists of refurbished and maintained igloos WS-3 and WS-3A. Secondary sources (contaminated soil) identified in previous investigations are further evaluated in this report. Another potential secondary source of contamination at the AOC is contaminated sediment, which if deposited adjacent to a stream/ditch during a storm event, has potential to leach contaminants to the groundwater.

6.2.2 Hydrogeology

A description of regional and AOC-specific geology and hydrology are provided in Sections 3.3.3 and 3.4.2, respectively, and are summarized below.

- The topography at Wet Storage Area varies with the elevation across the AOC ranging from approximately 1,028–1,077 ft amsl. The eastern portion of the AOC slopes slightly to the north by northeast. The topography in the western portion of the AOC slopes west to an unnamed tributary to Sand Creek (Figure 3-1). Surface water drainage associated with heavy rainfall events follows the topography and drains along ditches to the west, north, and northwest. Surface water west of the former igloos flows towards the unnamed tributary that flows north into Sand Creek that flows northeast.
- Soil beneath the AOC consists of the Mahoning silt loam, which is a gently sloping, poorly-drained soil formed in silty clay loam or clay loam glacial till, generally where bedrock is greater than 6 ft bgs. The Mahoning silt loam has low permeability, rapid runoff, and seasonal wetness.
- Because there are only two bedrock groundwater monitoring wells installed at the AOC, an AOC-specific potentiometric surface could not be generated; therefore, hydraulic gradients and flow directions for the AOC are based on the regional potentiometric surface as presented in Figure 3-4.
- The water table in the unconsolidated zone occurs at approximately 10–20 ft bgs (1,050 ft amsl) as is shown in the facility-wide potentiometric surface map (EQM 2010).

6.2.3 Contaminant Release Mechanisms and Migration Pathways

Based on the information presented above, the following contaminant release mechanisms and migration pathways have been identified at the AOC:

- Contaminant leaching from soil to the water table (vertical migration) and lateral transport to a downgradient receptor (i.e., Sand Creek and north of Wet Storage Area);
- Contaminated sediment transported to potential downstream receptors;
- Contaminated surface water migrating to potential downstream receptors;
- Contaminated sediment within wet ditches deposited on ditch banks as a secondary source of leaching to the water table (vertical migration) and lateral transport to potential downgradient receptors; and
- Contaminated sediment at the bottom of surface water bodies, assuming equilibrium with groundwater, and mixing with surface water based on a calculated, sample-specific dilution attenuation factor (DAF).

The first of these pathways, which considers a primary groundwater transport pathway, is treated explicitly in this fate and transport section. Sediment and surface water exposure pathways are evaluated in the HHRA and ERA presented in Sections 7.2 and 7.3, respectively. The fourth and fifth pathways listed above, which consider a secondary groundwater transport pathway and a primary groundwater transport pathway, respectively, are evaluated using the sediment screening analysis presented in Section 6.4.

One of the principal migration pathways at the AOC is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). However, because of the very heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within unconsolidated soil are difficult to predict. Precipitation that does not leave the AOC as surface runoff percolates into the subsurface. Some of the percolating water leaves this environment via evapotranspiration after little or no vertical migration.

The remainder of the water percolates into the water table. As discussed in Section 6.2.4, the rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Figure 6-1 illustrates the contaminant migration conceptual model.

Once the contaminant leachate percolates through the soil and reaches the water table, it migrates with the local groundwater and discharges at the downgradient receptor location. Groundwater flow likely occurs along preferential pathways (e.g., sand seams, channel deposits, or other stratigraphic discontinuities) having higher permeabilities. For inorganic chemicals, lateral migration through groundwater will be very limited due to their high retardation by the bedrock material (USACE 2003b).

Additional factors that affect the leaching rate include a chemical's solubility, sorption capacity (expressed by the K_d), and the amount of percolation. Insoluble chemicals will precipitate out of the solution in the subsurface or remain in insoluble forms with little leaching.

Another factor that affects whether a chemical will reach the water table through percolation of precipitation is the chemical's rate of decay. Most organic compounds decay at characteristic rates proportional to the chemical's half-life. For a given percolation rate, those chemicals with long half-lives have a greater potential for contaminating groundwater than those with shorter half-lives. For this analysis, the rate of decay/half-life was not considered.

Contaminant releases through gaseous emissions and airborne particulates are not significant at Wet Storage Area. The AOC is vegetated, located in a humid temperate climate, and soil moisture is typically high, which prevents dust borne contaminant migration. Therefore, there is likely little to no gaseous emission, and contaminant levels in the air pathway are minor to nonexistent.

6.2.4 Water Budget

The potential for contaminant transport begins with precipitation. Percolation is the driving mechanism for soil contaminants leaching to groundwater. The actual amount of rainwater available for flow and percolation to groundwater is highly variable and depends upon soil type and climatic conditions. A water balance calculation can be used as a tool to quantitatively account for all components of the hydrologic cycle. The quantified elements of the water balance are used for inputs to the soil leaching and groundwater transport models discussed later. The components of a simple steady-state water balance model include precipitation, evapotranspiration, surface runoff, and groundwater recharge or percolation.

These terms are defined as follows:

$$P = ET + Sr + q \qquad \text{(Equation 6-3)}$$

or

$$\text{Rainwater available for flow} = Sr + q = P - ET \qquad \text{(Equation 6-4)}$$

Where:

P = precipitation
Sr = surface runoff
ET = evapotranspiration
q = groundwater recharge or percolation

It is expected that loss of runoff also occurs in the form of evaporation. The remaining water, after runoff and evaporation, is available for percolation, which includes loss to the atmosphere by evapotranspiration. The water balance estimations were developed using the Hydrologic Evaluation of Landfill Performance (HELP) model (USEPA 1994a). See Appendix E, Table E-3 for parameters used in the HELP model to develop the water budget estimates used in the evaluation. Calculations using precipitation and temperature data for a 100-year period were generated synthetically using coefficients for Cleveland, Ohio (e.g., the nearest weather station to Camp Ravenna with HELP model coefficients).

The annual average water balance estimates indicate an evapotranspiration of 28% (10.3 inches) of total precipitation (37 inches). The remaining 72% (26.7 inches) of rainwater is available for surface water runoff and percolation to groundwater. Of the 72% (27 inches) of water available for runoff or percolation, groundwater recharge (percolation) accounts for 13% (3.6 inches), and surface runoff (along downgradient topography to nearest surface water bodies) accounts for the remaining 87% (23.1 inches).

6.3 SOIL SCREENING ANALYSIS

Soil screening analyses are screening evaluations performed to identify SRCs with the potential to leach to groundwater as CMCOPCs. The five steps for the soil leachability analysis are illustrated in Figure 6-2.

6.3.1 Soil Screening Analysis

The first step of the soil screening analysis is developing SRCs, as presented in Section 4.0. A summary of SRCs identified for soil and sediment is presented in Section 6.1.

The second step of the soil screening process (Figure 6-2) involves comparing maximum concentrations of SRCs with MCL-based generic soil screening levels (GSSLs). GSSLs were developed for Superfund sites for contaminant migration to groundwater (USEPA 1996a, USEPA 2015). The GSSL is defined as the concentration of a chemical in soil that represents a level of contamination below which there is no concern for impacts to groundwater under CERCLA, provided conditions associated with USEPA risk-based soil screening levels (SSLs) are met. Generally, if chemical concentrations in soil fall below the GSSL, and there are no groundwater receptors of concern or anticipated exposures, then no further study or action is warranted for that chemical. If the GSSL for a chemical is not available, the USEPA risk-based SSL for groundwater migration, dated June 2015 (USEPA 2015), will be obtained from the USEPA RSL website and used. If neither the GSSL nor the USEPA risk-based SSL for a chemical are available, then no further evaluation of the chemical is performed and it is eliminated from the list of initial CMCOPCs. However, some chemicals have been assigned surrogates by risk assessors if the chemical without an SSL is similar to another chemical with an SSL. Surrogates used for this analysis include acenaphthene for acenaphthylene and pyrene for benzo(ghi)perylene and phenanthrene.

The initial CMCOPC screen, as presented in Appendix E, Table E-4, eliminates 7 inorganic chemicals and 19 organic chemicals from further consideration. A total of 8 inorganic and 13 organic SRCs exceeded their GSSLs and were carried forward to the next screening step.

The third step of the soil screening process (Figure 6-2) involves comparing the maximum chemical concentrations with the site-specific soil screening levels (SSSLs). The SSSL is defined as the GSSL (or the USEPA risk-based SSL for groundwater protection if a GSSL is not available) multiplied by the AOC-specific DAF. Direct partitioning is used to derive GSSLs, assuming groundwater is in contact with the chemicals in soil and the groundwater concentration is equal to the leachate concentration. However, as leachate moves through soil, chemical concentrations are attenuated by adsorption and degradation. When the leachate reaches the water table, dilution by groundwater further reduces leachate concentrations. This concentration reduction can be expressed by a DAF. DAFs can vary based on AOC-specific characteristics (e.g., hydrogeologic properties, contaminated source area, and depth to contamination). As described in the *Soil Screening Guidance: Technical Background Document* (USEPA 1996a), chemical dilution in groundwater is estimated at each AOC from an AOC-specific DAF. The DAF, which is defined as the ratio of soil leachate concentration to receptor point concentration, is minimally equal to one. Dilution in groundwater is derived from a simple mixing zone equation (Equation 6-5) and relies upon estimating the mixing zone depth (Equation 6-6).

$$\mathrm{DAF} = 1 + \frac{(\mathrm{K} \times i \times \mathrm{d})}{(\mathrm{q} \times \mathrm{L})} \qquad \text{(Equation 6-5)}$$

Where:

DAF = dilution attenuation factor
K = aquifer hydraulic conductivity (m/yr)
i = horizontal hydraulic gradient (m/m)
q = percolation rate (m/yr)
L = source length parallel to groundwater flow (m)
d = mixing zone depth (m) (which is defined below)

$$d = \sqrt{0.0112 \times L^2} + d_a \times \left[1 - \exp\left(\frac{-L \times I}{K \times i \times d_a} \right) \right] \qquad \text{(Equation 6-6)}$$

Where:

d_a = aquifer thickness (m)
$d \leq d_a$

As stated above, if the aquifer thickness is less than the calculated mixing zone depth, then the aquifer thickness is used for “d” in the DAF calculation. The DAF calculation for the AOC is presented in Appendix E, Table E-5. It should be noted that the purpose of this screen is not to identify the chemicals that may pose risk at downgradient locations, but to target those chemicals that pose the greatest problem if they migrate from the AOC.

Based on this screening and an AOC-specific DAF of 5.4, barium, nickel, selenium, thallium, benzenemethanol, dibenzofuran, and pyrene were eliminated from further consideration. All the remaining SRCs exceeded their published or calculated GSSL multiplied by the respective DAF and were identified as initial CMCOPCs, based on leaching to groundwater. The SRCs identified as initial CMCOPCs are presented in Appendix E, Table E-6.

The fourth step of the soil screening process (Figure 6-2) involves eliminating initial CMCOPCs identified in the SSSL evaluation from further consideration that require more than 1,000 years to leach through the unsaturated zone before reaching the water table. A period of 1,000 years was conservatively selected to evaluate eventual migration of the contaminant front to the water table despite uncertainties in vadose zone hydraulic parameters and groundwater recharge over time. Additionally, USACE suggests a screening value of 1,000 years be used due to the high uncertainty associated with predicting conditions beyond that time frame (USACE 2003b). Therefore, the initial CMCOPCs at the selected sources were screened against a travel time of greater than 1,000 years. The travel time in this screen is the time required for a CMCOPC to migrate vertically from the base of the soil interval detected above the background concentration to the water table. This distance is the leaching zone, which is evaluated in Appendix E, Table E-7, which may vary across the AOC based on the varying depths of soil sample concentrations above the facility-wide background concentrations and the elevation of the water table.

The estimated travel time for each initial CMCOPC to reach the water table is determined using the following equations:

$$T = \frac{Lz \times R}{V_p} \qquad \text{(Equation 6-7)}$$

Where:

T = leachate travel time (year)
Lz = thickness of attenuation zone (ft)
R = retardation factor (dimensionless) (Equation 6-2)
V_p = porewater velocity (ft/year)

and

$$V_p = \frac{q}{\theta_w} \qquad \text{(Equation 6-8)}$$

Where:

q = percolation rate (ft/year)
θ_w = fraction of total porosity that is filled by water

If the travel time for a chemical from a source area exceeded 1,000 years, then the chemical was eliminated from the list of initial CMCOPCs. Seven inorganic and seven organic SRCs were eliminated from further consideration based on their travel times exceeding 1,000 years. Initial CMCOPCs with travel times less than 1,000 years were retained for further evaluation (Appendix E, Table E-7). The constituents selected for further evaluation with Seasonal Soil Compartment Model (SESOIL) are listed in Table 6-1.

In the fifth step (Figure 6-2), the initial CMCOPCs (presented in Table 6-1) were further evaluated using fate and transport models provided in Section 6.5.

6.3.2 Limitations and Assumptions of Soil Screening Analysis

It is important to recognize that acceptable soil concentrations for individual chemicals are highly AOC-specific. The GSSLs used in this screening are based on a number of default assumptions chosen to be protective of human health for most AOC conditions (USEPA 1996a). These GSSLs are expected to be more conservative than SSSLs based on AOC conditions. The conservative assumptions included in this analysis are: (1) no adsorption in the unsaturated zone or in the aquifer, (2) no biological or chemical degradation in the soil or aquifer, and (3) contamination is uniformly distributed throughout the source. However, the GSSL does not incorporate the contamination already existing within the aquifer.

6.4 SEDIMENT SCREENING ANALYSIS

Sediment SRCs were developed in Section 4.0 and are presented in Section 6.1. The purpose of this screening analysis is to identify the CMCOPCs based on contaminant migration from sediment to groundwater. Any identified CMCOPCs are modeled with Analytical Transient 1-, 2-, 3-Dimensional

(AT123D) model to a downgradient receptor if present. The four steps for the sediment screening analysis are illustrated in Figure 6-3.

Sediment SRCs were screened by developing leachate concentrations assuming equilibrium between sediment and groundwater. The predicted leachate concentrations are generally diluted based on a sample-specific DAF, which is calculated by dividing the calculated leachate concentrations by the co-located surface water concentrations. The resulting groundwater concentrations were compared against the groundwater screening criteria to develop sediment CMCOPCs. However, DAFs could not be calculated for Wet Storage Area because none of the chemicals that were detected in sediment and surface water were co-located. Therefore, to be conservative, a DAF of 1 was applied, indicating that there is no dilution (Table 6-2). This sediment screening analysis assumed that the sediment concentration and the recharging groundwater concentration were in equilibrium and that there was no dilution in groundwater. Based on this screening analysis (see Table 6-2), 4 inorganic SRCs (antimony, beryllium, cadmium, and silver) and 12 organic SRCs [3-methylnaphthalene, acenaphthylene, anthracene, benzo(a)pyrene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, and 2-butanone] were eliminated from further evaluation. One inorganic SRC (manganese) and three organic SRCs [benz(a)anthracene, benzo(b)fluoranthene, and naphthalene] were identified as sediment CMCOPCs and were evaluated with the AT123D model described in Section 6.5.

6.5 FATE AND TRANSPORT MODELING

Contaminant fate and transport modeling represents the fifth step in the fate and transport screening and evaluation process (Figure 6-2). SESOIL modeling was performed for chemicals identified as initial CMCOPCs from the soil screening analysis presented in Section 6.3 and summarized in Table 6-1. SESOIL modeling was performed to predict chemical concentrations in the leachate immediately beneath the selected source areas and just above the water table. If the predicted maximum leachate concentration of an initial CMCOPC was higher than the facility-wide background concentration and the lowest risk-based screening value (Resident Receptor Adult FWCUG, MCL, or RSL), the CMCOPC was further evaluated using the AT123D model to predict future maximum concentrations in groundwater beneath the source, as well as at downgradient receptor locations, if applicable. The downgradient receptor location (if required) is the closest surface water body feature downgradient from the source areas that is connected to the groundwater. The predicted CMCOPC concentrations in groundwater beneath the source were compared to available groundwater monitoring results for the AOC to validate modeling results and provide WOE for identifying or eliminating CMCOCs.

6.5.1 Modeling Approach

Contaminant transport includes the movement of water and dissolved material from the source areas to groundwater. This occurs as rainwater infiltrates the surface and percolates through the area of contamination, its surrounding soil, and into the saturated zone. The downward movement of water, driven by gravitational potential, capillary pressure, and other components of total fluid potential, mobilizes the contaminants and carries them through the soil into the mixing zone with the water table. Lateral transport within the unconsolidated zone is controlled by the groundwater gradient. Vertical transport (evaluated with SESOIL) through the overburden to the water table and horizontal transport (evaluated with AT123D) through the unconsolidated zone to downgradient receptor locations are illustrated in Figure 6-1.

The output of the contaminant fate and transport modeling is presented as the expected maximum concentration of modeled contaminants at the selected receptor locations. For SESOIL, the receptor location is the groundwater table beneath the source area. For this analysis, four sampling areas were considered as sources of contamination based on the results of the soil screening analysis. A separate SESOIL analysis was performed for each initial CMCOPC listed in Table 6-1 and is presented in Figure 6-4.

The predicted maximum leachate concentration just above the water table, observed in the SESOIL results, was compared against its applicable RVAAP facility-wide background concentration, as well as RVAAP FWCUGs for the Resident Receptor Adult, MCL, and RSL. If the predicted maximum leachate concentration of an initial CMCOPC was higher than the facility-wide background concentration, and the lowest risk-based screening value (Resident Receptor Adult FWCUG, MCL, or RSL), the CMCOPC was further evaluated using AT123D to predict future maximum concentrations in groundwater beneath the source, as well as at downgradient receptor locations, if applicable.

If a predicted maximum leachate concentration was lower than the screening criteria, the chemical was no longer considered a CMCOPC.

For chemicals identified as CMCOPCs, maximum concentrations predicted by AT123D in groundwater directly below the source areas and at the downgradient receptor locations were compared to the applicable RVAAP facility-wide background concentrations, as well as RVAAP FWCUGs for the Resident Receptor Adult, MCL, and RSL. If the predicted maximum concentration of a CMCOPC was higher than its facility-wide background concentration, and the lowest risk-based screening value (i.e., Resident Receptor Adult FWCUG, MCL, or RSL), the chemical was retained as a CMCOC. If the predicted maximum concentration of a CMCOPC in groundwater directly below the source areas and at the downgradient receptor location was lower than the screening criteria, the chemical would not be considered a CMCOC.

CMCOCs identified by modeling results were evaluated with respect to WOE for retaining or eliminating CMCOCs from further consideration as a basis for potential soil remedial actions. Lines of evidence include validating modeling results using available AOC-specific groundwater monitoring data. Modeled timelines for potential leaching and lateral transport were evaluated with respect to estimated times for contaminant releases during RVAAP operations to determine if peak leaching concentrations would likely have occurred in the past. Some CMCOCs present at or below RVAAP soil background concentrations may have predicted leachate or groundwater concentrations exceeding risk-based criteria due to conservative model assumptions; therefore, these were also identified and considered in the evaluation. Additionally, identified CMCOCs were compared to COCs identified in the HHRA to determine if they had an associated risk related to direct exposure to soil or if CMCOCs and COCs were co-located and may be addressed simultaneously under a potential remedial action.

6.5.2 Model Applications

The SESOIL model (GSC 1998) used for leachate modeling, when applicable, estimates pollutant concentrations in the soil profile following introduction via direct application and/or interaction with transport media. AT123D (DOE 1992) is an analytical groundwater pollutant fate and transport model. It computes the spatial-temporal concentration distribution of waste in the aquifer system and predicts the transient spread of a contaminant plume through a groundwater aquifer. The application of both of these models is discussed in the following subsections.

6.5.2.1 SESOIL Modeling

SESOIL defines the soil column as compartments extending from the ground surface through the unsaturated zone and to the upper level of the saturated soil zone or top of bedrock. Processes simulated in SESOIL are categorized in three cycles: hydrologic, sedimentation, and pollutant. Each cycle is a separate submodule in the SESOIL code. The hydrologic cycle includes rainfall, surface runoff, percolation, soil-water content, evapotranspiration, and groundwater recharge. The sediment washload cycle includes erosion and sediment transport.

The pollutant cycle includes convective transport, volatilization, adsorption/desorption, and degradation/decay. A chemical in SESOIL can partition in up to four phases: liquid, adsorbed, air, and pure. Data requirements for SESOIL are not extensive and utilize a minimum of AOC-specific soil and chemical parameters and monthly or seasonal meteorological values as input.

SESOIL output includes pollutant concentrations at various soil depths and pollutant loss from the unsaturated soil zone in terms of surface runoff, percolation to groundwater, volatilization, and degradation. The mathematical representations in SESOIL generally consider the rate at which the modeled processes occur, the interaction of different processes with each other, and the initial conditions of the waste area and surrounding subsurface matrix material.

The input data for SESOIL can be grouped into four types: climatic, chemical, soil, and application. There are 61 separate parameters contained in these 4 data groups. Wherever possible, AOC-specific parameter values were used for modeling. However, certain parameters were not available for the source areas and were estimated based on pertinent scientific literature, geochemical investigations, and checks for consistency between model results and historical data. Conservative estimates were used when a range of values existed or parameter values were not available.

6.5.2.2 Climate Data

The climatic data file of SESOIL consists of an array of mean monthly temperature, mean monthly cloud cover fraction, average monthly relative humidity, average monthly reflectivity of the earth's surface (i.e., shortwave albedo), average daily evapotranspiration, monthly precipitation, mean number of storm events per month, mean duration of rainfall, and mean length of rainy season. The climatic data are presented in Appendix E, Table E-9. The data set was taken from the Youngstown National Weather Service Office weather station at the Youngstown-Warren Regional Airport in Vienna, Ohio, as it was determined to be most appropriate in corresponding to the latitude and longitude at Camp Ravenna.

Climate data from the Youngstown weather station did not have all of the necessary climatic parameters for the HELP model simulation. Accordingly, the water balance evaluation presented in Section 6.2.4 was based on the nearest available weather station data with all necessary coefficients stored within the HELP model (Cleveland, Ohio). Inputs for SESOIL (Youngstown station) and HELP model (Cleveland station) produced virtually the same recharge rate (9.40 cm/yr for Cleveland and 9.42 cm/yr for Youngstown) for each location. Therefore, using the two different weather station data sets did not impact modeling results.

6.5.2.3 Chemical Data

The pollutant fate cycle of SESOIL focuses on various chemical transport and transformation processes that may occur in the soil zone. These processes include volatilization/diffusion, adsorption/desorption, cation exchange, biodegradation and hydrolysis, and metal complexation. The chemical-specific parameters used for SESOIL are presented in Appendix E, Table E-10. The distribution coefficients (K_ds) for inorganic chemicals and the K_{oc} values for organic chemicals were obtained from the chemical-specific parameter table associated with the USEPA Risk Based Generic Screening Tables (USEPA 2015). The K_ds for organic chemicals were estimated from organic, carbon-based K_{oc} using the relationship $K_d = (f_{oc})(K_{oc})$, where f_{oc} = mass fraction of the organic carbon soil content is obtained from AOC-specific measurements. In general, biodegradation rates are not applicable for inorganic CMCOPCs and biodegradation was not considered for the organic chemicals in this evaluation.

6.5.2.4 Soil Data

The soil data file of SESOIL contains input parameters describing the physical characteristics of the subsurface soil and is presented in Table 6-3. These parameters include soil bulk density, intrinsic permeability, soil disconnectedness index, soil porosity, organic carbon content, and cation exchange capacity. AOC-specific data were used from geotechnical samples collected at the AOC during the PBA08 RI (Table 5-8). There is, however, no measurement method for the soil disconnectedness index or a measured value of the Freundlich exponent. The soil disconnectedness index is a parameter that relates the soil permeability to the moisture content, and the Freundlich exponent relates to the concentration of a solute on the surface of an adsorbent to the concentration of the solute in the liquid with which it is in contact. Thus, SESOIL default values were used for these two parameters.

An average intrinsic permeability for the vadose zone, representing the unconsolidated zone above the water table, was calibrated using the percolation rate of 9.42 cm/yr (3.6 inches/year) as the calibration target. The model was calibrated against the percolation rate by varying the intrinsic permeability and keeping all other AOC-specific geotechnical parameters fixed. The final hydrogeologic parameter values used in this modeling are shown in Table 6-3. The soil porosity was set to the AOC-specific value. The intrinsic permeability, calibrated in SESOIL to the percolation rate (determined from a water balance estimated in HELP), was found to match the AOC-specific measurements from geotechnical samples.

The soil disconnectedness index replaces the moisture retention curves (or characteristic curves) used by other unsaturated zone leaching models. SESOIL's User Guide defines this parameter to be the exponent relating the "wetting" and "drying" time-dependent permeability of soil to its saturated permeability (Hetrick and Scott 1993). This "one variable" approach of using the soil disconnectedness index in SESOIL simplifies the data estimation process and reduces computational time. In addition, this parameter was calibrated for four different soil types ranging from sandy loam to clay (Hetrick et al. 1986), and calibrated values fell within the default range specified in the SESOIL's User Guide.

6.5.2.5 Source Terms

Analytical data from surface and subsurface soil collected at the AOC were used as source terms for SESOIL. All the samples collected at different depth intervals were compiled to provide a detailed loading option for SESOIL. The maximum soil concentrations for each CMCOPC, listed in Table 6-1, were used as source term concentrations for SESOIL.

6.5.2.6 Application Data

Two different layering schemes were developed for sample locations within the AOC due to varying thicknesses of the loading and leaching zones that are based on varying soil sample and groundwater depths throughout the AOC. Details of the model layers utilized in this modeling are presented in Appendix E, Table E-11.

Each model was arranged in four layers. The top layer (Layer 1) for each model consisted of the loading zone and was 1 ft thick.

Layer 2 was 3 ft thick and contained three sublayers and Layer 3 was 5.5 ft thick and contained four sublayers. Layers 2 and 3 served as a loading zone for arsenic and naphthalene and as a leaching zone for 3-nitrotoluene and beta-BHC. The fourth layer (Layer 4) was 0.5 ft thick and did not contain sublayers. Layer 4 was included just above the water table to read output results at the water table/vadose zone interface (i.e., leachate concentration entering groundwater).

6.5.3 SESOIL Modeling Results

SESOIL modeling was performed for initial CMCOPCs (i.e., arsenic, 3-nitrotoluene, naphthalene, and beta-BHC) that have the potential to reach the water table within 1,000 years based on the soil screening analysis results (Table 6-1). Table 6-4 presents the predicted peak leachate concentrations beneath the source areas relative to the discrete sample locations corresponding to the time of peak leachate concentrations. The Resident Receptor Adult FWCUGs, RVAAP facility-wide background concentrations, and MCL/RSL values for the CMCOPCs, if available, are also shown in this table for comparison purposes. None of initial CMCOPCs were eliminated based on the SESOIL modeling results; therefore, all the initial CMCOPCs were selected as the final CMCOPCs for evaluation using the AT123D model. Appendix E, Figures E-1 through E-4 show the leachate mass flux versus time plots generated by SESOIL to be used as input to AT123D modeling.

Arsenic, selenium, naphthalene, and beta-BHC were identified as the final soil CMCOPCs based on SESOIL results for each sample location within the AOC where the leachate concentration exceeded its screening criteria. This leachate concentration is not reflective of the groundwater concentration beneath the source. When the leachate reaches the water table, dilution by groundwater further reduces leachate concentrations.

6.5.4 AT123D Modeling in the Saturated Zone

The fate and transport processes accounted for in the AT123D model include advection, dispersion, adsorption/retardation, and decay. This model can be used as a tool for estimating the dissolved concentration of a chemical in three dimensions in the groundwater resulting from a mass release over a source area (i.e., point, line, area, or volume source). The model can handle instantaneous, as well as continuous, source loadings of CMCOPC concentrations. AT123D is frequently used by the scientific and technical community to perform quick and conservative estimates of groundwater plume movements in space and time. SESOIL and AT123D are linked in a software package (RISKPRO) so that mass loading to groundwater predicted by SESOIL can be transferred directly to AT123D. Therefore, AT123D was chosen to predict the maximum concentration of contaminants in groundwater after mixing with the leachate and the future concentrations for the contaminants in groundwater at the receptor locations.

The hydrogeologic parameter values used in this modeling are shown in Table 6-3. Most of the parameters presented in this table are AOC-specific values, unless otherwise indicated. The chemical-specific parameters used for AT123D are presented in Appendix E, Table E-12. A discussion of model assumptions and limitations is presented in Section 6.5.6.

Appendix E, Figures E-5 through E-12 show the predicted concentration versus time curves based on AT123D modeling for final CMCOPCs for soil and sediment.

6.5.5 AT123D Modeling Results

Results of AT123D modeling for final soil and sediment CMCOPCs are shown in Table 6-5. The results show predicted groundwater concentrations for CMCOPCs beneath the source area and at the selected downgradient receptor location (i.e., Sand Creek and north of Wet Storage Area). Observed groundwater concentrations from monitoring well FWGmw-013 is included in Table 6-5; however, it should be noted that this well may not exist at the sample location with the maximum concentration and should not be considered in direct correlation. The observed groundwater concentrations were added for comparison, not for screening criteria. The distances to the downgradient receptors were based on the distance along the groundwater flow direction to the closest surface water body.

The maximum predicted concentrations of arsenic and naphthalene were predicted to exceed the screening criteria in groundwater beneath the source area and were, therefore, modeled to the downgradient receptor location (i.e., Sand Creek and north of Wet Storage Area). The identified sediment CMCOPCs [manganese, benz(a)anthracene, benzo(b)fluoranthene, and naphthalene] were also predicted by analytical solutions to exceed screening criteria in groundwater beneath their source and were retained for lateral transport modeling using the AT123D model.

Lateral transport modeling showed the maximum predicted concentrations of final soil CMCOPCs (arsenic, 3-nitrotoluene, naphthalene, and beta-BHC) did not exceed the screening criteria at their downgradient receptor location (i.e., Sand Creek and north of Wet Storage Area). 3-Nitrotoluene and beta-BHC did not exceed the screening criteria in groundwater beneath the source area and were eliminated as a soil CMCOCs. However, arsenic and naphthalene exceeded screening criteria in groundwater beneath their respective source areas and were retained for further evaluation. None of the sediment CMCOPCs were predicted to exceed screening criteria at their downgradient receptor (Sand Creek), but all exceeded screening criteria in groundwater beneath their respective source areas and were retained for further evaluation. Figure 6-5 presents CMCOCs identified based on AT123D modeling.

6.5.6 Limitations/Assumptions

In general, a conservative modeling approach was used, which may overestimate the contaminant concentration in the leachate for migration from observed soil concentrations. Important assumptions used in this analysis include:

- The contaminant fate and transport evaluation included not only chemicals identified as being previously used during historical operations but also chemicals identified during the RVAAP SRC screening process.
- Some SRCs were identified due to the lack of background concentration data available or having limited or slight exceedances of established background concentrations.
- Chemical and biological degradation rates for organic CMCOPCs were not considered in the SESOIL and AT123D models.
- Using K_d and R to describe the reaction term of the transport equation assumes that an equilibrium relationship exists between the solid-phase and solution-phase concentrations and that the relationship is linear and reversible.
- Since AOC-specific data are not available, the K_d and K_{oc} values used in this analysis for all CMCOPCs represent literature or calculated values and may not represent conditions at the AOC.
- The K_d for inorganic chemicals used here assumed a pH of 6.8 [i.e., the middle value in USEPA's evaluation presented in the soil screening guidance document (USEPA 1996a)]. The K_d for inorganic chemicals varies with pH (generally decreasing with decreasing pH, although there are few exceptions); therefore, if AOC-specific pH measurements are greater or less than 6.8, the K_d and calculated screening parameters (such as R) will deviate from those presented here.
- Flow and transport in the vadose zone is one-dimensional (i.e., only in the vertical direction).
- This modeling used the current soil concentrations that were collected approximately 65 years after historical operations were terminated at the AOC. Therefore, it does not account for constituents that have already leached to groundwater.
- Flow and transport are not affected by density variations.

- A realistic distribution of soil contamination was not considered. The maximum concentration value was used as the source term concentration for SESOIL model layers; this is a highly conservative assumption that is expected to produce higher leachate concentrations for CMCOPCs than the average condition. The horizontal distribution of soil contamination was assumed based on concentration levels from nearby sample locations as opposed to taking into account the entire area.
- The water balance represents an overall average rainwater recharge and assumes an even distribution of infiltration in the modeled area. An average water balance assumes some areas will have higher or lower recharge based on the heterogeneity of the soil and varying topography.

The inherent uncertainties associated with using these assumptions must be recognized. K_d values are highly sensitive to changes in the major chemistry of the solution phase. Therefore, it is important that the values be measured or estimated under conditions that will closely represent those of the contaminant plume. Deviations from actual AOC-specific parameter values from assumed literature values may significantly affect contaminant fate predictions. It is also important to note that the contaminant plume will change over time and will be affected by multiple solutes present at the AOC. The effects of heterogeneity and anisotropy are not addressed in these simulations.

The discrepancy between the contaminant concentrations measured in the field and the values predicted by the model could be investigated by performing sensitivity analyses on the model input parameters that have the most influence on the model predictions.

These parameters are: (1) biodegradation rate constants for organic chemicals; (2) saturated hydraulic conductivity; (3) soil porosity; (4) f_{oc} for organic chemicals; (5) K_d for inorganic chemicals; and (6) longitudinal, transverse, and vertical dispersivity values. Generally, higher biodegradation rates will produce lower concentrations, and lower rates will produce higher concentrations for organic chemicals without impacting the results of the inorganic chemicals. Higher hydraulic conductivity and dispersivity cause higher advection and dispersion, thereby producing lower peaks near the source area, but increasing the migration distance. The reverse will be true with lower hydraulic conductivity and dispersivity values. Higher f_{oc} values have a similar effect on organic chemicals as higher K_d has on inorganic chemicals; they decrease the mobility of the chemicals as well as produce lower concentrations in groundwater.

6.6 EVALUATION TO IDENTIFY CMCOCS

This evaluation of contaminant fate and transport uses a soil screening analysis to identify SRCs that have potential to leach to groundwater, performs SESOIL modeling to conservatively estimate final CMCOPC leachate concentrations before the SRCs enter the groundwater system beneath the sources with highest level of contamination, and uses AT123D modeling to present a conservative maximum concentration in groundwater of final CMCOPCs beneath the sources and at downgradient receptor locations.

This analysis also includes a sediment screening analysis that was performed for sediment samples at the AOC. Typically, chemical-specific DAFs were calculated using co-located surface water and sediment concentrations for identified sediment SRCs. However, DAFs could not be calculated for Wet Storage Area because none of the chemicals that were detected in sediment and surface water were co-located. As a result, a DAF of 1 (indicating that there is no dilution) was used in the sediment screening analysis to identify CMCOPCs for predictive modeling and further evaluation.

The limitations and assumptions of the overall process are presented in Section 6.5.6. The text below provides a list of the remaining final CMCOCs and a qualitative assessment of the results and considerations of the limitations and assumptions.

6.6.1 Evaluation of Remaining Soil CMCOPCs

Arsenic – Of the 41 surface and subsurface soil samples collected, only four samples (WSAsb-021-5612-SO, WSAsb-024-5624-SO, WSAsb-026-5631-SO, and WSAss-020M-SO) exceeded the subsurface soil background concentration of 19.8 mg/kg at a maximum concentration of 21.3 mg/kg in the 4–7 ft bgs interval at location WSAsb-026. Arsenic was not considered a COC in the HHRA. Arsenic was not detected in groundwater samples collected from bedrock monitoring well FWGmw-013 between 2012–2013 (Table 6-5). Using the maximum soil concentration, arsenic modeling results indicate it would take approximately 100 years for a breakthrough in groundwater beneath the source at a concentration above the MCL (0.01 mg/L), and arsenic is not predicted to migrate to the downgradient receptor location at concentrations exceeding its MCL within 1,000 years (see Table 6-5). It should be noted here that the background concentration of arsenic in unconsolidated groundwater also exceeds the MCL. Therefore, if arsenic is detected in groundwater slightly above its MCL, it should be considered background related, and not due to contamination from the site.

Naphthalene – The maximum soil concentration for naphthalene was 0.081 mg/kg at WSAss-04M-SO, which was below the Resident Receptor Adult FWCUG at a TR of 1E-06, HQ of 0.1 (368 mg/kg) and RSL of 122 mg/kg, and was not considered a COPC in the HHRA. The naphthalene modeling results using this maximum concentration indicate it would take approximately 35 years for a breakthrough in groundwater beneath the source at a concentration above its RSL (0.00017 mg/L). Naphthalene has not been detected in groundwater samples collected from bedrock monitoring well FWGmw-013 between 2012–2013 (Table 6-5). Also, naphthalene is not predicted to migrate to the downgradient receptor location at concentrations exceeding its RSL within 1,000 years (see Table 6-5). Therefore, this evaluation concludes that the model predicted concentrations are conservative, and naphthalene would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

6.6.2 Evaluation of Remaining Sediment CMCOPCs

Manganese – The maximum sediment concentration for manganese (2,230 mg/kg) was above the Resident Receptor Adult FWCUG at a TR of 1E-06, HQ of 0.1 (1,482 mg/kg) and the sediment background concentration (1,950 mg/kg); however, manganese was not identified as a sediment COPC in the HHRA. Although manganese was detected at a concentration (0.58 mg/L) above the RSL (0.43

mg/L) in the groundwater samples collected from bedrock monitoring well FWGmw-013 between 2012–2013, the detections were well below the background concentration of manganese in unconsolidated groundwater (1.02 mg/kg) and bedrock groundwater (1.34 mg/L) (Table 6-5).

The conservative model assumes an equilibrium partitioning between sediment and groundwater and provides a predicted maximum groundwater concentration beneath the source of 34.3 mg/L (i.e., above the RSL of 0.43 mg/L). Even with the results of this conservative model, predicted manganese concentrations beneath the source decrease to below its RSL in less than 45 years and continue to decrease into the future. In addition, manganese is not predicted to migrate to the downgradient receptor location at concentrations exceeding its RSL within 1,000 years (Table 6-5).

Manganese is predicted to be in groundwater because the modeling assumed the sediment sample is directly in contact with the underlying groundwater and no dilution was applied (a chemical-specific DAF could not be calculated because there were no co-located sediment and surface water detections). Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and manganese would be expected to be below its RSL based on accounting for the vertical leaching distance.

Benz(a)anthracene – The maximum sediment concentration for benz(a)anthracene (0.12 mg/kg) was below the Resident Receptor Adult FWCUG at a TR of 1E-06, HQ of 0.1 (0.221 mg/kg), and benz(a)anthracene was not identified as a sediment COC in the HHRA. Benz(a)anthracene was not detected in groundwater samples collected from bedrock monitoring well FWGmw-013 between 2012–2013 (Table 6-5).

Although benz(a)anthracene was not detected in groundwater, the conservative model assumes an equilibrium partitioning between sediment and groundwater and provides a predicted maximum groundwater concentration beneath the source of 0.000485 mg/L (i.e., above the RSL of 0.000012 mg/L). Even with the results of this conservative model, benz(a)anthracene is not predicted to migrate to the downgradient receptor location at detectable concentrations within 1,000 years (Table 6-5).

Benz(a)anthracene is predicted to be in groundwater because the modeling assumed the sediment sample is directly in contact with the underlying groundwater, no dilution was applied (a chemical-specific DAF could not be calculated because there were no co-located sediment and surface water detections), and no biodegradation rate was applied. Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and benz(a)anthracene would be expected to be below its RSL based on accounting for the vertical leaching distance and its estimated site-specific biodegradation rate.

Benzo(b)fluoranthene – The maximum sediment concentration for benzo(b)fluoranthene (0.14 mg/kg) was below the Resident Receptor Adult FWCUG at a TR of 1E-06, HQ of 0.1 (0.221 mg/kg), and benzo(b)fluoranthene was not identified as a sediment COPC in the HHRA. Benzo(b)fluoranthene was not detected in groundwater samples collected from bedrock monitoring well FWGmw-013 between 2012–2013 (Table 6-5).

Although benzo(b)fluoranthene was not detected in groundwater, the conservative model assumes an equilibrium partitioning between sediment and groundwater and provides a predicted maximum groundwater concentration beneath the source of 0.000167 mg/L (i.e., above the RSL of 0.000034 mg/L). Even with the results of this conservative model, predicted benzo(b)fluoranthene concentrations beneath the source decrease to below its RSL after about 14 years and continue to decrease into the future. In addition, benzo(b)fluoranthene is not predicted to migrate to the downgradient receptor location at detectable concentrations within 1,000 years (Table 6-5).

Benzo(b)fluoranthene is predicted to be in groundwater because the modeling assumed that the sediment sample is directly in contact with the underlying groundwater, no dilution was applied (a chemical-specific DAF could not be calculated because there were no co-located sediment and surface water detections), and no biodegradation rate was applied. Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and benzo(b)fluoranthene would be expected to be below its RSL based on accounting for the vertical leaching distance and its estimated site-specific biodegradation rate.

Naphthalene – The maximum sediment concentration for naphthalene (0.068 mg/kg) was below the Resident Receptor Adult FWCUG at a TR of 1E-06, HQ of 0.1 (368 mg/kg), and naphthalene was not identified as a sediment COPC in the HHRA. Naphthalene was not detected in groundwater samples collected from bedrock monitoring well FWGmw-013 between 2012–2013 (Table 6-5).

Although naphthalene was not detected in groundwater, the conservative model assumes an equilibrium partitioning between sediment and groundwater and provides a predicted maximum groundwater concentration beneath the source of 0.0315 mg/L (i.e., above the RSL of 0.00017 mg/L). Even with the results of this conservative model, predicted naphthalene concentrations beneath the source decrease to below the RSL after about 40 years and continue to decrease into the future. Although naphthalene migrates to the downgradient receptor location in about 29 years, it is not predicted to be above the RSL within 1,000 years (Table 6-5).

Naphthalene is predicted to be in groundwater because the modeling assumed the sediment sample is directly in contact with the underlying groundwater, no dilution was applied (a chemical-specific DAF could not be calculated because there were no co-located sediment and surface water detections), and no biodegradation rate was applied. Therefore, this evaluation concludes that the model-predicted concentrations are highly conservative, and naphthalene would be expected to be below its RSL based on accounting for the vertical leaching distance and its estimated site-specific biodegradation rate.

6.7 SUMMARY AND CONCLUSIONS

Inorganic and organic SRCs exist in surface soil, subsurface soil, and sediment at Wet Storage Area. These SRCs include chemicals that were identified as potential contaminants from previous site usage and chemicals that were identified from the SRC screening process using available data. All SRCs were further evaluated to determine if residual concentrations in soil and sediment may potentially impact groundwater quality and warrant evaluation in an FS.

All SRCs identified in the surface soil, subsurface soil, and sediment at Wet Storage Area were evaluated through the stepwise fate and transport evaluation. Evaluation of modeling results with respect to current AOC groundwater data and model limitations identified the following CMCOPCs for soil and sediment:

- Arsenic and naphthalene in soil were predicted to exceed the screening criteria in groundwater beneath the source area; however, neither of these constituents were predicted to exceed the screening criteria in groundwater at the downgradient receptor location.
- Manganese, benz(a)anthracene, benzo(b)fluoranthene, and naphthalene in sediment were predicted to exceed the screening criteria in groundwater beneath the source area; however, none of these constituents were predicted to exceed the screening criteria in groundwater at the downgradient receptor location.

A qualitative assessment of the sample results and considerations of the limitations and assumptions of the models were performed to identify if any CMCOCs are present in soil or sediment at Wet Storage Area that may potentially impact groundwater beneath the source or at the downgradient receptor location. This qualitative assessment concluded that there were no CMCOCs present in soil and sediment that may impact the groundwater beneath the source or at the downgradient receptor location. No further action is required of soil and sediment to be protective of groundwater.

Table 6–1. Initial CMCOPCs Evaluated with SESOIL Modeling

SRC	Maximum Concentration (mg/kg)	Discrete or ISM Sample Location	Sample Depth (ft bgs)	Leachate Modeling? (Yes/No)
Inorganic Chemicals				
Arsenic	2.13E+01	WSAsb-026-5631-SO	4– 7	Yes
Explosives				
3-Nitrotoluene	8.00E-02	WSAss-001M-SO	0–1	Yes
Semi-volatile Organic Compounds				
Naphthalene	8.10E-02	WSAss-004M-SO	0–1	Yes
PCBs/Pesticides				
beta-BHC	3.40E-03	WSAss-011M-SO	0–1	Yes

bgs = Below ground surface.
BHC = Hexachlorocyclohexane.
CMCOPC = Contaminant migration chemical of potential concern.
ft = Feet.
ISM = Incremental sampling methodology.
mg/kg = Milligrams per kilogram.
PCB = Polychlorinated biphenyl.
SESOIL = Seasonal Soil Compartment Model.
SRC = Site-related contaminant.

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Table 6–2. Sediment Screening Results for Wet Storage Area

Analyte	CAS Number	Background Criteria (mg/kg)[a]	Maximum Sediment Concentration (mg/kg)	Sediment Sample ID	K_{oc} (L/kg)	Reference	K_d (L/kg)	Reference	Maximum Groundwater Concentration (mg/L)[b]	DAF[c]	Maximum Groundwater Concentration (mg/L) / DAF	MCL or RSL (mg/L)	MCL or RSL?	CMCOPC? (yes/no)
Inorganic Chemicals														
Antimony	7440-36-0	0.00E+00	9.50E-02	WSAsd-037-5649-SD	NA	NA	4.50E+01	g	2.11E-03	1	2.11E-03	6.00E-03	MCL	No
Beryllium	7440-41-7	3.80E-01	4.20E-01	WSAsd-037-5649-SD	NA	NA	7.90E+02	g	5.32E-04	1	5.32E-04	4.00E-03	MCL	No
Cadmium	7440-43-9	0.00E+00	1.50E-01	WSAsd-037-5649-SD	NA	NA	7.50E+01	g	2.00E-03	1	2.00E-03	5.00E-03	MCL	No
Manganese	**7439-96-5**	**1.95E+03**	**2.23E+03**	**WSAsd-037-5649-SD**	**NA**	**NA**	**6.50E+01**	**g**	**3.43E+01**	**1**	**3.43E+01**	**4.30E-01**	**RSL**	**Yes**
Silver	7440-22-4	0.00E+00	2.70E-02	WSAsd-037-5649-SD	NA	NA	8.30E+00	g	3.25E-03	1	3.25E-03	9.40E-02	RSL	No
Semi-volatile Organic Compounds														
2-Methylnaphthalene	91-57-6	NA	8.00E-02	WSAsd-037-5649-SD	2.48E+03	g	3.47E+00	h	2.31E-02	1	2.31E-02	3.60E-02	RSL	No
Acenaphthylene[d]	208-96-8	NA	1.10E-02	WSAsd-037-5649-SD	7.40E+03	i	1.04E+01	h	1.06E-03	1	1.06E-03	5.30E-01	RSL	No
Anthracene	120-12-7	NA	3.10E-02	WSAsd-037-5649-SD	1.64E+04	g	2.29E+01	h	1.35E-03	1	1.35E-03	1.80E+00	RSL	No
Benz(a)anthracene	**56-55-3**	**NA**	**1.20E-01**	**WSAsd-037-5649-SD**	**1.77E+05**	**g**	**2.48E+02**	**h**	**4.85E-04**	**1**	**4.85E-04**	**1.20E-05**	**RSL**	**Yes**
Benzo(a)pyrene	50-32-8	NA	9.20E-02	WSAsd-037-5649-SD	5.87E+05	g	8.22E+02	h	1.12E-04	1	1.12E-04	2.00E-04	MCL	No
Benzo(b)fluoranthene	**205-99-2**	**NA**	**1.40E-01**	**WSAsd-037-5649-SD**	**5.99E+05**	**g**	**8.39E+02**	**h**	**1.67E-04**	**1**	**1.67E-04**	**3.40E-05**	**RSL**	**Yes**
Benzo(ghi)perylene[e]	191-24-2	NA	6.40E-02	WSAsd-037-5649-SD	1.07E+07	i	1.50E+04	h	4.27E-06	1	4.27E-06	1.20E-01	RSL	No
Benzo(k)fluoranthene	207-08-9	NA	6.40E-02	WSAsd-037-5649-SD	5.87E+05	g	8.22E+02	h	7.78E-05	1	7.78E-05	3.40E-04	RSL	No
Chrysene	218-01-9	NA	1.20E-01	WSAsd-037-5649-SD	1.81E+05	g	2.53E+02	h	4.75E-04	1	4.75E-04	3.40E-03	RSL	No
Fluoranthene	206-44-0	NA	2.80E-01	WSAsd-037-5649-SD	5.55E+04	g	7.76E+01	h	3.61E-03	1	3.61E-03	8.00E-01	RSL	No
Indeno(1,2,3-cd)pyrene	193-39-5	NA	5.70E-02	WSAsd-037-5649-SD	1.95E+06	g	2.73E+03	h	2.09E-05	1	2.09E-05	3.40E-05	RSL	No
Naphthalene	**91-20-3**	**NA**	**6.80E-02**	**WSAsd-037-5649-SD**	**1.54E+03**	**g**	**2.16E+00**	**h**	**3.15E-02**	**1**	**3.15E-02**	**1.70E-04**	**RSL**	**Yes**
Phenanthrene[f]	85-01-8	NA	7.80E-02	WSAsd-037-5649-SD	1.82E+04	i	2.55E+01	h	3.06E-03	1	3.06E-03	1.20E-01	RSL	No
Pyrene	129-00-0	NA	1.90E-01	WSAsd-037-5649-SD	5.43E+04	g	7.61E+01	h	2.50E-03	1	2.50E-03	1.20E-01	RSL	No
Volatile Organic Compounds														
2-Butanone	78-93-3	NA	2.10E-03	WSAsd-037-5649-SD	4.51E+00	g	6.31E-03	h	3.33E-01	1	3.33E-01	5.60E+00	RSL	No

[a] Background criteria for sediment from final facility-wide background values for the Ravenna Army Ammunition Plant, published in the Final *Phase II Remedial Investigation Report for Winklepeck Burning Grounds at Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2001b).

[b] Maximum groundwater concentration = maximum sediment concentration divided by the distribution coefficient.

[c] An exposure unit specific DAF could not be calculated because there were no co-located constituents detected in sediment and surface water. The default DAF of 1 was used for all analytes.

[d] Acenaphthene RSL was used as a surrogate for acenaphthylene.

[e] Pyrene RSL was used as a surrogate for benzo(*ghi*)perylene.

[f] Pyrene RSL was used as a surrogate for phenanthrene.

[g] U.S. Environmental Protection Agency (USEPA) RSL generic tables June 2015; found at: < http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.

[h] K_d value for organic chemicals calculated by multiplying K_{oc} by mass fraction of the organic carbon soil content of 0.0014 (average geotechnical data from Wet Storage Area).

[i] USEPA 1994b. Risk Reduction Engineering Laboratory Treatability Database, Ver. 5.0, Office of Research and Development, Cincinnati, Ohio.

CAS = Chemical Abstract Service.
CMCOPC = Contaminant migration chemical of potential concern.
DAF = Dilution attenuation factor.
ID = Identification.
K_d = Distribution coefficient.
K_{oc} = Organic carbon distribution coefficient.
L/kg = Liters per kilogram.
MCL = Maximum contaminant level.
mg/kg = Milligrams per kilogram.
mg/L = Milligrams per liter.
NA = Not applicable.
RSL = Regional screening level (USEPA 2015).
Bold = Final CMCOPC to be modeled with Analytical Transient 1-, 2-, 3-Dimensional model.

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Table 6–3. Unit-Specific Parameters Used in SESOIL and AT123D Modeling

Parameters	Symbol	Units	Value	Source for Value
SESOIL				
Percolation Rate (Recharge Rate)	q	m/yr	9.42E-02	0.1 SESOIL Precipitation for Youngstown, Ohio
Horizontal Area of Aggregate	A_p	cm^2	Varies	Sample specific
Intrinsic Permeability - clayey sand	p	cm^2	1.05E-10	Calibrated from SESOIL model
Disconnectedness Index	c	unitless	11	Calibrated from SESOIL model
Freundlich Equation Exponent	n	unitless	1	SESOIL default
Fraction Organic Carbon	f_{oc}	unitless	1.40E-03	The average of PBA08 RI geotechnical samples WSAsb-025-5627-SO and WSAsb-025-5628-SO
Bulk Density	ρ_b	kg/L	1.74	
Moisture Content	w	wt %	17.2	
Water-filled Soil Porosity	Tw	unitless	0.30	
Air-filled Soil Porosity	Ta	unitless	0.056	
Porosity – total	n_T	unitless	0.356	
Vadose Zone Thickness	Vz	m	3.05	Based on average ground surface elevation and depth to water table from Figure 3-4
Leaching Zone Thickness	Th	m	0.15 to 2.7	Based on vadose zone thickness and results for CMCOPCs in soil
AT123D				
Aquifer Thickness	h	m	6	Conservative assumption for shallow bedrock aquifer. Facility-wide assumption for the unconsolidated aquifer presented the Load Line 1 investigation was 6 meters (USACE 2003b)
Hydraulic Conductivity in Saturated Zone	K_S	cm/s	4.15E-04	Geometric mean from RVAAP range in MKM 2007
Hydraulic Gradient	i	unitless	2.34E-02	Calculated from facility-wide potentiometric surface map determined from Figure 3-4

Table 6–3. Unit-Specific Parameters Used in SESOIL and AT123D Modeling (continued)

Parameters	Symbol	Units	Value	Source for Value
Effective porosity	n_e	unitless	0.2	Assumed for sandstone (USEPA 1985)
Dispersivity, longitudinal	α_L	m	30	Assumed
Dispersivity, transverse	α_T	m	3	0.1 α_L
Dispersivity, vertical	α_V	m	0.3	0.01 α_L
Retardation factor	R_d	unitless	chemical-specific	Presented in Table E-7 in Appendix E

MKM Engineers (MKM) 2007. Final Characterization of 14 AOCs at Ravenna Army Ammunition Plant. March 2007.

USACE 2003b. Phase II Remedial Investigation Report for the Load Line 1 at the Ravenna Army Ammunition Plant, Ravenna, Ohio. June 2003.

USEPA 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water, Revised 1985 Parts 1 and 2, EPA/600/6-85/002. Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. September 1985.

AT123D = Analytical Transient 1-,2-,3-Dimensional model.
cm^2 = Square centimeters.
CMCOPC = Contaminant migration chemical of potential concern.
cm/s = Centimeters per second.
kg/L = Kilograms per liter.
m = Meter.
m/yr = Meters per year.
PBA08 RI = Performance Based Acquisition 2008 Remedial Investigation.
RVAAP = Ravenna Army Ammunition Plant.
SESOIL = Seasonal soil compartment model.
wt % = Weight bb percent.

Table 6–4. Summary of SESOIL Modeling Results

Initial CMCOPC	Maximum Soil Concentration (mg/kg)	Sample Location	Maximum Depth of Contamination (ft bgs)	Depth to Groundwater (ft bgs)	Predicted $C_{L,\,max}$ Beneath Source (mg/L)	Time Required to Reach $C_{L,\,max}$ (years)	MCL/RSL (mg/L)	Resident Receptor Adult FWCUG[a] (mg/L)	Facility-wide Background Unconsolidated Groundwater (mg/L)	Final CMCOPC?[b] (yes/no)
Inorganic Chemicals										
Arsenic	**2.13E+01**	**WSAsb-026**	**9.5**	**10**	**1.16E+00**	**487**	**1.00E-02**	**5.60E-05**	**1.17E-02**	**Yes**
Explosives										
3-Nitrotoluene	**8.00E-02**	**WSAss-001M**	**1**	**10**	**3.75E-02**	**20**	**1.70E-03**	**None**	**None**	**Yes**
Semi-volatile Organic Compounds										
Naphthalene	**8.10E-02**	**WSAss-004M**	**9.5**	**10**	**6.89E-03**	**57**	**1.70E-04**	**None**	**None**	**Yes**
PCBs/Pesticides										
beta-BHC	**3.40E-03**	**WSAss-011M**	**1**	**10**	**2.50E-04**	**126**	**2.50E-05**	**4.70E-05**	**None**	**Yes**

[a] The FWCUG is based on a target risk of 1E-06 and a hazard quotient of 0.1.

[b] The final CMCOPC was identified comparing predicted maximum leachate concentration to MCL/RSL, FWCUGs, and facility-wide background. A constituent is an initial CMCOPC if its predicted leachate concentration exceeds its MCL/RSL within 1,000 years.

bgs = Below ground surface.
CMCOPC = Contaminant migration chemical of potential concern.
BHC = Hexachlorocyclohexane.
ft = Feet.
FWCUG = Facility-wide cleanup goal.
MCL= Maximum contaminant level.
$C_{L,\,max}$ =Maximum leachate concentration
mg/kg = Milligram per kilogram.
mg/L = Milligram per liter.
PCB = Polychlorinated biphenyl.
RSL = Regional screening level.
SESOIL = Seasonal soil compartment model.
Bold = CMCOPCs exceeding MCL/RSL, FWCUGs, and facility-wide background concentrations.

Table 6–5. Summary of AT123D Modeling Results

Final CMCOPC	Maximum Leachate Concentration, $C_{L,\,max}$ [a] (mg/L)	Predicted Max Groundwater Concentration[b] ($C_{gw,MAX}$) Beneath Source (mg/L)	Predicted Max Groundwater Concentration[b] ($C_{gw,MAX}$) Downgradient Receptor (mg/L)	Distance to Downgradient Receptor (ft)	Observed Maximum Groundwater Concentrations[c] (mg/L)	MCL/RSL (mg/L)	Resident Receptor Adult FWCUG[d] (mg/L)	Facility-wide Background Unconsolidated Groundwater (mg/L)	CMCOC for Further WOE Evaluation?[e] (yes/no)
Final CMCOPCs in Soil									
Inorganic chemicals									
Arsenic	1.16E+00	9.75E-02	6.95E-06	750	ND	1.00E-02	5.60E-05	1.17E-02	Yes
Explosives									
3-Nitrotoluene	3.75E-02	7.88E-04	4.19E-05	440	ND	1.70E-03	None	None	No
Semi-volatile Organic Compounds									
Naphthalene	6.89E-03	2.61E-04	5.71E-06	960	ND	1.70E-04	None	None	Yes
Pesticides/PCBs									
beta-BHC	2.50E-04	1.05E-05	2.96E-07	420	ND	2.50E-05	4.70E-05	None	No
Final CMCOPCs in Sediment									
Inorganic chemicals									
Manganese	3.43E+01	3.43E+01	9.73E-08	700	5.80E-01	4.30E-01	1.58E-01	1.02E+00	Yes
Semi-volatile Organic Compounds									
Benz(a)anthracene	4.85E-04	4.85E-04	0.00E+00	700	ND	1.20E-05	4.00E-06	None	Yes
Benzo(b)fluoranthene	1.67E-04	1.67E-04	0.00E+00	700	ND	3.40E-05	2.00E-06	None	Yes
Naphthalene	3.15E-02	3.15E-02	2.08E-05	700	ND	1.70E-04	None	None	Yes

[a] Represents seasonal soil compartment model (SESOIL) predicted maximum leachate concentration just above the water table for soil CMCOPCs and the maximum groundwater concentration divided by the dilution attenuation factor for sediment CMCOPCs.

[b] The predicted concentration was estimated using the results from SESOIL and applying AT123D model.

[c] Observed groundwater concentrations were from sampling of monitoring well FWGmw-013 in 2012 and 2013.

[d] The Resident Receptor Adult FWCUG is based on a target risk of 1E-06 and a hazard quotient of 0.1.

[e] The CMCOC was identified by comparing predicted concentration in groundwater beneath the source to MCL/RSL, Resident Receptor Adult FWCUGs, and facility-wide background concentrations. A constituent is a CMCOC if its predicted concentration in groundwater exceeds all its screening criteria within 1,000 years.

AT123D = Analytical Transient 1-,2-,3-Dimensional model.
BHC = Hexachlorocyclohexane.
CMCOC = Contaminant migration chemical of concern.
CMCOPC = Contaminant migration chemical of potential concern.
$C_{L,\,max}$ =Maximum leachate concentration
$C_{gw,\,max}$ =Maximum groundwater concentration
ft = Feet.
FWCUG = Facility-wide cleanup goal.
MCL = Maximum contaminant level.
mg/L = Milligrams per liter.
ND = Not detected.
PCB = Polychlorinated biphenyl.
RSL = Regional screening level.
WOE = Weight-of-evidence.

Not to scale

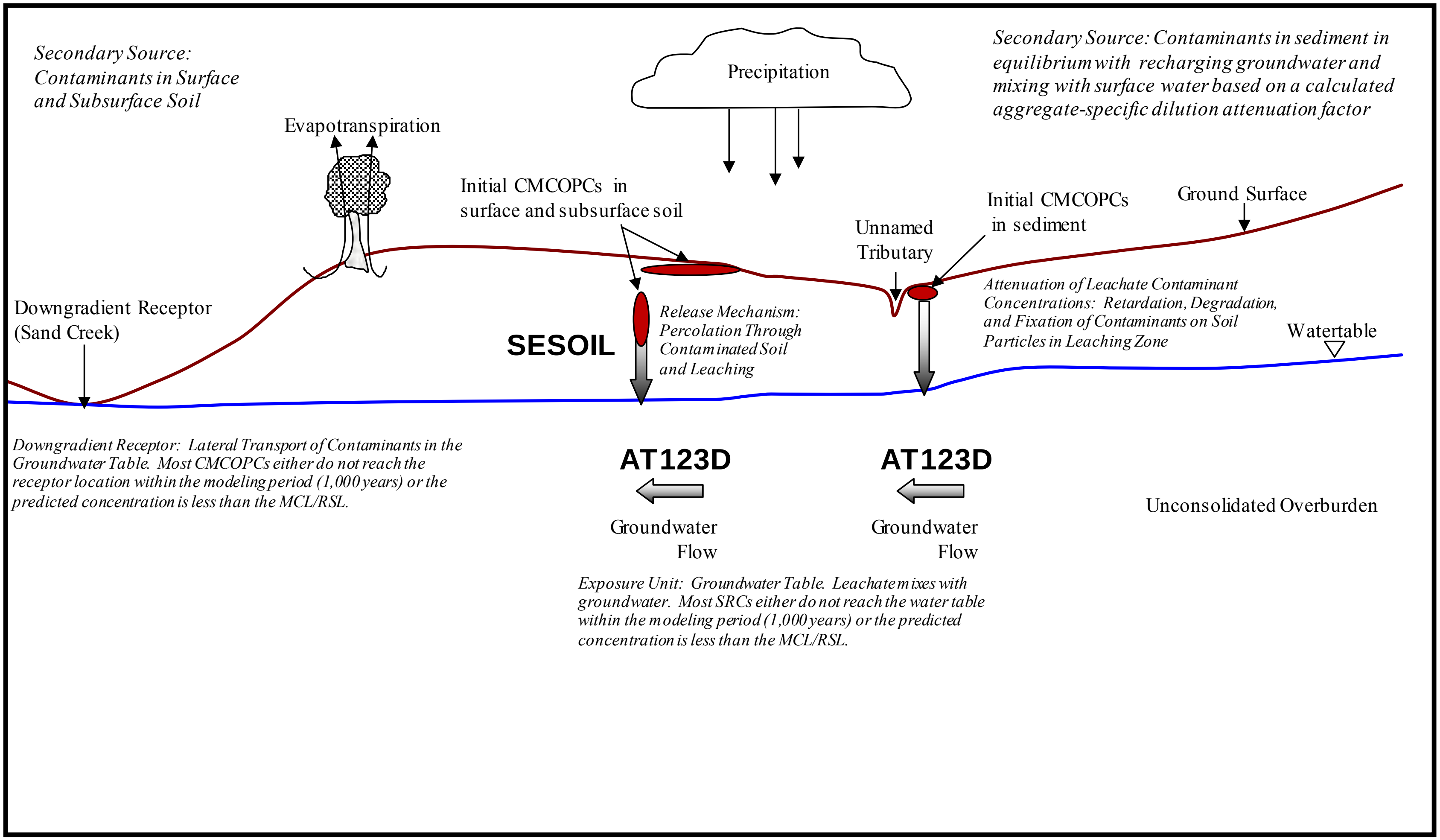


Figure 6–1. Contaminant Migration Conceptual Model

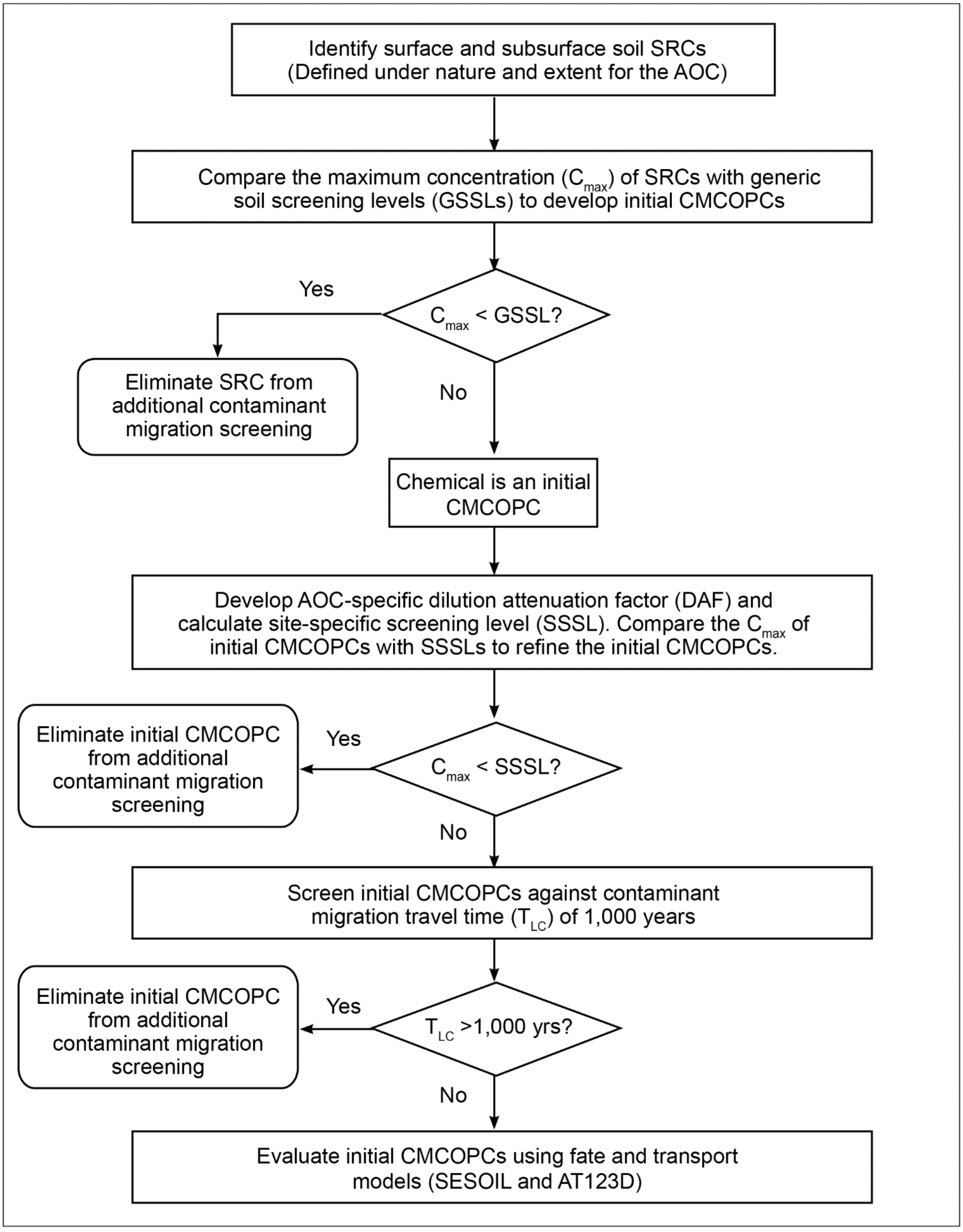


Figure 6–2. Initial CMCOPCs Identified in Soil Screening Analysis for SESOIL Evaluation

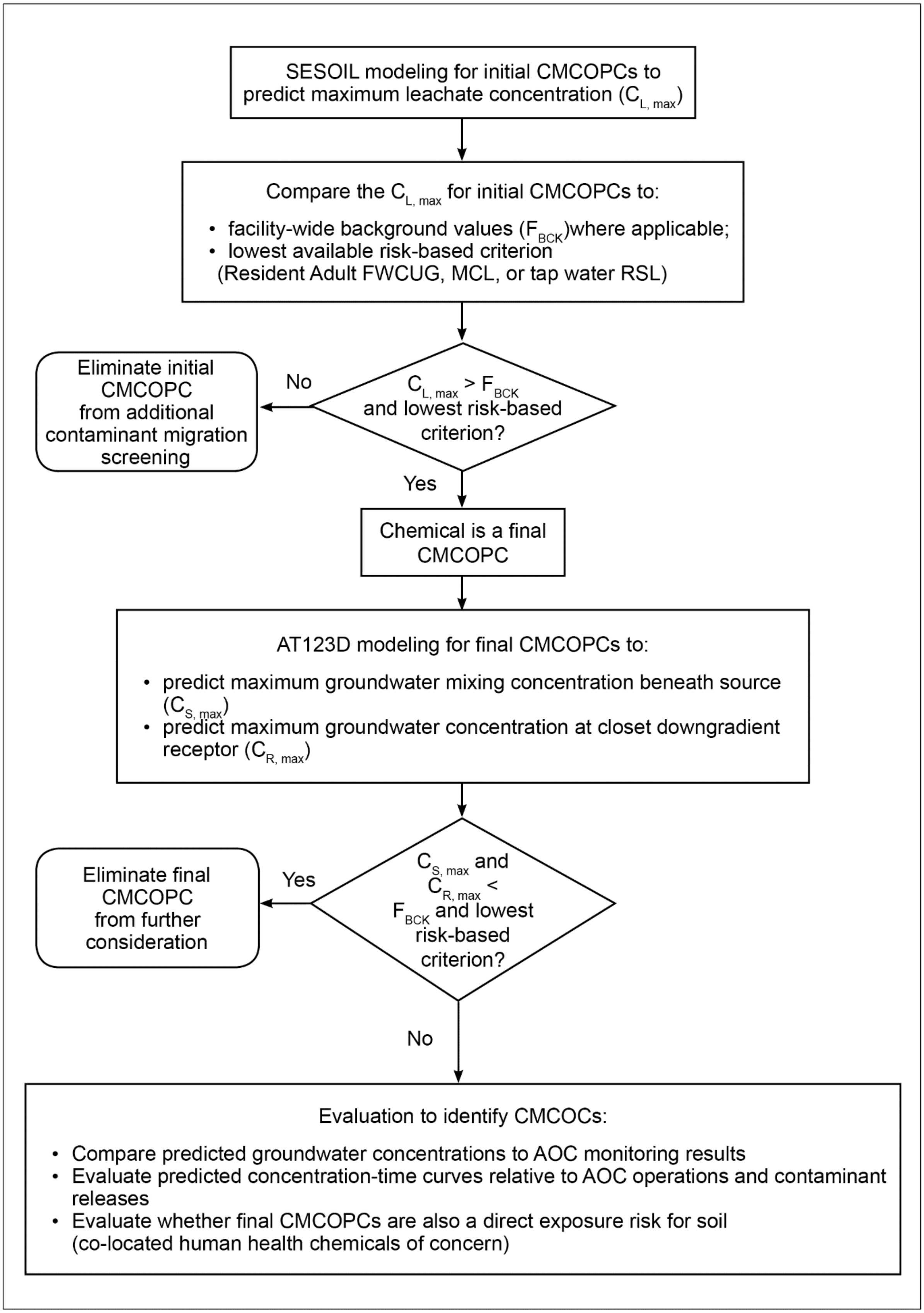


Figure 6–2. Initial CMCOPCs Identified in Soil Screening Analysis for SESOIL Evaluation (continued)

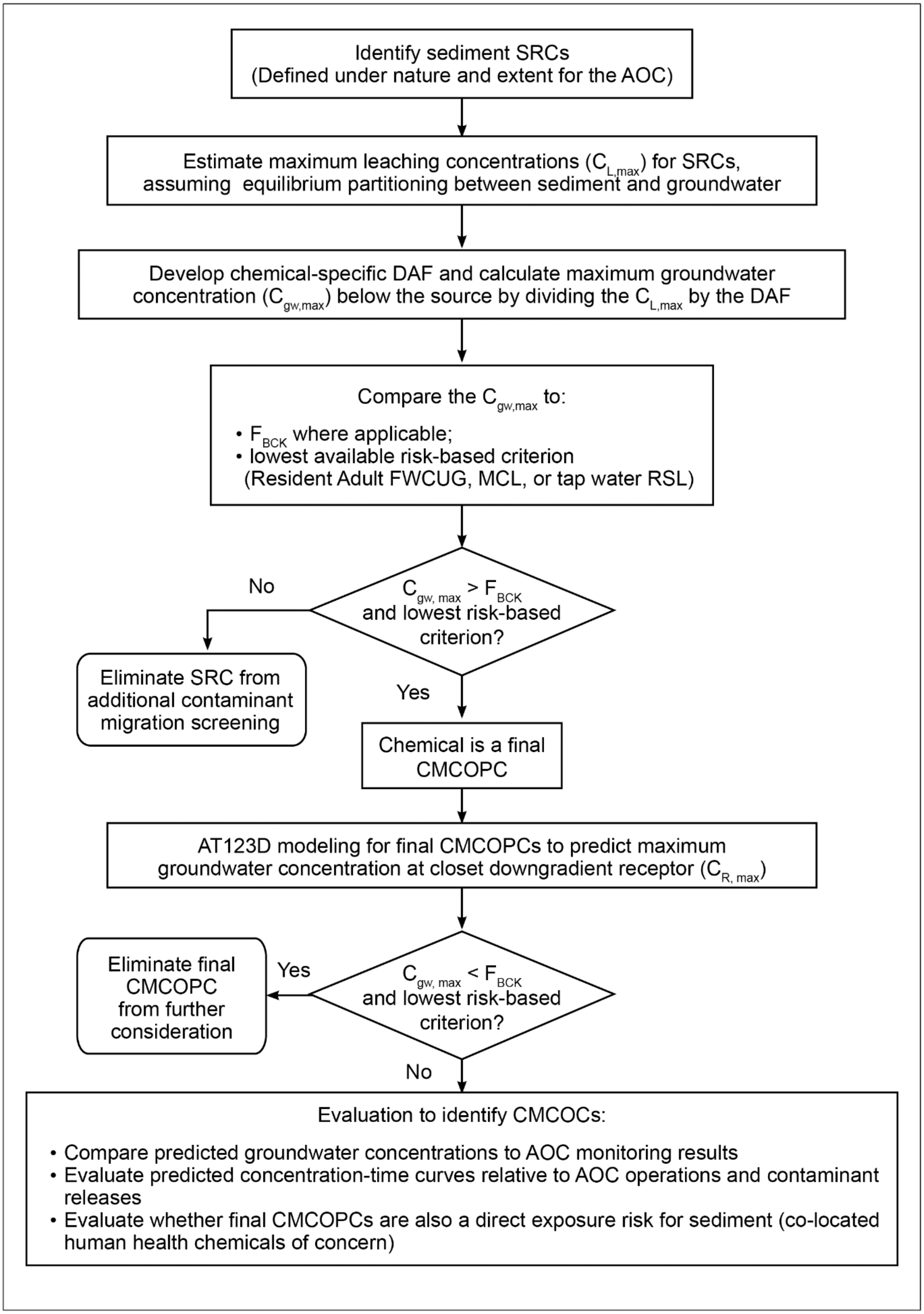
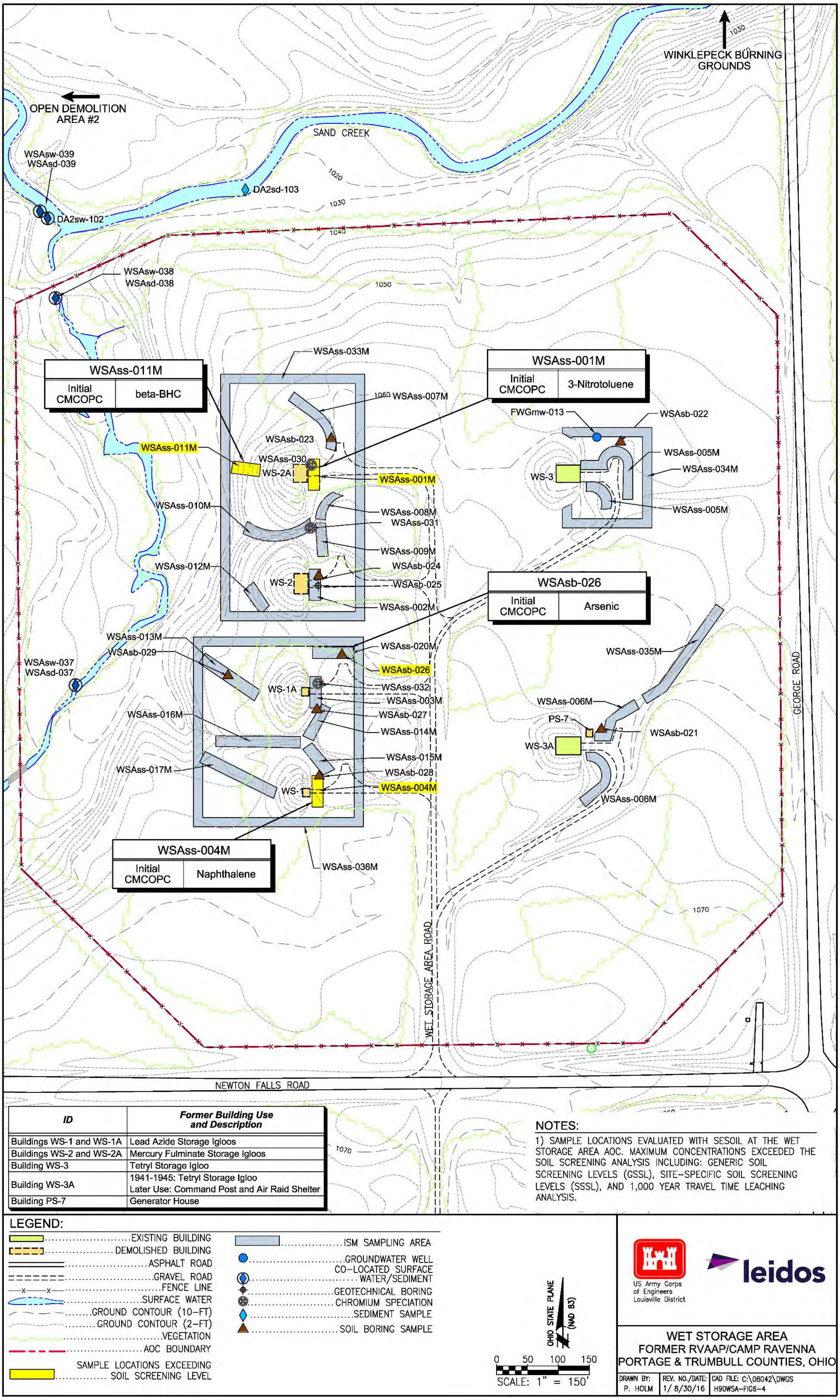


Figure 6–3. AOC Fate and Transport Modeling Approach - Sediment

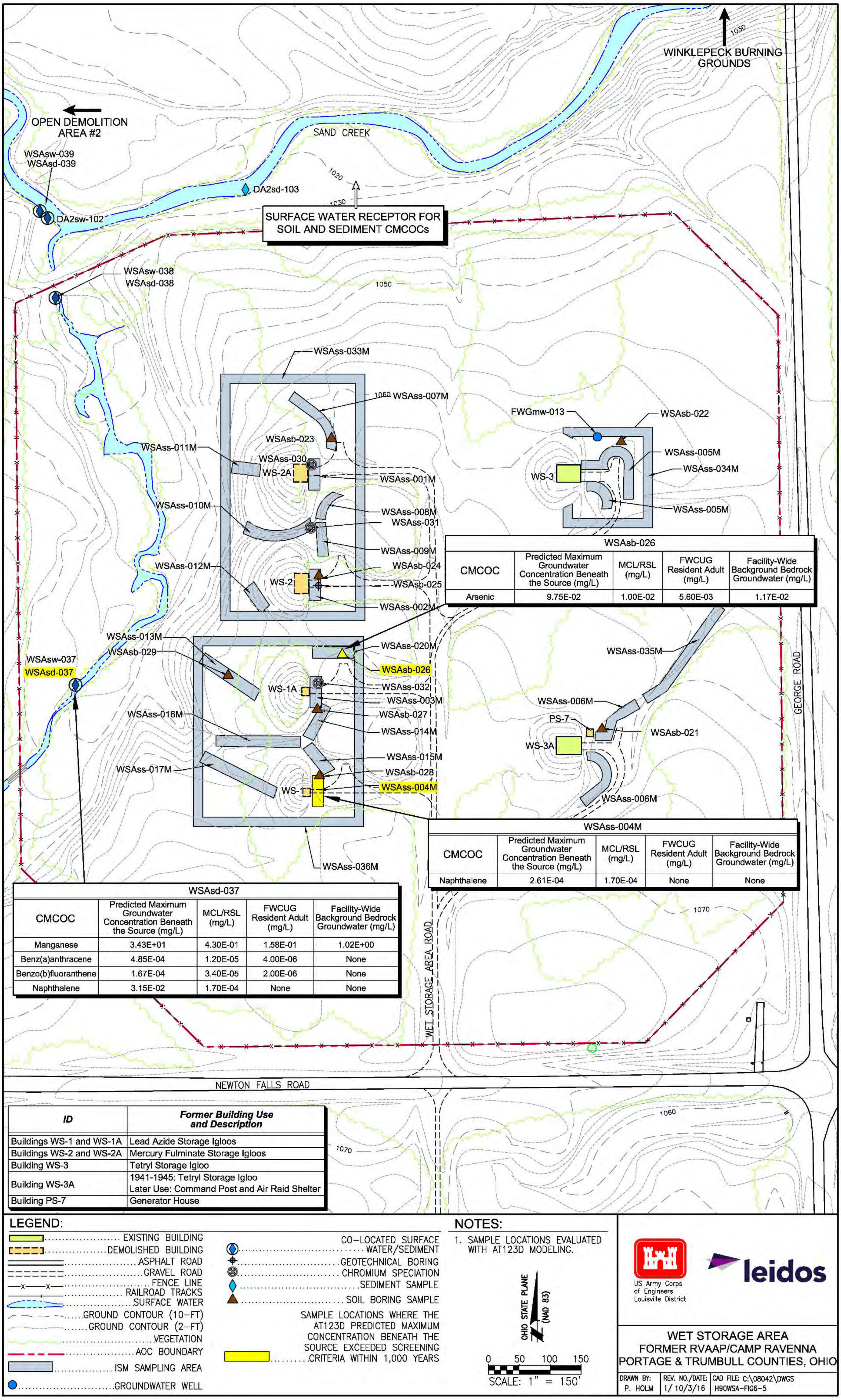


ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

NOTES:

1) SAMPLE LOCATIONS EVALUATED WITH SESOIL AT THE WET STORAGE AREA AOC. MAXIMUM CONCENTRATIONS EXCEEDED THE SOIL SCREENING ANALYSIS INCLUDING: GENERIC SOIL SCREENING LEVELS (GSSL), SITE-SPECIFIC SOIL SCREENING LEVELS (SSSL), AND 1,000 YEAR TRAVEL TIME LEACHING ANALYSIS.

Figure 6–4. Initial CMCOPCs Identified in Soil Screening Analysis for SESOIL Evaluation



WSAsb-026

CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)	Facility-Wide Background Bedrock Groundwater (mg/L)
Arsenic	9.75E-02	1.00E-02	5.60E-03	1.17E-02

WSAss-004M

CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)	Facility-Wide Background Bedrock Groundwater (mg/L)
Naphthalene	2.61E-04	1.70E-04	None	None

WSAsd-037

CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)	Facility-Wide Background Bedrock Groundwater (mg/L)
Manganese	3.43E+01	4.30E-01	1.58E-01	1.02E+00
Benz(a)anthracene	4.85E-04	1.20E-05	4.00E-06	None
Benzo(b)fluoranthene	1.67E-04	3.40E-05	2.00E-06	None
Naphthalene	3.15E-02	1.70E-04	None	None

ID	Former Building Use and Description
Buildings WS-1 and WS-1A	Lead Azide Storage Igloos
Buildings WS-2 and WS-2A	Mercury Fulminate Storage Igloos
Building WS-3	Tetryl Storage Igloo
Building WS-3A	1941-1945: Tetryl Storage Igloo Later Use: Command Post and Air Raid Shelter
Building PS-7	Generator House

Figure 6–5. CMCOCs Identified for Further Weight-of-Evidence Evaluation Based on AT123D Modeling

7.0 RISK ASSESSMENT

7.1 DATA EVALUATION FOR HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

The purpose of this data evaluation is to develop a set of chemical data suitable to use for the HHRA and ERA. Wet Storage Area data were evaluated to establish data aggregates and identify a list of SRCs.

7.1.1 Data Aggregates

This section provides a description of the data aggregates for the media for which human and ecological receptors are potentially exposed, followed by a summary of SRCs in Section 7.1.2. Section 4.0 includes a summary of available data. Data collected at Wet Storage Area were aggregated by environmental medium and exposure depth (e.g., surface soil), EU, and sample type (i.e., discrete or ISM). Samples included in the risk assessment data sets for soil are listed in Tables 7-1 and 7-2. Samples included in the risk assessment data sets for sediment and surface water are listed in Tables 7-3 and 7-4.

7.1.1.1 Soil Data

EUs were established at Wet Storage Area as part of the data aggregation prior to the risk assessment evaluations. The EUs take into account how the areas were previously used and the extent of potential contamination within a given area.

Wet Storage Area is an approximately 36-acre AOC used from 1941–1945 to store primary explosives, including lead azide, mercury fulminate, and tetryl. These highly explosive and shock sensitive materials were stored in a controlled manner at Wet Storage Area in water-filled drums within six separate storage igloos. Four of the igloos (WS-1, WS-1A, WS-2, and WS-2A) located in the western portion of the AOC were decontaminated and demolished in 2003 and 2004. The two remaining igloos (WS-3 and WS-3A) are located in the eastern portion of the AOC (MKM 2007). During operation of Wet Storage Area, close control of the highly reactive material was maintained in water-filled drums stored in igloos. Therefore, sample coverage to define nature and extent focused on operational portions of the AOC, which is consistent with evaluation of the AOC as a single EU. Although Wet Storage Area is considered a single EU, soil data within the area were aggregated by the following depth intervals:

- Surface soil with an exposure depth of 0–1 ft bgs was evaluated for the Resident Receptor (Adult and Child) and for potential risk to ecological receptors, as this layer is the most active biological zone (USACE 2003a). Table 7-1 presents the risk assessment data set for surface soil (0–1 ft bgs) data. For this risk assessment, 18 surface soil (0–1 ft bgs) ISM samples collected during the October and November 2004 Characterization of 14 AOCs (MKM 2007) and 4 surface soil ISM samples collected in March 2010 for the PBA08 RI were used to characterize surface soil. One surface soil sample collected as part of the Characterization of 14 AOCs, WSAss-020M-SO, is a contingency ISM sample added to fulfill QA/QC requirements in December 2004 after completion of the planned 2004 sampling. This sample was collected near igloo WS-1A; however, the precise location and boundaries for this ISM area were not recorded. Uncertainty associated with this sample is addressed in the uncertainty discussion in Section 7.2.5. Discrete surface soil samples collected in 2010 for chromium speciation were used to identify the appropriate risk assessment screening values for chromium. All other discrete surface soil samples collected in 2010 were not used for risk assessment screening purposes because all discrete samples were collected from within the area of small ISM sampled areas, and ISM and discrete data should not be combined into a single statistical analysis. For surface soil ISM samples, each sample result was evaluated as an individual decision unit. Discrete sample data were used to supplement the evaluation of ISM results and are included in the uncertainty assessment.

- Subsurface soil with an exposure depth of 1–13 ft bgs was evaluated for the Resident Receptor (Adult and Child). Discrete soil data from samples collected in March 2010 with a starting depth within this interval were used to evaluate subsurface soil. Table 7-2 presents the risk assessment data for subsurface soil (1–13 ft bgs).

7.1.1.2 Sediment and Surface Water Data

The HHRA evaluated surface water and sediment as one EU. Surface water drainage generally follows the topography of the AOC toward the west and the north. Perennial surface water at Wet Storage Area is present within the unnamed tributary on the west side of the AOC which flows from south to north and enters into Sand Creek northwest of the AOC.

Two co-located surface water and composite sediment samples were collected within the unnamed tributary (Figure 4-1): one at the ingress of the tributary onto the AOC (WSA-037), and one approximately 100 ft from the point of confluence with Sand Creek (WSA-038). These samples were collected to characterize current conditions of the surface water and assess potential soil runoff to surface water entrance and exit pathways from the AOC and were evaluated in the HHRA.

Two additional surface water and sediment samples were collected from Sand Creek (one upstream and one downstream of the confluence with the unnamed tributary) at locations proximate to Wet Storage Area. These samples were collected beyond the AOC boundaries; therefore, they are not included in the risk assessment data set for Wet Storage Area. The Off-AOC EU samples collected upgradient and downgradient of Wet Storage Area were only evaluated in the nature and extent of contamination.

Samples included in the risk assessment data sets for surface water and sediment are listed in Tables 7-3 (surface water) and 7-4 (sediment). The small size of the surface water and sediment data sets reflect the small size of this EU.

7.1.2 Identification of SRCs

Section 4.4 presents the statistical methods and screening criteria used to identify SRCs. The purpose of identifying SRCs is to determine the presence or absence of contamination that is above naturally occurring levels.

The 1978 Installation Assessment identified the major contaminants of the former RVAAP to be TNT, composition B, sulfates, nitrates, lead styphnate, and lead azide. Additional site-specific contaminants at Wet Storage Area include explosives and propellants, heavy metals (arsenic, chromium, lead, and mercury), and PAHs from potential diesel use at Generator House PS-7. The evaluation of historical chemical contamination is not limited to these chemicals; rather, this evaluation is expanded to include all eligible chemical data that are available.

The SRC screen was not limited to only contaminants that may have been a product of previous site use. Rather, the SRC screen followed the three steps outlined in the FWCUG Report, as summarized below, using all chemical data available:

- **Background screening:** MDCs of naturally occurring inorganic chemicals were compared to the facility-wide background concentrations for RVAAP, which are summarized in the FWCUG Report (USACE 2010a). Inorganic chemicals detected above facility-wide background concentrations or having no background concentrations were retained as SRCs. All detected organic chemicals were retained as SRCs.
- **Screening of essential human nutrients:** Chemicals considered essential nutrients (e.g., calcium, chloride, iodine, iron, magnesium, potassium, phosphorous, and sodium) are an integral part of the human food supply and are often added to foods as supplements. USEPA recommends these chemicals not be evaluated so long as they are: (1) present at low concentrations (i.e., only slightly elevated above naturally occurring levels) and (2) toxic at very high doses (i.e., much higher than those that could be associated with contact at the AOC) (USEPA 1989). Essential nutrients detected near or below their RDA/RDI-based SLs were eliminated as SRCs.
- **Frequency-of-detection screening:** In accordance with the FWCUG Report and as revised in the Position Paper for Human Health CUGs (USACE 2012b), analytes detected in less than 5% of the samples are screened out from further consideration, with the exception of explosives and propellants. However, for this AOC, no frequency-of-detection screening was performed for subsurface soil, sediment, or surface water because fewer than 20 discrete samples were available for these data sets. Frequency-of-detection screening was not applied to ISM samples.

Details of the SRC screening for each exposure medium are provided in Appendix G, Tables G-1 through G-4. The SRCs identified for Wet Storage Area are summarized in Table 7-5.

7.2 HUMAN HEALTH RISK ASSESSMENT

This HHRA identifies COCs that may pose potential health risks to humans resulting from exposure to contamination at Wet Storage Area. The HHRA was conducted as part of the PBA08 RI and is based on the methods from the following guidance documents:

- FWHHRAM (USACE 2005a),
- FWCUG Report (USACE 2010a),
- Position Paper for Human Health CUGs (USACE 2012b), and
- Technical Memorandum (ARNG 2014).

To accomplish the goal of streamlined, risk-based decision making, the FWCUG Report was developed to support risk assessments of the remaining AOCs within the former RVAAP. The FWCUG Report contains calculated FWCUGs and guidance for applying the FWCUGs to accelerate the risk assessment process. This approach takes advantage of the many risk assessment inputs and decisions that have previously been accepted by stakeholders through the application of the CERCLA process at the former RVAAP.

Most of the agreed upon risk assessment methodology has been documented in the FWHHRAM (USACE 2005a) and follows standard USEPA-approved risk assessment guidance. This includes the process to identify RVAAP COPCs (Figure 4-5); a TR of 1E-06, HQ of 0.1 to identify COPCs; and a TR of 1E-05, HQ of 1 to identify COCs.

Other approaches, such as calculating the sum-of-ratios (SOR), were developed in the FWCUG Report (USACE 2010a) and Position Paper for Human Health CUGs (USACE 2012b). The Technical Memorandum (ARNG 2014) amends the risk assessment process to establish future Land Uses and applicable receptors to be evaluated in an RI.

The approach to risk-based decision making is as follows:

1. **Develop FWCUGs** – Use the risk assessment process presented in the FWHHRAM to develop FWCUGs for all COPCs identified from the facility-wide data set at RVAAP. This process has been completed in the FWCUG Report.
2. **RI Characterization Sampling** – Perform sampling and analysis to characterize an AOC and establish baseline chemical concentrations. A summary and the results of the RI characterization sampling for Wet Storage Area are presented in Section 4.0.
3. **Mapping and Data Analysis to Identify SRCs and COPCs** – Follow the requirements specified in the FWHHRAM and the Position Paper for Human Health CUGs (USACE 2012b), perform data analysis and mapping to identify SRCs and COPCs, establish EUs, and calculate exposure point concentrations (EPCs) for each COPC. The results of the mapping and data analysis for Wet Storage Area to identify SRCs are presented in Sections 4.0 and 5.0 and are summarized in Section 7.1.
4. **Identification of COCs** – Compare EPCs to FWCUGs to determine COCs.
5. **Address Identified COCs** – Develop FS, PP, and ROD to address any COCs requiring remedy.

Identifying COPCs and COCs follows the four steps for a streamlined risk assessment established in the FWCUG Report: identify media of concern, identify COPCs, present AOC Land Use and appropriate receptors, and compare to appropriate FWCUGs to identify COCs. These steps are discussed in the following subsections.

7.2.1 Identify Media of Concern

Media of concern at Wet Storage Area are surface and subsurface soil, sediment, and surface water, as defined in Section 7.1.1. Groundwater is present at this AOC and will be evaluated (including a risk assessment) in a separate document, as explained in Section 1.2.

7.2.2 Identify COPCs

Section 4.4 presents the statistical methods and screening criteria used to identify SRCs. COPCs are a subset of the SRCs in each exposure medium present at concentrations that indicate the potential for impacts to human receptors. The COPC screen follows the approach specified in the FWCUG Report and is summarized in this section.

To identify COPCs, the MDCs of all SRCs were screened against the most stringent chemical-specific FWCUG of all RVAAP receptors at a cancer TR level of 1E-06 and non-carcinogenic target HQ of 0.1 for the Resident Receptor (Adult and Child) and National Guard Trainee. If no FWCUGs existed for an SRC, the USEPA residential RSL (from RSL table dated June 2015) was used for this screen. No reference dose (RfD) or cancer potency factors are available for acenaphthylene, benzo(ghi)perylene, and phenanthrene; therefore, the RSL for pyrene was used for these PAHs (NDEP 2006).

Hexavalent chromium was detected in one of three discrete surface soil samples collected at Wet Storage Area for chromium speciation. Since hexavalent chromium was detected as part of the conservative screening approach for identifying COPCs, the FWCUG for hexavalent chromium (the more toxic of the two chromium species evaluated) was used at this stage.

Details of the COPC screening for each exposure medium are provided in Appendix G, Tables G-1 through G-4. The COPCs identified for the media of concern at Wet Storage Area are presented in Table 7-6 and are summarized below.

7.2.2.1 <u>COPCs in Surface Soil</u>

A total of 51 chemicals were detected in surface soil (0–1 ft bgs) ISM samples; 42 of these chemicals (14 inorganic chemicals, 21 SVOCs, 5 pesticides, and 2 explosives) were identified as SRCs. Risk-based screening identified four inorganic chemicals (aluminum, arsenic, chromium, and cobalt) and six SVOCs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] as COPCs in surface soil.

7.2.2.2 <u>COPCs in Subsurface Soil</u>

A total of 42 chemicals were detected in discrete subsurface soil samples collected from the 1–13 ft bgs exposure depth. Of these, 23 chemicals (4 inorganic chemicals, 17 SVOCs, 1 pesticide, and 1 VOC) were identified as SRCs. Risk-based screening identified arsenic, cobalt, and benzo(a)pyrene as COPCs for subsurface soil (1–13 ft bgs).

7.2.2.3 COPCs in Sediment

Composite sediment samples were collected from within the unnamed tributary at the ingress of the tributary to the AOC and at the egress of the AOC, approximately 100 ft from the point of confluence with Sand Creek. A total of 37 chemicals were detected in the sediment samples; 20 of these chemicals (5 inorganic chemicals, 14 SVOCs, and 1 VOC) were identified as SRCs. Risk-based screening identified manganese and benzo(a)pyrene as COPCs in sediment.

7.2.2.4 COPCs in Surface Water

A total of 14 chemicals were detected in surface water samples collected from within the unnamed tributary; 5 of these chemicals, all inorganic chemicals, were identified as SRCs. No COPCs were identified in surface water from risk-based screening.

7.2.3 Land Use and Representative Receptors

Camp Ravenna is a controlled-access facility. Wet Storage Area is located northwest of the intersection of George Road and Newton Falls Road near the geographic center of RVAAP and is currently inactive. Three Land Uses for the RVAAP restoration program are specified in the Technical Memorandum (ARNG 2014) for consideration in the RI along with the following Representative Receptors:

1. Unrestricted (Residential) Land Use – Resident Receptor (Adult and Child).
2. Military Training Land Use – National Guard Trainee.
3. Commercial/Industrial Land Use – Industrial Receptor (USEPA's Composite Worker).

Unrestricted (Residential) Land Use is considered protective for all three Land Uses at Camp Ravenna. Therefore, if an AOC meets the requirements for Unrestricted (Residential) Land Use, then the AOC is also considered to have met the requirements of the other Land Uses (i.e., Commercial/Industrial and Military Training), and those other Land Uses do not require evaluation.

As stated in Paragraph 6.d of the Technical Memorandum (ARNG 2014), if an AOC fails to meet Unrestricted (Residential) Land Use, then an FS will be completed that evaluates cleanup options for all three Land Uses [i.e., Unrestricted (Residential) Land Use, Military Training Land Use, and Commercial/Industrial Land Use]. Remedial alternatives for meeting each Land Use are to be evaluated per the current guidelines for selecting a remedy for the AOC. The preferred remedy is one that would meet Unrestricted (Residential) Land Use. RI/FS Reports in progress at the time of the Technical Memorandum's approval on February 11, 2014 will not be revised to include an evaluation of the Commercial/Industrial Land Use as an Alternative if it achieves no further action for Unrestricted (Residential) Land Use.

7.2.4 Compare to Appropriate FWCUGs

Previous sections have outlined the process for identifying SRCs and COPCs. Comparing COPC exposure concentrations to FWCUGs and determining COCs follows guidance presented in the Position Paper for Human Health CUGs (USACE 2012b) and Technical Memorandum (ARNG 2014).

The COC determination process is as follows:

- Report all carcinogenic- and non-carcinogenic-based FWCUGs corresponding to a TR of 1E-05, target HQ of 1 using the most stringent of the Resident Receptor (Adult and Child) FWCUGs to evaluate Unrestricted (Residential) Land Use for each COPC. If no FWCUG is available for a COPC, the Residential RSL, adjusted to represent a TR of 1E-05 or target HQ of 1, is used.
- Report critical effect and target organ for each non-carcinogenic-based FWCUG.
- Compare the selected FWCUG to the EPC, including an SOR.
    - For non-carcinogens, compare the EPC to the target HQ FWCUG. Sum the ratios of the EPC/FWCUG for COPCs that affect similar target organs or do not have an identified target organ.
    - For carcinogens, compare the EPC to the TR FWCUG. Sum the ratios of EPC/FWCUG for all carcinogens.
- Identify the COPC as a COC for a given receptor if:
    - The EPC exceeds the most stringent of the Resident Receptor (Adult and Child) FWCUGs for either the cancer TR of 1E-05 or the target HQ of 1; or
    - The SOR for all carcinogens or all non-carcinogens that may affect the same organ is greater than one. Chemicals contributing at least 10% to the SOR are also considered COCs. In accordance with the Position Paper for Human Health CUGs (USACE 2012b), chemicals contributing greater than 5% but less than 10% to the SOR must be further evaluated before being eliminated as COCs.

The process for calculating FWCUGs rearranges cancer risk or non-cancer hazard equations in order to obtain a concentration that will produce a specific risk or hazard level (USEPA 1991, USACE 2010a). For example, the FWCUG for arsenic at the cancer risk level of 1E-05 for the Resident Receptor Adult is the concentration of arsenic that produces a risk of 1E-05 when using the exposure parameters specific to the Resident Receptor Adult.

For carcinogens, risk is expressed as the probability that an individual will develop cancer over a lifetime as a result of exposure to the carcinogen. Cancer risk from exposure to contamination is expressed as the increased chance of cancer above the normal background rate. In the United States, the background chance of contracting cancer is a little more than 3 in 10 for women and a little less than 5 in 10 for men, or 3E-01 to 5E-01 (American Cancer Society 2015). The calculated incremental lifetime cancer risks (ILCRs) are compared to the range specified in the NCP of 10^{-6} to 10^{-4}, or 1 in a million to 1 in 10,000 exposed persons developing cancer (USEPA 1990). Cancer risks below 10^{-6} are considered acceptable; cancer risks above 10^{-4} are considered unacceptable. The range between 10^{-6} and 10^{-4} is of concern, and any decisions to address risks further in this range, either through additional study or engineered control measures, should account for the uncertainty in the risk estimates. The Ohio EPA Division of Environmental Response and Revitalization (DERR) program has adopted a human health cumulative ILCR goal within this range of 1E-05 to be used as the level of acceptable excess cancer risk and for developing remediation goals for the site. The DERR notes that the defined risk goal should be applied as a goal, recognizing the need to retain flexibility during the evaluation and selection of remedial alternatives.

In addition to developing cancer from exposure to chemicals, an individual may experience other adverse effects. The term "adverse effects" is used to describe a wide variety of systemic effects ranging from minor irritations, such as eye irritation and headaches, to more substantial effects, such as kidney or liver disease and neurological damage. The risk associated with toxic (i.e., non-carcinogenic) chemicals is evaluated by comparing an estimated exposure (i.e., intake or dose) from AOC media to an acceptable exposure expressed as an RfD. The RfD is the threshold level below which no adverse effects are expected to occur in a population, including sensitive subpopulations. The ratio of intake over the RfD is the HQ (USEPA 1989).

The SOR is used to account for the potential additive effects from exposure to multiple chemicals that can cause the same effect (e.g., cancer) or affect the same target organ. Cancer risk is assumed to be additive for all carcinogens. Non-cancer risk is assumed to be additive for chemicals with similar sites of toxicological action (i.e., target organ such as liver or critical effect such as adversely affecting the ability to reproduce). This approach compares the EPC of each COPC to the FWCUG to determine a ratio. The sum of these individual ratios is then compared to one. The SOR method is based on the principle that a ratio greater than one represents unacceptable cumulative exposure (i.e., above FWCUGs if adjusted for exposure to multiple COPCs), and a ratio less than or equal to one represents acceptable cumulative exposure (i.e., below FWCUGs if adjusted for exposure to multiple COPCs). The FWCUGs for some chemical/receptor combinations are less than the background concentration. In these instances, chemical concentrations are compared to background concentrations to identify COCs. Since the background concentration is not risk-based, these chemicals are not included in the SOR calculations. COCs identified by comparing EPCs to FWCUGs are further evaluated in an uncertainty analysis to identify COCs requiring evaluation in the FS.

Selecting FWCUGs, calculating EPCs for comparison to FWCUGs, and the resulting risk-based COCs are detailed in the following sections.

7.2.4.1 <u>Selection of Appropriate FWCUGs</u>

As specified in the Technical Memorandum (ARNG 2014), EPCs for each AOC should initially be evaluated using the most stringent Resident Receptor (Adult and Child) FWCUGs to determine if no further action is necessary at an AOC to attain Unrestricted (Residential) Land Use. If this assessment indicates COCs exist that prevent Unrestricted (Residential) Land Use, an FS must be completed to evaluate cleanup options for all three Land Uses [i.e., Unrestricted (Residential) Land Use, Military Training Land Use, and Commercial/Industrial Land Use].

Unrestricted (Residential) Land Use is evaluated using FWCUGs for the Resident Receptor (Adult and Child). These FWCUGs, provided in Table 7-7 (for soil and sediment), are the lower of the Resident Receptor (Adult and Child) values for each COPC and endpoint (non-cancer and cancer). The critical effect or target organ associated with the toxicity values used to calculate the FWCUGs are also provided in this table.

The SLs provided in Table 7-7 for the Resident Receptor (Adult and Child) are the FWCUGs corresponding to a TR of 1E-05, target HQ of 1. If no FWCUG is available for a COPC, the residential RSLs, adjusted to represent a TR of 1E-05 or target HQ of 1, are used for the Resident Receptor.

Chromium Speciation

FWCUGs are available for hexavalent and trivalent chromium. Existing data at other AOCs, such as the Building 1200 and Anchor Test Area AOCs (USACE 2012c, USACE 2012a), indicate chromium exists predominantly in the trivalent state rather than the more toxic hexavalent state. Implementing the chromium speciation process per the PBA08 SAP is discussed below.

- **Hexavalent and total chromium sample collection and results** – To determine whether FWCUGs for trivalent or hexavalent chromium are most applicable to Wet Storage Area and to support risk management decisions, three discrete surface soil samples were collected and analyzed for hexavalent and total chromium. Three samples were collected in March 2010 per the PBA08 SAP. Two samples were collected from areas previously identified as having elevated total chromium concentrations, and one was collected from an area identified as having chromium concentrations near background concentrations. No hexavalent chromium was detected in two of the three samples. Hexavalent chromium was detected in the third sample at a concentration of 0.52 mg/kg. Total and hexavalent chromium results for these three samples are summarized in Table 7-8.
- **Percent hexavalent chromium in the chromium speciation samples** – As documented in the PBA08 SAP, "Chromium speciation evaluates the concentration ratio of hexavalent chromium to total chromium. This ratio will be calculated by collecting and analyzing three samples per AOC for both hexavalent chromium and total chromium." No hexavalent chromium was detected in two of the three chromium speciation samples collected at Wet Storage Area. Hexavalent chromium was detected in the third speciation sample at 0.52 mg/kg, which is 3.2% of the total chromium measured in this sample. The total chromium concentration in sample WSAss-031 (0.52 mg/kg) is well below the facility-wide background concentrations of 17.4 mg/kg in surface soil and 27.3 mg/kg in subsurface soil. The FWCUG for hexavalent chromium is based on a cancer unit risk factor (URF) calculated using a chromium mixture containing 14% hexavalent chromium and 86% trivalent chromium. The sample results are below the 14% hexavalent chromium used as the basis for the cancer URF, which was used to calculate the hexavalent chromium FWCUGs.
- **Comparing the concentration of hexavalent chromium detected in the chromium speciation samples to the residential RSL for hexavalent chromium** – The FWCUG for hexavalent chromium is more appropriately applied to total chromium because it was calculated from a cancer URF based on a chromium mixture containing 1/7 (14%) hexavalent

chromium (USEPA 2010). The residential RSL (3 mg/kg based on a TR of 1E-05) for hexavalent chromium is specific to hexavalent chromium (i.e., it has been adjusted for the chromium mixture used in the toxicity study). The concentration of hexavalent chromium in the chromium speciation samples (ranging from not detected to 0.52 mg/kg) is less than 3 mg/kg, indicating hexavalent chromium is not present above the residential RSL.

- **Comparing the concentration of total chromium to the FWCUG for trivalent chromium** – After implementing the chromium speciation process specified in the PBA08 SAP, hexavalent chromium was determined to be present at a very low concentration (i.e., below the residential RSL for hexavalent chromium), and the percent of hexavalent chromium is less than 14%. Therefore, hexavalent chromium is not of concern at Wet Storage Area, and the reported concentrations of total chromium were compared to the FWCUGs for trivalent chromium for identifying COCs at this AOC.

7.2.4.2 Exposure Point Concentrations for Comparison to FWCUGs

Surface Soil

Surface soil (0–1 ft bgs) at Wet Storage Area was characterized using ISM sampling. The ISM analytical result can provide a more reliable estimate of the average concentration for a decision unit but cannot be combined with analytical results from discrete samples (USACE 2009b). As noted in the *Technical and Regulatory Guidance for Incremental Sampling Methodology* (ITRC 2012), different objectives require different spatial scales for ISM sample areas.

Some objectives call for characterizing contaminant concentrations over a relatively large area (e.g., multiple acres) if the primary objective is to conduct a risk assessment to represent an exposure concentration within a human health exposure area. Other objectives focus on distinguishing concentration differences on a much smaller scale (e.g., within a few feet) to delineate potential remediation areas. In accordance with the PBA08 SAP, only small targeted ISM grid sampling was used to supplement historical data at Wet Storage Area. ISM sample areas at Wet Storage Area ranged from 0.02–0.08 acres for the 2004 data and from 0.07–0.41 acres for the 2010 data. Each of these ISM samples alone is too small to represent an EU. The ISM samples collected in 2004 were intended to represent the potential contaminant concentration in the areas most likely impacted by a release from the storage igloos. Samples were collected directly in front of the storage igloos; from the front corner of the igloos, near the drain spout; and in the ditch between the igloos (see Figures 5-1 through 5-4). The ISM samples collected in 2010 were designed to delineate each group of previous ISM samples and define a decision unit around those samples.

EPCs are intended to provide representative concentrations that a receptor might contact during the period of exposure. Exposure to surface soil was based on ISM samples. The ISM was used to determine an average concentration representative of the soil contained within a defined area (i.e., the “decision unit”). Therefore, individual ISM results were compared directly to the surface soil FWCUGs for the Wet Storage Area receptors.

Subsurface Soil

EPCs were calculated for the 1–13 ft bgs subsurface soil exposure depth using analytical results from the discrete samples presented in Table 7-2. Per the FWHHRAM, the EPC is either the 95% Upper Confidence Limit (UCL) of the mean or the MDC, whichever value is lowest. If the 95% UCL could not be determined, the EPC is the MDC.

Sediment

Two composite sediment samples, collected from the unnamed tributary, were used to characterize risks from exposure to sediment within Wet Storage Area. Because of the small number of samples, each sample was evaluated separately (i.e., the detected concentration of the COPC in the sample was used as the EPC for comparison to the FWCUG).

Surface Water

Two discrete surface water samples were collected from the unnamed tributary at the ingress and egress of the AOC. Because of the small number of surface water samples, each sample was evaluated separately (i.e., the detected concentration of the COPC in each sample was used as the EPC for comparison to the FWCUG).

7.2.4.3 Identification of COCs for Unrestricted (Residential) Land Use

Wet Storage Area COCs for Unrestricted (Residential) Land Use, as represented by the Resident Receptor (Adult and Child), are presented below.

COCs for Surface Soil (0–1 ft bgs)

The COC screening for surface soil for the Resident Receptor (Adult and Child) is detailed in Appendix G, Tables G-5 through G-8. Arsenic and five PAHs [benz(a,h)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were identified as COCs for the Resident Receptor (Adult and Child), as explained below:

COPCs with EPCs Lower than the Resident Receptor (Adult and Child) FWCUG: All aluminum, chromium, cobalt, and benzo(k)fluoranthene concentrations were lower than the Resident Receptor (Adult and Child) FWCUG.

COPCs with EPCs Exceeding the Resident Receptor (Adult and Child) FWCUG: Reported concentrations of arsenic, benz(a)anthracene, benzo(b)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene exceeded the FWCUG at one or more sample locations.

The reported concentrations of arsenic and PAHs [benz(a)anthracene, benzo(b)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] exceeded their FWCUGs for the Resident Receptor (Adult and Child) at one surface soil ISM location each. These exceedances are discussed below.

- **Arsenic** – The reported arsenic concentrations at nine ISM sample locations [ranging from 16–21 mg/kg) exceed the FWCUG of 4.25 mg/kg and the surface soil background concentration of 15.4 mg/kg. Mixing of soil during igloo demolition activities in 2003 (i.e., prior to the 2004 and 2010 sampling events) likely resulted in mixing of surface soil into the subsurface, thus blurring the distinction between surface and subsurface background concentrations and it is appropriate to compare soil concentrations to both surface and subsurface background concentrations. With the exception of WSAss-020M (21 mg/kg), the reported concentrations in all other 21 ISM samples are less than the subsurface soil background concentration (19.8 mg/kg). WSAss-020M was collected as part of the Characterization of 14 AOCs and is a small contingency ISM sample added to fulfill QA/QC requirements in December 2004 after completion of the planned 2004 sampling. This sample was collected near igloo WS-1A; however, the precise location and boundaries for this ISM area were not recorded. As the detected concentration in WSAss-020M is greater than the facility-wide subsurface soil background concentration and the FWCUG, arsenic is identified as a COC in surface soil at that location.
- **PAHs –** The reported concentrations of five PAHs [benz(a,h)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] in WSAss-004M, ranging from 0.94–8.2 mg/kg, exceeded their FWCUGs. The WSAss-004M ISM area is approximately 0.02 acres and represents the parking area at the end of the driveway in front of former igloo WS-1. Based on these results, benz(a,h)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene were identified as COCs in surface soil at WSAss-004M.

The EPCs for all other soil COPCs were less than their respective FWCUGs.

SOR analysis: No additional COPCs were identified as COCs based on the SOR analysis summarized below:

- Four COPCs (aluminum, arsenic, chromium, and cobalt) identified in surface soil have FWCUGs for non-cancer endpoints. Aluminum, arsenic, chromium, and cobalt were detected below the facility-wide surface and/or subsurface background concentrations at many ISM sample locations. Inorganic chemicals were not included in the SOR for samples where the detected concentration is less than the facility-wide surface or subsurface soil background concentrations. The total SORs (Table G-6), regardless of endpoint, were less than or equal to one; therefore, no additional COCs were identified using this analysis.
- Eight COPCs [arsenic, cobalt, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] identified in surface soil have FWCUGs for the cancer endpoint (as previously discussed, chromium was evaluated for non-carcinogenic effects as trivalent chromium). An SOR was calculated for these eight chemicals for each ISM sample (Table G-7) where at least two COPCs were contributing to the SOR. Arsenic and cobalt were detected below the facility-wide background

concentration for surface soil in most ISM sample locations. Cobalt and arsenic were not included in the SOR for samples where the detected concentration is less than the facility-wide surface or subsurface soil background concentrations. The SORs for sample location WSAss-004M was greater than one due largely to benzo(a)pyrene (in WSAss-020M), as noted below and in Appendix G, Table G-8.

  - The SOR for sample location WSAss-004M was 38, due primarily to benzo(a)pyrene. Benz(a,h)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene each contribute 5% or more to the SOR. Benz(a,h)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene were previously identified as COCs at this location; therefore, no additional COCs were identified based on the SOR analysis.

COCs in Subsurface Soil (1–13 ft bgs)

The COC screening for the subsurface soil exposure depth (1–13 ft bgs) for the Resident Receptor (Adult and Child) is detailed in Appendix G, Table G-9. No COCs were identified in the subsurface soil as COCs for the Resident Receptor (Adult and Child), as explained below:

COPCs with EPCs Lower than the Resident Receptor (Adult and Child) FWCUG***:*** The EPCs for cobalt and benzo(a)pyrene are lower than the FWCUGs for the Resident Receptor (Adult and Child).

COPCs with EPCs Exceeding the Resident Receptor (Adult and Child) FWCUG***:*** The EPC for arsenic (17.8 mg/kg) exceeds the FWCUG of 4.25 mg/kg but is less than the subsurface soil facility-wide background concentration of 19.8 mg/kg. Arsenic is not a COC for subsurface soil.

SOR Analysis: No COCs were identified by the SOR analysis. The SOR analysis is summarized below:

- Two COPCs identified in subsurface soil have FWCUGs for non-cancer effects (arsenic and cobalt). The EPCs for these COPCs are less than the background criteria; therefore, an SOR for non-cancer endpoints was not calculated.
- Three COPCs [arsenic, cobalt, and benzo(a)pyrene] identified in subsurface soil have FWCUGs for the cancer endpoint. The EPCs for arsenic and cobalt are less than the background criteria; therefore, these COPCs were not included in an SOR calculation. As benzo(a)pyrene was the only remaining COPC, an SOR for the cancer endpoint was not calculated.

COCs for Sediment

COC screening for sediment for the Resident (Adult and Child) Receptor is detailed in Appendix G, Table G-10. No COCs were identified in composite sediment samples because all detected concentrations of the COPCs manganese and benzo(a)pyrene were below FWCUGs.

SOR Analysis: No COCs were identified by the SOR analysis. The SOR analysis is summarized below:

- Only one COPC (manganese) identified in sediment has a FWCUG based on non-cancer effects; therefore, an SOR for non-cancer endpoints was not calculated.
- Only one COPC [benzo(a)pyrene] identified in sediment has a FWCUG for the cancer endpoint; therefore, an SOR for the cancer endpoint was not calculated.

COCs for Surface Water

No COPCs, and therefore, no COCs were identified for surface water at Wet Storage Area.

7.2.5 Uncertainty Assessment

The sources of uncertainty, as well as the potential bias they impart to the risk assessment (i.e., whether conservatism is increased or decreased) and approaches for minimizing their impact on the conclusions of the RI, are briefly discussed below.

7.2.5.1 Uncertainty in Estimating Potential Exposure

Sources of uncertainty in estimating potential human exposure include sampling and analysis limitations, comparing these limitations with background concentrations to identify SRCs, and estimating EPCs.

Sampling Limitations – Uncertainties arise from limits on the media sampled, the total number and specific locations that can be sampled, and the parameters chosen for analysis to characterize the AOC. Surface soil has been characterized using ISM sampling biased toward areas anticipated to have the highest level of potential contamination. The results of surface soil sampling were used to efficiently guide selection of locations for discrete subsurface soil sampling locations with a bias toward the areas of highest potential contamination. One ISM sample collected in 2004 was added to the samples originally planned at this AOC to meet QA/QC requirements. The precise location and size of this ISM sample was not recorded. This sample was analyzed for inorganic chemicals, SVOCs, and explosives. All inorganic chemical results were similar to the results of the other 21 surface soil samples included in the HHRA. Two SVOCs (pyrene and fluoranthene) were detected below their lowest FWCUGs and no explosives were detected. Therefore, including this sample in the risk assessment data set is a minor source of uncertainty.

In addition to the ISM samples, discrete samples are available from the 0–1 ft bgs interval of the soil borings used to evaluate subsurface soil. The results of these discrete samples were considered in the context of the ISM samples in which they were located. The results of the ISM and discrete sample evaluation are included in Table 7-9. The discrete sample results parallel the conclusions of the ISM samples. Two analytes [tetryl and bis(2-ethylhexyl)phthalate] were detected (0.026 and 0.084 mg/kg) in the discrete surface soil samples, but were not detected in the ISM samples. Both of these analytes were detected in only one sample each, well below their screening FWCUGs [16 mg/kg for tetryl and 39 mg/kg for bis(2-ethylhexyl)phthalate]. With the exception of arsenic, cadmium, copper, and iron, the MDCs of the chemicals in the discrete samples were less than the MDCs in ISM samples. The conclusions drawn from the ISM samples regarding arsenic, cadmium, copper, and iron are not changed by the discrete samples as noted below:

- Arsenic was detected in the discrete surface soil in one of eight samples (21.5 mg/kg in WSAsb-026) above the subsurface facility-wide concentration of arsenic (19.8 mg/kg). Arsenic was detected in 1 of 22 ISM surface soil samples (21.3 mg/kg in WSAss-020M) above the subsurface facility-wide concentration of arsenic. Discrete surface soil sample WSAsb-026 was collected from the approximate location of ISM surface soil sample WSAss-020M. Based on the ISM result, arsenic was identified as a COC in WSAss-020M. Because the concentrations in discrete sample WSAsb-026 and corresponding ISM sample WSAss-020M are essentially the same and arsenic was already identified as a COC with the ISM data, evaluation of the discrete data confirmed the identification of arsenic as a COC is appropriate.
- The MDCs of cadmium and iron (0.5 and 33,600 mg/kg) in the discrete samples were higher than the MDCs in the ISM (0.19 and 32,000 mg/kg); however, all of the detected concentrations in the discrete and ISM samples were below the screening FWCUGs (6.41 and 180,000 mg/kg). Because the MDCs were below the screening FWCUGs, the discrete data evaluation did not identify cadmium or iron as an additional COPC or COC.
- Copper was detected in five of eight discrete surface soil samples at concentrations (19.4–22.1 mg/kg) above the facility-wide background concentration for copper in surface soil (17.7 mg/kg) but below the facility-wide background concentration in subsurface soil (32.3 mg/kg). Copper was detected in 17 of 22 ISM samples at concentrations (18–21 mg/kg) above facility-wide surface soil, but below facility-wide subsurface soil background concentrations. All of the detected concentrations in the discrete and ISM samples were below the screening FWCUG (311 mg/kg). Because the MDC of the discrete sample was below the subsurface facility-wide background concentration and screening FWCUG for copper, the discrete data evaluation did not identify copper as an additional COPC or COC.

Analytical Limitations – Uncertainty is associated with the chemical concentrations detected and reported by the analytical laboratory. The quality of the analytical data used in the risk assessment was maximized and uncertainty was minimized by implementing QA/QC procedures that specify how samples are selected and handled; however, sampling errors, laboratory analysis errors, and data analysis errors can occur. Beyond the potential for errors, there is normal variability in analytical results.

Some current analytical methods are limited in their ability to achieve detection limits at or below risk-based SLs. Under these circumstances, it is uncertain whether the true concentration is above or below the SLs, which are protective of human health. When analytes have a mixture of detected and non-detected concentrations, EPC calculations may be affected by these detection limits. Risks may be overestimated as a result of some sample concentrations being reported as non-detected at the maximum detection limit (MDL), when the actual concentration may be much smaller than the MDL. Risks may also be underestimated if some analytes that were not detected in any sample were removed from the COPC list. If the concentrations of these analytes are below the MDL but are above the SL, the risk from these analytes would not be included in the risk assessment results.

Identifying SRCs – Part of determining SRCs is to identify chemicals detected above established RVAAP background concentrations. This screen does not account for potential sources of chemicals, and background concentrations are only available for inorganic chemicals.

Uncertainty associated with screening against background concentrations results from statistical limitations and natural variation in background concentrations. Because of these variations, inorganic chemical concentrations below the background concentration are likely representative of background conditions. Inorganic chemical concentrations above the background concentration may be above background conditions or may reflect natural variation. This is especially true for measured concentrations close to the background concentration.

At Wet Storage Area, eight inorganic chemicals (aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, and nickel) had MDCs in surface soil that were above but close to (i.e., less than two times) the background concentration. Cadmium, silver, and thallium had no background concentrations for comparison. Arsenic in subsurface soil and manganese in sediment also had MDCs that were 1.1–1.2 times the background concentration. The consequences of carrying most of these inorganic chemicals forward as SRCs, even if they actually represent background concentrations, is negligible because they are not toxic at near background concentrations. By contrast, naturally occurring arsenic and manganese in soil and sediment exceed risk-based FWCUGs. Therefore, the consequence of identifying arsenic or manganese as SRCs if they are, in fact, representative of background can have a significant impact on the conclusions of the risk assessment.

The MDCs of arsenic in surface and subsurface soil at Wet Storage Area were 21 and 21.3 mg/kg, respectively. The RVAAP background concentration for arsenic in surface soil is 15.4 mg/kg and in subsurface soil is 19.8 mg/kg. The MDCs of manganese in surface and subsurface soil at Wet Storage Area were 1,130 and 572 mg/kg, respectively. The RVAAP background concentration for manganese in surface soil is 1,450 mg/kg and in subsurface soil is 3,030 mg/kg. Because building demolition activities disturbed the soil, including removing surface soil and exposing subsurface soil at the surface, it is appropriate to compare surface soil sample results to subsurface background concentrations. Based on this information, arsenic and manganese appear to be present at Wet Storage Area at naturally occurring concentrations.

Other studies indicate arsenic may be naturally occurring in Ohio soil at greater than 20 mg/kg. For example, an environmental study of three locations in Cuyahoga County performed for Ohio EPA (Weston 2012) showed arsenic ranged from 4.6–25.2 mg/kg (22.9 mg/kg excluding statistical outliers) in surface soil (0–2 ft bgs) and 5.3–34.8 mg/kg (22.6 mg/kg excluding statistical outliers) in subsurface soil (2–4 ft bgs). In addition, Vosnakis and Perry (2009) published the results of arsenic concentration studies that included 313 samples of Ohio soil. Naturally occurring arsenic in these samples ranged from 1.6–71.3 mg/kg with 95th percentiles of 21.7 mg/kg in surface soil, 25.5 mg/kg in subsurface soil, and upper tolerance limits of 22.8 mg/kg for surface soil and 29.6 mg/kg for subsurface soil. In other studies, native soil concentrations of arsenic in Ohio have been reported as ranging from 0.5–56 mg/kg (Ohio EPA 1996), and the U.S. Geological Survey's Certificate of Analysis of the Devonian Ohio Shale estimates arsenic concentrations of 68.5 mg/kg are naturally present in bedrock shale (USGS 2004).

Based on this information, arsenic appears to be present at Wet Storage Area at naturally occurring concentrations.

Background concentrations of manganese in soil and sediment are not as well studied as arsenic. The RVAAP site-specific background concentrations of manganese are 1,450 mg/kg in surface soil, 3,030 mg/kg in subsurface soil, and 1,950 mg/kg in sediment. The maximum detected manganese concentrations at Wet Storage Area are 1,130 mg/kg in surface soil, 572 mg/kg in subsurface soil, and 2,270 mg/kg in sediment. There are no sources of arsenic or manganese at Wet Storage Area, and the detected concentrations at this AOC likely represent natural variation in background concentrations.

Organic chemicals were not screened against background concentrations even though some organic compounds are present in the environment as a result of natural or human activities not related to the CERCLA releases at the AOC. For example, PAHs are present in the environment as a result of burning fossil fuels and as a component of road dust, vehicle exhaust, tire wear particles, pavement, and slag used as railroad ballast and fill. Samples collected near roadways or parking areas may represent normal "urban" sources of PAHs. These issues represent significant sources of uncertainty at sites where low levels of PAHs are found over large areas of the AOC. At Wet Storage Area, PAHs were detected across the entire AOC; one or more PAHs were detected in 6 of 6 surface soil ISM samples and 2 of 19 discrete subsurface soil samples analyzed for SVOCs. PAH concentrations were less than the Resident Receptor (Adult and Child) FWCUGs in all but one surface soil sample locations (WSAss-004M) where concentrations were up to 25 times the FWCUG of 0.221 mg/kg for benzo(a)pyrene and 4.2 times the FWCUG of 0.221 mg/kg for dibenz(a,h)anthracene.

Although no background concentrations for PAHs were established for RVAAP, the *Phase II Remedial Investigation Report for Winklepeck Burning Grounds* (USACE 2001b), which established the background concentrations for inorganic chemicals, included characterizing naturally occurring background metal concentrations in surface and subsurface soil at Camp Ravenna using samples from outside the process areas. Surface soil samples were collected at 15 locations on the eastern half of Camp Ravenna. These background locations were chosen using aerial photographs and site visits with the concurrence of Ohio EPA and USACE to reflect areas not impacted by RVAAP activities and to establish background values that are unaffected by any human activity. The background locations were situated upgradient and generally upwind of known or suspected contaminant sources.

Background sampling was conducted in April and May 1998. All background samples were analyzed for TAL metals, cyanide, and SVOCs. Two of the background samples were also analyzed for VOCs and pesticides/PCBs. The background soil sampling effort established concentrations for naturally occurring metals in soil at RVAAP.

In establishing the background concentrations for naturally occurring metals, data were screened to identify outliers in the inorganic chemical results. Ohio EPA guidance (Comment Resolution Meeting, December 2, 1998) called for using upper and lower cutoff limits based on quartiles to identify outliers. The upper cutoff limit is the third quartile (75th percentile) plus one and a half times the interquartile range. All results that exceeded the upper cutoff limit were examined to determine if the results should be used in establishing the background concentrations for naturally occurring metals. Outliers were removed so that background values would most nearly represent natural conditions and exclude human disturbance whether from RVAAP or pre-RVAAP activities.

Statistical outliers were identified in 5 surface soil and 15 subsurface soil samples. All analytical results for four of these samples [BKGss-011(b)-0794-SO, BKGss-012(b)-0795-SO, BKGss-015(b)-0798-SO, and BKGss-005(b)-0788-SO] were removed from the surface soil background data set.

The primary reason for eliminating these four samples from the surface soil background data set was that PAHs were elevated and these sampling locations were near pre-existing homes or farms and could have been influenced by activities associated with those structures (e.g., burning wood and fossil fuels, vehicle exhaust, or building materials such as slag used as fill or tar paper and shingles). The other 11 outlier samples were not excluded from the background calculations primarily because no SVOCs were detected in those samples and thus the outliers did not appear to be associated with human activities.

Concentrations of PAHs in surface soil at Camp Ravenna associated with pre-RVAAP anthropogenic sources calculated from the 15 RVAAP background surface soil samples are shown in Table 7-10. Since the purpose here is to identify PAH levels associated with anthropogenic activities unrelated to CERCLA releases from operations at RVAAP, it is appropriate to include all 15 background samples in these calculations.

The following criteria were used per the method used in establishing the background concentrations for naturally occurring metals (USACE 2001b):

- For analytes with a frequency of detection greater than 50%, a distribution (determined using the Shapiro-Wilk test) that is neither normal nor log-normal, and a sample size of 59 or less, the maximum result represents the nonparametric 95% upper tolerance limit and was identified as the background concentration for naturally occurring metals. These conditions apply to four of the PAHs detected in background samples [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and chrysene].
- For analytes with a frequency of detection between 0 and 50% with a sample size of 15, the maximum result represents the 99th percentile value and was identified as the background concentration for naturally occurring metals. These conditions apply to the remainder of the PAHs detected in background samples.

These results demonstrate the large variability in environmental concentrations of PAHS. For example, benzo(a)pyrene was detected in 8 of 15 background surface soil samples at concentrations ranging from 0.058–3.7 mg/kg.

Other studies of environmental concentrations of PAHs in Ohio soil show similar variability. For example, in the environmental study of three locations in Cuyahoga County performed for Ohio EPA (Weston 2012), PAHs were detected in only 1 of 36 surface soil samples with a reported concentration of benzo(a)pyrene of 1.33 mg/kg. Aerial photographs indicate this sample was collected near an old road or trail, but no other sources of PAHs are apparent.

In addition to these RVAAP and Cuyahoga County studies, numerous other environmental studies have been conducted that examine environmental levels of PAHs in rural and urban surface soil (e.g., ATSDR 1995, Bradley et al. 1994, IEPA 2005, MADEP 2002, and Teaf et al. 2008). Reported minimum, maximum, and 95th percentile concentrations of benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene from numerous studies are shown in Table 7-11. These studies further demonstrate the high variability in environmental levels of PAHs within a single study area and among multiple studies.

The lack of established RVAAP background concentrations for identifying SRCs for PAHs is a source of uncertainty. Evaluating potential RVAAP process-related sources and other common anthropogenic (non-CERCLA) sources using available PAH environmental data minimizes the impact of this uncertainty on the conclusions of the RI (see Section 7.2.6).

Exposure Point Concentrations – Surface soil was characterized using ISM. ISM is used to determine an average concentration representative of the soil contained within an ISM sample location (i.e., the “decision unit”). For ISM samples, 30–50 aliquots of surface soil are generally collected from random locations within a decision unit and combined into a single sample. Using ISM reduces the uncertainty associated with estimating a statistical average concentration within a decision unit. However, due to the small size of the ISM sample areas at Wet Storage Area, the individual ISM sample results, while representative of the area sampled, are not representative of exposure concentrations across an EU for the receptors evaluated. ISM data were used to represent EPCs for surface soil based on the assumption that the samples collected were random samples from an exposure area. This assumption is not true for Wet Storage Area where sample locations were biased to identify areas of highest chemical concentrations, the sampled areas were small (0.02–0.08 acres for the 2004 data and 0.07–0.41 acres for the 2010 data), and the FWCUGs assume all exposure occurs within these elevated sampled areas. For ISM samples to yield representative EPCs, the sampling area should encompass an area approximately equal to the probable future-use exposure area. Smaller ISM sampling areas, particularly those biased toward areas anticipated to have the highest level of potential contamination, do not yield an EPC that represents realistic exposure concentrations. Therefore, EPCs generated from these data are likely to represent an overestimate of potential exposure concentrations.

Soil data at Wet Storage Area were aggregated into surface and subsurface soil as described in Section 7.1.1. Based on AOC characteristics and the operational constraints during its use, the sample coverage to define nature and extent of operationally impacted areas of the AOC is adequate.

EPCs were calculated for the 1–13 ft bgs sample intervals using analytical results from the discrete samples listed in Table 7-2. At Wet Storage Area, subsurface soil samples were collected only from historical ISM areas with screening criteria exceedances to further delineate the vertical extent of contamination. Soil borings for discrete samples were located in areas of highest potential contamination based on previous sampling results, resulting in calculated EPCs that provide conservative estimates of exposure concentrations across the EU.

In addition to calculating EPCs for subsurface soil, individual discrete sample results above FWCUGs were evaluated to identify whether potential hot spots are present as a result of specific source areas.

The EPCs of arsenic, cobalt, and benzo(a)pyrene are less than FWCUGs, but the MDC of arsenic exceeds the FWCUG at Wet Storage Area for the Resident (Adult and Child). This result is described below.

Arsenic – The MDC of arsenic at Wet Storage Area is 21.3 mg/kg in subsurface soil (1–13 ft bgs). The RVAAP background concentration for arsenic in subsurface soil is 19.8 mg/kg. The reported arsenic concentration in 1 of 22 surface soil (WSAss-020M) and 1 of 19 subsurface soil samples (WSAsb-026, collected in the approximate area of ISM sample WSAss-020M) exceeds 19.8 mg/kg. As noted previously, regional studies indicate arsenic may be naturally occurring in Ohio soils at greater than 20 mg/kg. Arsenic appears to be present at Wet Storage Area at naturally occurring concentrations and there is no known source of arsenic at Wet Storage Area. Based on this evaluation, arsenic does not represent a hot spot and is not identified as a COC.

There is some evidence that using stainless steel grinding blades when processing ISM samples could contribute chromium and nickel to the ISM soil samples. However, neither of these metals were identified as COCs at Wet Storage Area; therefore, the impact of the potential contribution from grinding is minimal.

7.2.5.2 Uncertainty in Use of FWCUGs

Sources of uncertainty in the FWCUGs used to identify COCs include selecting appropriate receptors and exposure parameters, exposure models, and toxicity values used in calculating FWCUGs.

Selection of Representative Receptors – Wet Storage Area is not currently used for training. While residential Land Use is unlikely, an evaluation using Resident Receptor (Adult and Child) FWCUGs is included to provide an Unrestricted (Residential) Land Use evaluation as required by CERCLA and the Army. As stated in Paragraph 6.d of the Technical Memorandum (ARNG 2014), if an AOC fails to meet the Unrestricted (Residential) Land Use, then all three Land Uses [i.e., Unrestricted (Residential) Land Use, Military Training Land Use, and Commercial/Industrial Land Use] will be evaluated.

Exposure Parameters and Exposure Models – For each primary exposure pathway included in the FWCUGs, assumptions are made concerning the exposure parameters (e.g., amount of contaminated media a receptor can be exposed to and intake rates for different routes of exposure) and the routes of exposure. Most exposure parameters have been selected so that errors occur on the side of human health protection. When several of these upper-bound values are combined in estimating exposure for a pathway, the resulting risk can be in excess of the 99th percentile and, therefore, outside of the range that may be reasonably expected. Thus, the consistent selection of upper-bound parameters generally leads to overestimation of the potential risk.

Toxicity Values – The toxicity of chemicals is under constant study and values change from time to time. The toxicity values used in calculating FWCUGs were the most recent values available at the time (September 2008). These values are designed to be conservative and provide an upper-bound estimate of risk.

The toxicity and mobility of many inorganic chemicals in the environment is dependent on the chemical species present. Two important examples are arsenic and chromium. The toxicity values used in developing the FWCUGs are for inorganic arsenic, and do not distinguish between arsenite and arsenate. Chromium is generally present in the environment as either the trivalent (Cr+3) or hexavalent (Cr+6) species, with the trivalent form generally being more stable and, therefore, more common. FWCUGs are available for hexavalent chromium and trivalent chromium.

Trivalent chromium has not been shown to be carcinogenic. It is an essential micronutrient but can also be toxic at high doses (i.e., above the RfD used to calculate the FWCUG). The FWCUGs for trivalent chromium are based on non-cancerous effects. Hexavalent chromium is much more toxic than trivalent chromium. It is classified as a "known human carcinogen" and may also cause non-cancerous effects. The cancer URF for hexavalent chromium published in USEPA's Integrated Risk Information System (IRIS) is based on epidemiological data on lung cancer in workers associated with chromate production. Workers in the chromate industry are exposed to trivalent and hexavalent compounds of chromium. The cancer mortality in the study used to establish the URF was assumed to be due to hexavalent chromium. It was further assumed that hexavalent chromium constituted no less than 1/7 of the total chromium in air to which the workers were exposed. As noted in IRIS, the assumption that the ratio of hexavalent to trivalent chromium was 1:6 in this study may lead to a seven-fold underestimation of risk when using this URF to evaluate exposure to hexavalent chromium alone.

To avoid the underestimation of risk, selecting the FWCUG for chromium includes a step that compares the maximum concentration of hexavalent chromium detected in chromium speciation samples to the residential RSL for hexavalent chromium. The detected concentrations of hexavalent chromium in the chromium speciation samples are less than the residential RSL for hexavalent chromium, and support using the trivalent chromium FWCUGs for evaluating total chromium results. Using speciation samples to identify the appropriate FWCUG minimizes the associated uncertainty.

FWCUGs Below Background Concentrations – One purpose of the HHRA process is to identify COCs and cleanup goals for evaluating remedial alternatives for remediating residual contamination that has resulted from process operations at the AOC. The FWCUGs are risk-based values. In some cases, natural or anthropogenic background concentrations, unrelated to process operations, exceed the risk-based FWCUGs. For naturally occurring inorganic chemicals, this problem is addressed by using the background concentration as the cleanup goal. This introduces uncertainty in the chosen cleanup goal because there is uncertainty in assigning a specific value to background, which can be highly variable.

No background concentrations are available for organic chemicals, although PAHs are often present in the environment from natural and anthropogenic sources and regulatory standards are often much lower than baseline levels of PAHs in urban and rural surface soil, especially near areas of vehicle traffic (e.g., roads and parking areas). Given their frequent presence in environmental media, and especially in areas influenced by vehicle exhaust and tire particles, it is important to compare risk-based cleanup levels with typical environmental concentrations before utilizing unrealistically low cleanup targets. Numerous studies have been conducted that examine ambient levels of PAHs in rural and urban surface soil (e.g., ATSDR 1995, Bradley et al. 1994, MADEP 2002, and Teaf et al. 2008). These studies indicate that given the multitude of non-point mobile sources for PAHs, it is not uncommon for ambient concentrations to exceed health-based regulatory recommendations. Some states have begun to consider ambient anthropogenic levels by establishing minimum SLs based on environmental studies. For example, the New York State Department of Environmental Conservation has established a minimum soil cleanup objective of 1 mg/kg for benz(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene and 0.1 for dibenz(a,h)anthracene based on the 95th percentile concentrations of these PAHs in rural areas near roads (NYSDEC 2006).

7.2.5.3 Uncertainty in the Identification of COCs

All of the sources of uncertainty described in the previous sections potentially impact the identification of COCs. The exposure and toxicity values used to calculate FWCUGs and RSLs as well as the approach for identifying SRCs, COPCs, and ultimately COCs based on the FWCUGs and RSLs were designed to ensure the over rather than underestimation of potential risk. The uncertainty assessment attempts to put the identified COCs in perspective to facilitate informed risk management decisions for the AOC.

The SOR is used to account for the potential additive effects from exposure to multiple chemicals that can cause the same effect or affect the same target organ. Cancer risk is assumed to be additive for all carcinogens. Non-cancer risk is assumed to be additive for chemicals with similar sites of toxicological action. In the event that any combination of COPCs results in synergistic effects, risk might be underestimated. Conversely, the assumption of additivity would overestimate risk if a combination of COPCs acted antagonistically. It is unclear whether the potential for chemical interaction has been inadvertently understated or overstated. It seems unlikely that the potential for chemical interaction contributes significant uncertainty to the conclusions of the risk assessment.

7.2.6 Identification of COCs for Potential Remediation

COCs were identified in Section 7.2.4 as any COPC having an EPC greater than a FWCUG for a given receptor or any COPC contributing significantly to an SOR greater than one. For inorganic chemicals with FWCUGs below background concentrations, the background concentration was used as the point of comparison. The TR for the FWCUGs used to identify COCs is 1E-05 per the Ohio EPA DERR program, which has adopted a human health cumulative ILCR goal of 1E-05 to be used as the level of acceptable excess cancer risk and for developing site remediation goals.

The results of the COC screening (Section 7.2.4) are combined with the results of the uncertainty assessment (Section 7.2.5) to identify COCs to be carried forward for potential remediation.

COCs for Potential Remediation: Surface Soil (0–1 ft bgs)

Arsenic and five PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were identified as COCs for the Resident Receptor (Adult and Child) in surface soil are described below:

- **Arsenic –** Arsenic was identified as a surface soil COC exceeding the FWCUG and surface and subsurface background criteria in ISM sample WSAss-020M, collected near igloo WS-1A. The detected concentration (21 mg/kg) just slightly exceeded the facility-wide subsurface soil background concentration (19.8 mg/kg). The reported arsenic concentration in the larger ISM sample (WSAss-036M) collected in 2010 to delineate the southwest portion of Wet Storage Area (which surrounds the approximate location of WSAss-020M) was 14.8 mg/kg. Arsenic is a common element in Ohio soil and values exceeding 20 mg/kg are not uncommon (ODNR 2010). Naturally occurring arsenic in a study of 313 samples of Ohio soil ranged from 1.6–71.3 mg/kg with 95th percentiles of 21.7 mg/kg in surface soil (Vosnakis and Perry 2009). There is no known operational source for arsenic associated with this AOC. Based on the low magnitude of exceedance of the facility-wide subsurface soil background concentration, concentration below the facility-wide surface and subsurface background concentrations of the surrounding ISM, regional Ohio background concentrations, and absence of an operational source, arsenic is not identified as a COC for potential remediation for the Resident (Adult and Child) in Wet Storage Area.
- **PAHs** – Five PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were identified as surface soil COCs exceeding their FWCUGs and contributing to an SOR greater than one in Wet Storage Area surface soil at ISM sample location WSAss-004M. Since ISM samples represent an average concentration across the area sampled, no statistical analysis of ISM data was conducted (i.e., the detected concentration in each ISM sample was compared directly to FWCUGs). However, the ISM sample areas at Wet Storage Area range from 0.02–0.08 acres for the 2004 data and from 0.07–0.41 acres for the 2010 data. Each of these ISM samples alone is too small to represent a residential EU. The ISM samples collected in 2004 were intended to represent the potential contaminant concentration in the areas most likely impacted by a release from the igloo. The ISM samples collected in 2010 were designed to delineate each group of previous ISM samples and define a decision unit around those samples. The WSAss-004M ISM area is approximately 0.02 acres and represents the parking area at the end of the driveway in front of former igloo WS-1. It is one of eight ISM samples collected in the vicinity of igloos WS-1 and WS-1A. However, only two of the eight samples (WSAss-004M and WSAss-036M) were analyzed for PAHs because no PAH-containing material was used or stored at the AOC, and nothing was burned there. The PAH concentrations reported at WSAss-004M likely represent diesel and gasoline engine exhaust particles from trucks idling in front of the storage igloo. Sample WSAss-036M was collected in March 2010 to define the lateral extent of contamination in this area. Sample WSAss-036M defines the area around igloos WS-1 and WS-1A, including the area of sample WSAss-004M (Figure 5-3). As noted previously, the decision unit should not be smaller than the anticipated exposure area. The PAH concentrations reported in WSAss-036M (ranging from not detected to 0.033 mg/kg) are more representative

of the larger EU area and are below FWCUGs for the Resident (Adult and Child). These sample results are not indicative of an operations-related point source of PAHs and may represent background concentrations for PAHs. Due to the low PAH concentrations reported in surrounding sample WSAss-036M and the absence of an identified source of PAHs other than roads, vehicle exhaust, and building debris, PAHs were not identified as COCs for potential remediation.

COCs for Potential Remediation: Subsurface Soil, Surface Water and Sediment

No COCs were identified for the Resident Receptor (Adult and Child) in subsurface soil, surface water, or sediment.

7.2.7 Summary of HHRA

This HHRA documents COCs that may pose potential health risks to human receptors resulting from exposure to contamination at Wet Storage Area. This HHRA was conducted as part of the RI and was based on the streamlined approach described in the FWCUG Report (USACE 2010a), Position Paper for Human Health CUGs (USACE 2012b), and Technical Memorandum (ARNG 2014). The components of the risk assessment (receptors, exposure media, EPCs, and results) are summarized below.

Receptors – Camp Ravenna is a controlled-access facility. Wet Storage Area is located in the central portion of the facility and is not currently used for training. Three Land Uses for the RVAAP restoration program are specified in the Technical Memorandum (ARNG 2014) for consideration in the RI along with their Representative Receptors. Unrestricted (Residential) Land Use [Resident Receptor (Adult and Child)] is considered protective for all three Land Uses at Camp Ravenna. Therefore, if an AOC meets the requirements for Unrestricted (Residential) Land Use, then the AOC is also considered to have met the requirements of the other Land Uses (i.e., Commercial/Industrial and Military Training).

Exposure Media – Media of concern at Wet Storage Area are surface and subsurface soil, sediment, and surface water.

Exposure Point Concentration – For surface soil (0–1 ft bgs), the EPC is the detected concentration in each ISM sample collected at Wet Storage Area. For the subsurface soil (1–13 ft bgs) depth interval, EPCs were calculated using analytical results from discrete soil boring samples listed in Table 7-2. The EPC was either the 95% UCL of the mean or the MDC, whichever value is lowest. If the 95% UCL could not be determined, the EPC is the MDC. The limited number of sediment and surface water samples were evaluated individually (i.e., the number of samples was too small to calculate 95% UCLs).

Results of Human Health Risk Assessment – No COCs were identified for potential remediation for soil, sediment, or surface water at Wet Storage Area.

7.3 ECOLOGICAL RISK ASSESSMENT

7.3.1 Introduction

The ERA presented in this report follows a unified approach of methods integrating Army, Ohio EPA, and USEPA guidance. This ERA approach is consistent with the general approach by these agencies and primarily follows the Level I Scoping ERA, Level II Screening ERA, and Level III baseline ecological risk assessment (BERA) outlined in the *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2008), with specific application of components from the FWERWP, *Risk Assessment Handbook Volume II: Environmental Evaluation* (USACE 2010b), and *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997). The process implemented in this report combines these guidance documents to meet requirements of the Ohio EPA and Army, while following previously accepted methods established for RVAAP. This unified approach resulted from coordination between USACE and Ohio EPA during the summer of 2011.

7.3.1.1 Scope and Objective

Wet Storage Area contains habitat that supports ecological receptors. These terrestrial and aquatic habitats have known chemical contamination (MKM 2007). Habitat types and an assessment of the ecological resources found at Wet Storage Area are presented in subsequent subsections. Additionally, the results of a historical ERA (an ERS performed as part of the Characterization of 14 AOCs) and the PBA08 RI are provided to determine whether a qualitative ERA (Level I) is sufficient, based on the quality of the habitat and the presence of contamination, or whether a more rigorous ERA (Level II or III) should be conducted.

7.3.2 Level I: Scoping Level Ecological Risk Assessment

The ERA method for Level I follows guidance documents listed in Section 7.3.1. Level I is intended to evaluate if the AOC had past releases, the potential for current contamination, and if there are important ecological resources on or near the AOC.

The following two questions should be answered when the Level I ERA is complete:

1. **Are current or past releases suspected at the AOC?** Current or past releases are determined by evidence that chemical contaminants or COPECs are present.
2. **Are important ecological resources present at or in the locality of the AOC**? Important ecological resources are defined in the *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2008) and *Technical Document for Ecological Risk Assessment: Process for Developing Management Goals* (BTAG 2005).

If an AOC has contaminants but lacks important ecological resources, the ERA process can stop at Level I. Contamination and important ecological resources must both be present to proceed to a Level II Screening Level ERA.

7.3.2.1 AOC Description and Land Use

Wet Storage Area is approximately 36 acres. Important aquatic resources exist on the AOC, including wetlands and an unnamed tributary to Sand Creek. The habitat is mostly shrubland and forest, and the size of the habitat is large enough to completely support cover and food for small birds and mammals that typically require approximately 1 acre (USEPA 1993). The habitat area at Wet Storage Area represents 0.16% of the 21,683 acres at Camp Ravenna.

Future use at Wet Storage Area is anticipated to be within the Military Training or Commercial/Industrial Land Use scenarios.

7.3.2.2 Evidence of Historical Chemical Contamination

The 1978 Installation Assessment identified the major contaminants of the former RVAAP to be TNT, composition B, sulfates, nitrates, lead styphnate, and lead azide. Additional site-specific contaminants at Wet Storage Area include explosives and propellants, heavy metals (arsenic, chromium, lead, and mercury), and PAHs from potential diesel use at Generator House PS-7. The evaluation of historical chemical contamination is not limited to these chemicals; rather, this evaluation is expanded to include all eligible chemical data that are available.

The goal of the historical ERA (MKM 2007) was to identify COPECs in soil for Wet Storage Area. The historical ERA followed instructions presented in the *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2003) and consisted of the first two of six steps listed in Figure III of the FWERWP (USACE 2003a). These two steps identify the evaluation procedures, which were used to determine AOC-related COPECs. First, the MDC of each chemical was compared to its respective facility-wide background concentration. Chemicals were not considered COPECs if the MDC was below the background concentration. For all chemicals detected above background concentrations, the MDC was compared to an ESV. The hierarchy of screening values was based on the guidance included in the FWERWP and *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2003). In addition to the ESV comparison, it was determined if the chemical was a persistent, bioaccumulative, and toxic (PBT) compound. Chemicals were retained as COPECs if they exceeded background concentrations and the ESV, if the chemical exceeded background concentrations and had no toxicity information, or if the chemical was a PBT compound.

Groundwater was not included in the historical ERA. As explained in Section 3.2.2 of the FWERWP, groundwater is not considered an exposure medium to ecological receptors because these receptors are unlikely to contact groundwater greater than 5 ft bgs. As discussed in Section 3.4.2, groundwater occurs at the nearest monitoring well at approximately 20 ft bgs. In addition, sediment and surface water were not characterized at Wet Storage Area during the historical ERA.

The historical ERA table for soil is included in Appendix H, Table H-1 and contains the following:

- Frequency of detection,
- Average concentration,
- MDC,
- Background concentration,
- SRC determination,
- ESVs used for COPEC determinations,
- Comparison of MDC to ESV,
- PBT compound identification,
- COPEC determination, and
- COPEC rationale.

Historical COPECs for Soil – The historical ERA conducted as part of the Characterization of 14 AOCs reported 45 chemicals detected in surface soil (0-1 ft bgs) at Wet Storage Area (MKM 2007). Of the 45 chemicals detected, four chemicals (calcium, magnesium, potassium, and sodium) were essential nutrients and were excluded from the COPEC screen. A total of 15 inorganic chemicals and 24 organic chemicals were determined to be SRCs because they either exceeded background concentrations or did not have an associated background concentration for comparison. Seven inorganic chemicals (arsenic, chromium, iron, lead, mercury, nickel, and zinc) and eight organic chemicals [beta-BHC, benz(a)anthracene, benzo(a)pyrene, carbazole, chrysene, dibenzofuran, 3-nitrotoluene, and nitrocellulose] were identified as COPECs because detected concentrations were above ESVs (Table 7-11), or there were no ESVs for comparison.

Historical COPECs for Sediment – No historical sediment samples were collected at the AOC.

Historical COPECs for Surface Water – No historical surface water samples were collected at the AOC.

Summary of Historical ERA – As explained previously, a historical ERA was performed to determine COPECs at Wet Storage Area in surface soil. The COPECs are summarized in Table 7-11. Based on the identified COPECs, ecological risk in surface soil was predicted in the historical investigation, and an additional investigation was recommended for Wet Storage Area (MKM 2007).

7.3.2.3 Ecological Significance

Sources of data and information about the ecological resources at Wet Storage Area include the *Integrated Natural Resources Management Plan* (INRMP) (OHARNG 2014), *Facility-wide Biological and Water Quality Study* (USACE 2005b), previous characterization work (e.g., Characterization of 14 AOCs), and visits to Wet Storage Area conducted for the PBA08 RI.

One of the two key questions to answer in the Level I Scoping ERA is whether there are ecologically important and especially ecologically significant resources at Wet Storage Area. Ecological importance is defined as a place or resource that exhibits unique, special, or other attributes that makes it of great value. Ecological significance is defined as an important resource found at an AOC or in its vicinity that is subject to contaminant exposure.

The underlying basis for this distinction can be found in *Ecological Significance and Selection of Candidate Assessment Endpoints* (USEPA 1996b), and is stated as follows:

> "A critical element in the ERA process requires distinguishing important environmental responses to chemical releases from those that are inconsequential to the ecosystem in which the site resides: in other words, determining the ecological significance of past, current, or projected site-related effects."

Important places and resources identified by the Army and Ohio EPA (Appendix H, Table H-2) include wetlands, terrestrial areas used for breeding by large or dense aggregations of animals, habitat known to be used by threatened or endangered species, state land designated for wildlife or game management, locally important ecological places, and state parks. The Army and Ohio EPA recognize 17 important places and resources. The Army recognizes an additional 16 important places (BTAG 2005), and the Ohio EPA recognizes another 6 important places (Ohio EPA 2008). In total, there are 39 important places. Presence or absence of an ecologically important place can be determined by comparing environmental facts and characteristics of Wet Storage Area with each of the important places and resources listed in Appendix H, Table H-2.

Ecological significance is defined as an important resource found at an AOC or in its vicinity that is subject to contaminant exposure. Thus, any important places and resources listed in Appendix H, Table H-2 are elevated to ecologically significant when present on the AOC and there is exposure to contaminants. For all 39 important places and resources, it is relatively clear that the ecological place or resource is either present or absent on the AOC; therefore, the decision process is objective. If no important or significant resource is present at an AOC, the evaluation will not proceed to Level II regardless of the presence of contamination. Instead, the Level I Scoping ERA would acknowledge that there are important ecological places, but that those resources are not ecologically significant, and no further evaluation is required.

Management Goals for the AOC – Regardless of whether the evaluation is concluded at Level I or continues to Level II, there is another level of environmental protection for Wet Storage Area through the natural resource management goals expressed in the INRMP (OHARNG 2014). OHARNG manages the ecological and natural resources at Camp Ravenna to maintain or enhance the current integrity of the natural resources and ecosystems at the facility. Natural resource monitoring and management activities in place at Camp Ravenna may also be applicable to any degradation noted from contamination.

Some natural resources management goals of OHARNG (listed in Appendix H, Table H-3) benefit Wet Storage Area. For example, Goal 1 states the natural resources need to be managed in a compatible way with the military mission, and Goal 5 requires the Army to sustain usable training lands and natural resources. These management goals help detect degradation (whether from training activities or historical contamination). While the applicability of the remaining 10 management goals to Wet

Storage Area varies, all of the management goals are intended to monitor, maintain, or enhance the Camp Ravenna and RVAAP natural resources and ecosystem. While these goals are for managing all types of resources at and near Wet Storage Area, they do not affect decisions concerning the presence or absence of important or significant ecological places or resources at Wet Storage Area.

Important Places and Resources – Ecological importance means a place or resource that exhibits a unique, special, or other attribute that makes it of great value. Examples of important places and resources include wetlands, terrestrial areas used for breeding by large or dense aggregations of animals, and habitat of rare species. An important resource becomes significant when found on an AOC and there is contaminant exposure. The unnamed tributary to Sand Creek and the wetlands are important/significant ecological resources at Wet Storage Area.

Terrestrial Resources – Wet Storage Area is dominated by terrestrial resources, as described below.

Habitat Descriptions and Species. The INRMP and SAIC scientist visits indicated Wet Storage Area consists of two vegetation types (Figure 7-1). The AOC is dominated by a temporarily flooded forest alliance consisting of green ash (*Fraxinus pennsylvanica),* American elm (*Ulmus americana*), and hackberry (*Celtis occidentalis* and *laevigata*) (Figure 7-1 and Photograph 7-1) in the western portion of the habitat area and dry, mid-successional, cold-deciduous shrubland (Photograph 7-2) in the eastern portion of the habitat area. This characterization was originally established by a vegetation study using aerial photography and field verification (USACE 1999) and was later used in the INRMP (OHARNG 2008).

Photograph 7–1. Tributary to Sand Creek in Western Part of the Habitat Area (photograph taken May 17, 2010)

Photograph 7–2. Habitats in the Eastern Part of the Habitat Area (photograph taken August 12, 2008)

SAIC scientists conducted a field survey at Wet Storage Area in May 2010 and identified three main habitat types: temporarily flooded forest alliance consisting of green ash (*Fraxinus pennsylvanica),* American elm (*Ulmus americana*), and hackberry (*Celtis occidentalis* and *laevigata*); dry, mid-successional, cold-deciduous shrubland; and mixed-deciduous, successional forest habitat. The shrubland habitat has declined over the last decade, while the mixed-deciduous successional forest community has increased. The area occupied by the temporarily flooded forest alliance community has remained approximately the same.

The green ash (*Fraxinus pennsylvanica),* American elm (*Ulmus americana*), and hackberry (*Celtis occidentalis* and *laevigata*) temporarily flooded forest alliance is associated with the floodplains of Sand Creek and a large unnamed tributary to Sand Creek on the west and north sides of the AOC (Figure 7-1 and Photograph 7-1). Mature northern red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), and basswood (*Tilia americana*) occupy the steep slopes overlooking the streams.

The decrease in the shrubland is attributable to plant succession. In general, the shrubland habitat that has been lost has been replaced by the forest habitat described below. The shrubland areas occur around the former igloos, bunker sites, and roads in the central portion of the AOC (Photograph 7-2). Despite the cessation of continued disturbance from periodic mowing and recent demolition activities, shrubs and small trees remain the dominant habitat type at the AOC. Many of the shrub species are colonial and spread by vegetative propagation. Common species include various willows (*Salix* spp.), gray dogwood (*Cornus racemosa*), autumn olive (*Elaeagnus umbellata*), blackberry (*Rubus allegheniensis*), hawthorn (*Crataegus* spp.), and multiflora rose (*Rosa multiflora*). Despite some apparent decrease of the area covered by this habitat type over the last decade, it is presently the dominant habitat at the AOC.

The increase in forested area is attributed primarily to plant succession, as young tree species in the upland shrubland habitat grow into mature trees. The dominant tree species in the mixed-deciduous successional forest habitat are red maple (*Acer rubrum*), elm (*Ulmus* sp), and black cherry (*Prunus serotina*). The forested areas occur in the upland areas adjacent to the igloos, bunker sites, and the roads at the AOC. The forest includes small open areas and understory that results in multi-story vegetation. The vegetation provides multiple layers for the various foraging height preferences of birds, mammals, insects, and other organisms.

SAIC scientists assessed the habitats at Wet Storage Area to be healthy and functioning in August 2008 and May 2010 (Photographs 7-1 and 7-2). Functional habitat was determined by noting the absence of large bare spots and dead vegetation or other obvious visual signs of an unhealthy ecosystem. Additional habitat photographs are provided in Appendix H.

Threatened, Endangered, and Other Rare Species. The northern long-eared bat (*Myotis septentrionalis*; federally threatened) exists at Camp Ravenna. There are no other federally listed wildlife species and no critical habitat on Camp Ravenna. Wet Storage Area has not been previously surveyed for state- or federally-listed threatened or endangered species; however, there have been no documented sightings of rare, threatened, or endangered species at the AOC (OHARNG 2014).

Other Terrestrial Resources. While there are no other known important terrestrial places and resources, there are other resources at or near Wet Storage Area (e.g., vegetation, animals) that interact in their ecosystems and support nutrient cycling and energy flow. For example, wildlife such as wild turkey (*Meleagris gallopavo*) and white-tailed deer (*Odocoileus virginianus*) could use the area. The INRMP provides information about species and habitat surveys at Camp Ravenna (e.g., timber and ecological succession) (OHARNG 2014). There are no other reported surveys of habitats and wildlife at Wet Storage Area beyond those summarized in the INRMP (OHARNG 2014).

Aquatic Resources – There are three types of aquatic resources at Wet Storage Area: an unnamed tributary to Sand Creek, drainage ditches/natural conveyances, and wetlands.

Habitat Descriptions and Species. Perennial surface water at Wet Storage Area is limited to the unnamed tributary to Sand Creek, which flows through the western portion of the AOC. The tributary's closest approach is within 150 ft of the former igloos (Figure 7-1). Sand Creek is located outside the AOC, north of the fence line. Surface water also occurs intermittently throughout the AOC as storm water runoff within constructed drainage ditches or natural conveyances. Each igloo has a system of drainage ditches that surrounds the structure and borders its access road. Intermittent storm water runoff would generally flow to the north and northwest and within discontinuous ditch lines adjacent to access roads within Wet Storage Area. There is no permanent water in the drainage ditches/natural conveyances, and water is expected to accumulate temporarily after rain events. Precipitation data for RVAAP are provided in Section 3.5. The storm frequency is 35 days per year, and precipitation occurs 154 days per year. This is a sufficient amount of precipitation to create and maintain aquatic habitat at Wet Storage Area, as evidenced by the presence of the wetlands.

Wetlands. Important wetland resources exist at the AOC. Wetlands are important habitats with water-saturated soil or sediment whose plant life can survive saturation. Wetlands are home to many different species and are also chemical sinks that can serve as detoxifiers and natural water purifiers. It is expected the wetlands at Wet Storage Area perform these and other related functions.

A wetlands delineation conducted in 2006 identified 26 wetlands of varying sizes and quality (from Category 1 to Category 3) on the AOC (OHARNG 2006). Most jurisdictional wetlands on the AOC are associated with drainage ditches/natural conveyances (see Photographs H-1 and H-2 in Appendix H). A wetland complex consisting of approximately 1.2 acres of high quality, Category 3 wetlands exists on the floodplain of the unnamed tributary to Sand Creek within the western portion of the AOC (Photograph 7-1).

An SAIC Professional Wetland Scientist used the Ohio Rapid Assessment Method (ORAM) (Ohio EPA 2001) in May 2010 to assess the condition of the wetland complex discussed above and to determine the potential ecological importance of those wetlands (Appendix H, Figure H-1).

Using the ORAM, wetlands are classified into three categories:

- Category 1 wetlands are described as “limited quality waters.” They are considered to be a resource that has been degraded, has limited potential for restoration, or is of such low functionality that lower standards for avoidance, minimization, and mitigation can be applied. Scores range from 1–29.
- Category 2 includes wetlands of moderate quality and wetlands that are degraded but exhibit reasonable potential for restoration. Scores range from 30–59.
- Category 3 includes wetlands of very high quality and wetlands of concern regionally and/or statewide, such as wetlands that provide habitat for species listed as threatened or endangered. Scores range from 60–100.

The field sheets detailing the ORAM at Wet Storage Area are presented in Appendix H, Figure H-1. Figure 7-1 shows the locations of the wetlands.

A wetland complex is located on the floodplain of the unnamed tributary to Sand Creek within the western portion of the AOC (Photograph 7-1). The wetland complex is approximately 1.2 acres and consists of forested vegetation. Based on the ORAM, the wetland complex is classified as Category 3 (score of 66), which indicates a high quality, forested wetland (Appendix H, Figure H-1).

Threatened and Endangered and Other Rare Species. The northern long-eared bat (*Myotis septentrionalis*; federally threatened) exists at Camp Ravenna. There are no other federally listed wildlife species and no critical habitat on Camp Ravenna. Wet Storage Area has not been previously surveyed for state- or federally-listed threatened or endangered species; however, there have been no documented sightings of rare, threatened, or endangered species at the AOC (OHARNG 2014).

Other Aquatic Resources. While there are no other known aquatic resources (Appendix H, Table H-2) at or near Wet Storage Area (e.g., vegetation, animals), the existing populations interact in their ecosystems and support nutrient cycling and energy flow. There are no other reported surveys of habitats and wildlife at Wet Storage Area beyond those summarized in the INRMP (OHARNG 2014). There are three nearby biological and water quality stations. The following subsections provide a summary of the biological and water quality stations in the vicinity of Wet Storage Area.

Biological/Water Quality Sampling Stations. Ohio EPA and USACE investigated several streams at Camp Ravenna in a network of various biological/water quality sampling stations (USACE 2005b). The purpose of this investigation was to document ecological effects of AOCs on stream or pond biota and conditions. Three sampling stations were located in the vicinity of Wet Storage Area. Of these, two stations (S-2 and S-3) were located upstream of Wet Storage Area, and the third station (S-4) was located downstream. Biological/water quality stations upstream of Wet Storage Area (S-2 and S-3) provide information about potential contamination from upstream AOCs and if upstream AOCs may be contributing to adverse biological, chemical, and physical measurements in the vicinity of Wet Storage Area. The sampling station downstream of Wet Storage Area (S-4) provides information about potential contamination from Wet Storage Area and upstream AOCs. If the downstream sampling station has a positive rating (e.g., good, excellent, full attainment, and other positive terms reported in the study), it means Wet Storage Area and other upstream AOCs are not adversely impacting the quality of Sand Creek.

According to the *Facility-wide Biological and Water Quality Study* (USACE 2005b), each sampling location included a sediment sampling/assessment, surface water sampling/assessment, fish and macroinvertebrate community assessment, and habitat assessment. The sampling reach for stream sampling stations ranged 120–210 meters.

Sediment evaluations were conducted in June 2003 using guidelines established in *Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et al. 2000), sediment reference values (SRVs) for inorganic chemicals (Ohio EPA 2003), and USEPA Region 5 ecological screening levels (ESLs) (USEPA 2003). Sediment samples were analyzed for SVOCs, pesticides, PCBs, TAL metals, explosives, percent solids, cyanide, ammonia, nitrate, and phosphorus. Surface water grab samples collected in June and September 2003 were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature cited in the Facility-wide Biological and Water Quality Study. Surface water samples were analyzed for TAL metals, pesticides, PCBs, explosives, SVOCs, and several nutrients.

Fish and macroinvertebrate sampling and assessments occurred in August and September 2003. Fish were sampled using electrofishing methods. Macroinvertebrate communities were assessed using artificial substrates (quantitative sampling) supplemented with a composite natural substrate sample. Both the fish and macroinvertebrate community assessments followed the methods contained in *Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities* (Ohio EPA 1989).

The physical habitat assessment was conducted in June 2003 and used the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA (Rankin 1989, 1995). The types(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score.

Sampling Station Locations. Station S-2 is located at the intersection of Sand Creek [river mile (RM) 5.9] and Newton Falls Road, approximately 4,000 ft west and upstream of Wet Storage Area. Station S-2 is included as a reference station for S-4, which is located downstream of the AOC.

Station S-3 (RM 4.84) is situated along an unnamed tributary to Sand Creek that intersects Newton Falls Road approximately 600 ft southeast and upstream of Wet Storage Area. The tributary stream also flows through the western side of Wet Storage Area and provides the closest upstream reference point for the AOC.

Station S-4 (RM 4.5) is located on Sand Creek at George Road, approximately 2,000 ft northeast of Wet Storage Area. The station is the closest downstream sampling point to the AOC on Sand Creek. On May 17, 2010, SAIC scientists visited the S-4 area. The reconnaissance included approximately 50 meters upstream and downstream from the bridge at George Road. At the time of the visit, the stream was running clear despite recent rainfall in the area. The substrate consisted of boulder, cobble, and gravel deposits on bedrock. A thin layer of silt (1–2 mm thick) covered most of the substrate, indicating some erosion from upstream. Rocks were covered with moss and algae. Stream banks were generally well-vegetated with a mix of shrubs and trees. Minor stream bank erosion was observed. Sand Creek is confined within a moderately deep gorge that extends along most of the northern boundary of Wet Storage Area. Vegetation within the gorge consists of mature deciduous trees and shrubs.

Summary of Sampling/Assessment Results. Table 7-12 shows the ratings of the attributes for all three sampling stations (S-2, S-3, and S-4). Review of the *Facility-wide Biological and Water Quality Study* (USACE 2005b) data from the three sampling stations showed many positive attribute ratings (e.g., very good, excellent, or full attainment) and no sign of aquatic impairment. Each station was rated at Full Use Attainment Status, which indicated that all indices met the Ohio EPA biological criteria.

At S-2, all inorganic chemicals tested in sediment were below Ohio SRVs and threshold effects concentration (TEC) levels. No explosives and PCBs were detected in sediment samples collected from S-2. The few SVOCs and pesticides were detected at low levels, with all concentrations below TEC or ESL guidelines. Ammonia and total phosphorus levels were measured below screening guidelines, but total cyanide was measured above ESL guidelines (USACE 2005b). None of the surface water chemical concentrations at S-2 exceeded Ohio Water Quality Standards (WQSs) aquatic life maximum or average water quality criteria, and none of the chemicals measured exceeded criteria protective of the warm water habitat aquatic life use (USACE 2005b). Overall, the sediment quality and water quality at S-2 were rated “excellent.” The fish community at S-2 was rated “good.” The Index of Biotic Integrity (IBI) score was 40, and 15 species were reported. The macroinvertebrate community at S-2 was rated “excellent.” Based on the fish and macroinvertebrate community assessment, no biological impairment associated with chemical contaminants was observed at S-2. The physical habitat was also evaluated at S-2, and the QHEI score was 78.5, indicating an “excellent” stream habitat capable of supporting warm water habitat biological communities.

At S-3, all inorganic chemicals tested in sediment were below Ohio SRVs and TEC levels. All tested explosives and PCBs were not detected in sediment samples collected from S-3. The few detected pesticides were measured at low levels, with all concentrations below TEC or ESL guidelines. At S-3, eight SVOCs (PAH compounds) were measured above TEC levels, and two PAH compounds were measured above ESL guidelines. Ammonia and total phosphorus levels were measured below screening guidelines. None of the surface water chemical concentrations at S-3 exceeded Ohio WQS aquatic life maximum or average water quality criteria, and none of the chemicals measured exceeded criteria protective of the warm water habitat aquatic life use (USACE 2005b). Overall, the sediment quality at S-3 was rated "good," and the water quality was rated "excellent." The fish community at S-3 was rated "good," with an IBI score of 48 and eight species reported. The macroinvertebrate community at S-3 was rated "good." Based on the fish and macroinvertebrate community assessment, no biological impairment associated with chemical contaminants was observed at S-3. The physical habitat was also evaluated at S-3, and the QHEI score was 68, indicating a "good" stream habitat capable of supporting warm water habitat biological communities.

At S-4, all inorganic chemicals detected in sediment were below Ohio SRVs and TEC levels. All explosives and PCBs were not detected in sediment samples collected from S-4. The few SVOCs and pesticides were detected at low levels, with all concentrations below TEC or ESL guidelines. Ammonia and total phosphorus levels were measured below screening guidelines, but total cyanide was measured above ESL guidelines (USACE 2005b). None of the surface water chemical concentrations at S-4 exceeded Ohio WQS aquatic life maximum or average water quality criteria, and none of the chemicals exceeded criteria protective of the warm water habitat aquatic life use (USACE 2005b). Overall, the sediment quality and water quality at S-4 were rated "excellent." At S-4, the fish community was rated "good." The IBI score was 37, and 13 species were reported. The macroinvertebrate community at S-4 was also rated "good." Based on the fish and macroinvertebrate community assessment, no biological impairment associated with chemical contaminants was observed at S-4. The physical habitat was also evaluated at S-4, and the QHEI score was 75.5, indicating an "excellent" stream habitat capable of supporting warm water habitat biological communities. These favorable sediment/water quality findings at S-4 support the observation that Wet Storage Area is not contributing contamination to Sand Creek.

Ecosystem and Landscape Roles and Relationships – There are four spatial areas evaluated to assess the ecosystem and landscape roles and relationships at Wet Storage Area: the AOC itself, the vicinity of the AOC, the entire Camp Ravenna, and the ecoregion of northeastern Ohio. Information about the first spatial area (the AOC) is provided in the terrestrial and aquatic resources subsections above.

Vicinity of the AOC. Three vegetation communities border Wet Storage Area (Figure 7-1) and include a variety of forest and shrubland communities. There are no apparent differences in habitat quality of these plant communities inside or outside of the AOC. For example, the dominant forest alliance in the north, west, and southwestern portion of the habitat area [green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and hackberry (*Celtis occidentalis* and *laevigata*)] extends at least 500 ft beyond the northern, western, and southwestern boundaries of the AOC. To the northeast and south are the dry, mid-successional, cold-deciduous shrubland [gray dogwood (*Cornus racemosa*) and hawthorn (*Crataegus* spp.)] that occupy the small area between the habitat boundary and the roads.

Across George Road to the east, mixed cold-deciduous successional forest [white ash (*Fraxinus Americana*) and red maple (*Acer rubrum*)] occur. These types and qualities of habitat are not unique and can be found at many other areas at Camp Ravenna.

Figure 7-1 shows there are many wetlands inside the AOC. Other small wetlands are located near the east, northeast, and southeast boundaries of the habitat area. Perennial surface water features exist in the fenced AOC boundary in the form of the unnamed tributary to Sand Creek (Figure 7-1). By definition, this unnamed tributary and the wetlands are considered important ecological resources (BTAG 2005).

The closest recorded rare species [northern blue-eyed grass (*Sisyrinchium septentrionale*)] is located approximately 325 ft south/southeast of the AOC (Table 7-13) (OHARNG 2014); it is a state threatened species. The next closest rare species [mayfly (*Stenonema ithica)* and butternut (*Juglans cinerea*)] are located about 500 and 800 ft north/northeast of the AOC; they are a state species of concern and a federal species of concern, respectively.

No beaver dams are in or near the AOC. There is a 100-year floodplain along the unnamed tributary to Sand Creek located in the western portion of the AOC. There are biological and water quality stations within 600 ft of the AOC.

The Entire RVAAP. Wet Storage Area is considered a medium-sized (approximately 36 acres) AOC which represents 0.16% of the total area of Camp Ravenna (21,683 acres). There are approximately 2,310 acres of forest type FL1 [temporarily flooded forest alliance (green ash/American elm/hackberry)] at Camp Ravenna based on the INRMP map (OHARNG 2014); this represents 10.6% of the habitat at Camp Ravenna. There are approximately 1,650 acres of forest type FU5 [mixed cold-deciduous successional forest (e.g., red maple and elm)] (OHARNG 2014), representing 7.6% of the habitat at Camp Ravenna. There are approximately 2,900 acres of shrubland type SU1 (e.g., gray dogwood and hawthorn) (OHARNG 2014), representing 13.4% of the habitat at Camp Ravenna. There are approximately 1,970 acres of jurisdictional and "planning level survey" wetlands (OHARNG 2014), representing 9.1% of all habitat at Camp Ravenna. These types of resources are abundant and are not unique at Wet Storage Area and Camp Ravenna.

Ecoregion. In the area surrounding Camp Ravenna, forests occupy a high percentage of the terrain. Ohio's forests cover approximately 8,000,000 acres or 30% of the state (USDA 2009). The Erie/Ontario Drift and Lake Plain ecoregion (USGS 1998) are located in the northeastern part of Ohio, and both contain the same communities of forest alliance (green ash/American elm/hackberry); successional forest (e.g., red maple and elm); and dry, mid-successional, cold-deciduous, shrubland (e.g., gray dogwood and hawthorn) as Camp Ravenna. The Erie/Ontario Drift and Lake Plain ecoregion exhibits rolling to level terrain formed by lacustrine and low, lime drift deposits. Lakes, wetlands, and swampy streams occur where stream networks converge or where the land is flat and clayey (USGS 1998). The U.S. Forest Service (USFS) has a Forest Inventory Data Online tool that was queried for the forest types in the surrounding counties in or near Camp Ravenna (USFS 2011). In 2009, approximately 138,840 acres of forest type FL1 were found throughout northwestern Ohio in Cuyahoga, Geauga, Mahoning, Portage, Stark, Summit, and Trumbull counties that surround Camp Ravenna (USFS 2011).

The shrubland was not individually found in this query because it is not classified as a main group of trees in the forest inventory data tool. However, shrubland (SU1) is common across the ecoregion (USDA 2011). Wetlands across the ecoregion make up 207,800 acres (USEPA 1999). Thus, the vegetation communities and wetlands at Wet Storage Area are also found in the surrounding counties in the ecoregion of northeastern Ohio.

In summary, the current vegetation types of temporarily flooded forest alliance (green ash/ American elm/hackberry); successional forest habitat (e.g., red maple and elm); dry, mid-successional, cold-deciduous shrubland (e.g., gray dogwood and hawthorn); and wetlands are found in the vicinity of Wet Storage Area. The two forest types, shrublands, and wetlands are in abundance at RVAAP and the larger surrounding local ecoregion. There is no known unique resource at Wet Storage Area that cannot be found in the immediate vicinity of the AOC, Camp Ravenna, and in a large part of the ecoregion of northeastern Ohio.

7.3.2.4 <u>Evaluation of Historical Chemical Contamination and Ecological Significance</u>

There are 15 surface soil COPECs identified in the historical ERA as part of the Characterization of 14 AOCs: arsenic, chromium, iron, lead, mercury, nickel, zinc, beta-BHC, benz(a)anthracene, benzo(a)pyrene, carbazole, chrysene, dibenzofuran, 3-nitrotoluene, and nitrocellulose (Section 7.3.2.2).

The Army and Ohio EPA provide a checklist of important ecological places and resources to determine if such ecological resources are present in an AOC and nearby. There is an unnamed tributary to Sand Creek and wetlands at the AOC. OHARNG environmental management goals and objectives are applicable to Wet Storage Area, including Goal 1 requiring natural resources management to be compatible with military mission, and Goal 5 requiring the Army to sustain usable training grounds and natural resources.

Wet Storage Area is made up of approximately 36 acres of shrubland and forest communities. Current forest communities consist of green ash/American elm/hackberry and red maple/elm/black cherry. Wetlands associated with the unnamed tributary to Sand Creek, drainage ditches, and natural conveyances are found at the AOC. The vegetation types and wetlands at Wet Storage Area are found nearby, at Camp Ravenna, and in the ecoregion.

Due to the contamination and important or significant resources at Wet Storage Area, this ERA will continue to a Level II Screening Level ERA.

7.3.3 Level II: Screening Level Ecological Risk Assessment

The Level II method follows the guidance documents listed in Section 7.3.1 and identifies evaluation procedures used for problem formulation and ecological effects evaluation to determine AOC-related COPECs. This work includes defining habitats/environmental settings, suspected contaminants, possible pathways, and mechanisms for ecotoxicity and contaminant transport. Level II also includes establishing screening values.

In addition, technical and refinement factors can be used to assess outcomes of the above procedures. The factors include using mean exposure concentrations and discussing approved ESVs, wetland quality at the AOC, and other topics that evaluate and refine the COPECs from the Level II Screening ERA. This assessment is Step 3A in the ERA process (USEPA 1997).

7.3.3.1 Generic Ecological Conceptual Exposure Model

The conceptual site exposure model identifies the interconnections of contaminant sources and transport mechanisms for contaminant migration through the environment to the receptors. The conceptual site exposure model includes the following and provides an understanding of the relationships of all sources, release and transport pathways, potential exposure media, and receptors.

- **Source Media –** Based on historical AOC information, operations associated with various former activities, storage igloos, and former igloos at Wet Storage Area are the contaminant source. The operations contributed chemicals to the surrounding soil, sediment, and surface water.
- **Transport Mechanisms –** Soil contaminants can migrate via erosion and leaching. Migration to sediment and surface water via erosion is controlled by the amount of precipitation, type of ground cover, and topography of the AOC. Little erosion is expected to occur at the AOC because although parts of the land are relatively sloped, the slopes have a high percentage of vegetative ground cover (i.e., trees and shrubs with occasional grasses and herbs) that will further help to increase infiltration and decrease erosion. This extensive vegetative cover includes forests and shrublands. While much of the precipitation landing on this area is expected to infiltrate the soil, some rainfall will leave the AOC as runoff. For example, there are shallow drainages that provide a flow pathway from the former igloos to one or more of the small wetlands. If any water moves across the surface, it would likely go through these drainage conveyances.
- **Exposure Media –** Exposure media are media where contaminants are available for exposure to ecological receptors. Potential exposure media at Wet Storage Area are soil, sediment, surface water, vegetation, and animals.
- **Exposure Pathways –** A main exposure pathway is ingesting contaminated food. Other pathways may include ingesting soil, sediment, and water and dermal contact by receptors with soil, sediment, or water.
- **Ecological Receptors –** A variety of ecological receptors, such as terrestrial birds and mammals, are present in the area. Receptors associated with various published toxicological endpoints (e.g., reproduction and physiology) are assumed to represent these various plants and animals.

7.3.3.2 Habitats and Species (Including Generic Receptors)

Habitats and species were defined in the Level I ERA (Section 7.3.2). For example, three types of habitats were described. Habitats, species, and other resources were analyzed, and it was determined that important or significant ecological resources are present at Wet Storage Area and in its vicinity. Wetlands and an unnamed tributary to Sand Creek are present at the AOC. Contamination is present;

therefore, a Level II analysis is needed. Level II assumes ecological receptors are sensitive to various chemicals based on a variety of toxicological data from field-observed effects and laboratory tests. The ESV is utilized as a toxicity metric representing multiple generic receptors, including plants, microorganisms, and animals.

7.3.3.3 Procedure to Identify COPECs

The screening level approach to evaluate sample results from the PBA08 RI followed a similar approach to that used in the historical ERA. Section 5.1 details chemical concentration data. The PBA08 RI included collecting discrete surface soil (0–1 ft bgs) samples and ISM surface soil (0–1 ft bgs) samples at locations around historical ISM sample locations. Discrete samples and ISM samples are not combined in the PBA08 RI COPEC screening, and only ISM soil samples collected during the PBA08 RI and the historical ERA were used in the analysis. For sediment and surface water, only discrete samples collected within the Wet Storage Area boundary during the PBA08 RI were used to evaluate the unnamed tributary to Sand Creek, located in the western portion of the AOC. This ERA uses updated SRVs (Appendix H, Table H-4) and ESVs that follow the revised *Ecological Risk Assessment Guidance* (Ohio EPA 2008), as provided in Appendix H, Tables H-5 through H-7.

The hierarchy of ESVs is based on the information found in the Ohio EPA risk assessment guidance (Ohio EPA 2008) and FWERWP (USACE 2003a). The MDC of each chemical is compared to its respective facility-wide background concentration. Sediment concentrations are also compared to the SRV. Chemicals are not considered site-related if the MDC is below the background concentration. For all chemicals detected above background concentrations, the MDC is compared to the chemical-specific ESV (or SRVs for sediment if an ESV is not available). In addition to the ESV comparison, it was determined if the chemical is a PBT compound. Chemicals are retained as COPECs if they exceed background concentrations (and SRVs for sediment) and the ESV, if the chemical exceeds background concentrations (and SRVs for sediment) and had no toxicity information, or if the chemical is considered a PBT compound. MDC to ESV ratios are used to determine the integrated COPECs that result from the combined current and historical data sets. A ratio greater than one suggests a possible environmental consequence. Any chemicals with ratios greater than one are identified as integrated COPECs.

Based on comment resolution with Ohio EPA in July 2014, the selection of integrated COPECs for surface water was modified to include two screens. Along with comparing the MDC to the Ohio EPA outside mixing zone maximum (OMZM) ESV, when available, Ohio EPA requested the MDC and average concentrations also be compared to the Ohio EPA outside mixing zone average (OMZA) ESV at each EU when available (Appendix H, Tables H-7 and H-11).

Maximum Detected Concentrations – The MDCs were compared to background concentrations and ESVs (Appendix H, Tables H-8 through H-11) for each detected chemical. These comparisons are provided in Appendix H, Table H-8 for surface soil, Table H-9 for sediment, and Tables H-10 and H-11 for surface water.

Ecological Screening Values – Although the historical ERA used ESVs from the 2003 version of the *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2003), this ERA uses updated ESVs from the 2008 version of this guidance document. The hierarchy for soil is ecological soil screening levels (EcoSSLs), PRGs, and ESLs. The hierarchy for sediment is the sediment quality guidelines, followed by ESLs. When needed, the hierarchy for surface water is the Ohio EPA water quality criteria, national recommended water quality criteria, and ESLs. Appendix H, Tables H-5 through H-7 provide values and sources for ESVs.

7.3.3.4 Integrated COPECs for Soil (0-1 ft bgs)

During the PBA08 RI, 51 chemicals were detected in surface soil. Five chemicals (calcium, iron, magnesium, potassium, and sodium) were essential nutrients and were excluded as SRCs. A total of 14 detected inorganic chemicals and 28 organic chemicals were determined to be SRCs because they either exceeded background concentrations or did not have an associated background concentration for comparison. Of the 42 SRCs, 6 inorganic chemicals (aluminum, arsenic, cobalt, lead, mercury, and zinc) and three organic chemicals [benz(a)anthracene, benzo(a)pyrene, and chrysene] exceeded the ESVs and are identified as integrated COPECs (Table 7-14). In addition, four organic chemicals (3-nitrotoluene, nitrocellulose, carbazole, and dibenzofuran) were selected as integrated COPECs because they do not have an ESV. Four PBT compounds (4,4'-DDE; endrin; alpha-chlordane; and beta-BHC) were also identified as integrated COPECs, even though they did not exceed their ESVs. One other integrated COPEC (mercury) was also a PBT compound. The calculated ratio of MDC to ESV is shown in Table 7-14 for each integrated COPEC. Appendix H, Table H-8 presents the details of the ESV comparisons for surface soil.

Most of the soil COPECs reported in the historical ERA (Table 7-11) are also identified in the current ERA. The historical ERA (Characterization of 14 AOCs) identified three inorganic COPECs (chromium, iron, and nickel) that are not integrated COPECs. Chromium and nickel were below the new ESV (Ohio EPA 2008, Appendix H, Table H-5), and iron was considered an essential nutrient in the new data set. Five new integrated COPECs (aluminum; cobalt; 4,4'-DDE; endrin; and alpha-chlordane) are identified in the PBA08 RI. The addition of aluminum as an integrated COPEC is based on a higher detection in new samples collected during the PBA08 RI. The addition of cobalt is due to an updated, more stringent ESV. The addition of 4,4'-DDE; endrin; and alpha-chlordane is due to detections of these three organic chemicals in new samples collected during the PBA08 RI. Based on the presence of integrated COPECs, this ERA predicts the potential for ecological risk in surface soil.

7.3.3.5 Integrated COPECs for Sediment

During the PBA08 RI, 37 chemicals were detected in sediment in the unnamed tributary to Sand Creek, located in the western portion of the AOC. Sediment ESVs are published in Appendix H, Table H-6. Detected chemical concentrations were compared to sediment background concentrations, SRVs, and ESVs (Appendix H, Table H-9), and the results are summarized in Table 7-15. A detected inorganic chemical and 15 organic chemicals were determined to be SRCs because they either exceeded background concentrations or did not have an associated background concentration for comparison. Of the 16 SRCs, 4 integrated COPECs [manganese, 2-methylnaphthalene, acenaphthylene, and benz(a)anthracene] were identified in sediment. Manganese was an integrated COPEC by default (i.e., the chemical did not have an ESV and exceeds its background concentration), while 2-methylnaphthalene, acenaphthylene, and benz(a)anthracene exceeded their ESVs. No sediment samples were collected during the historical ERA; therefore, no comparison to the historical results is possible.

7.3.3.6 Integrated COPECs for Surface Water

During the PBA08 RI, 14 chemicals were detected in surface water in the unnamed tributary to Sand Creek, located within the western portion of the AOC. Five chemicals (calcium, iron, magnesium, potassium, and sodium) were essential nutrients and were excluded as SRCs. Five detected inorganic chemicals were determined to be SRCs because they either exceeded background concentrations or did not have an associated background concentration for comparison. None of the SRCs were retained as integrated COPECs for surface water because they do not exceed their OMZM or OMZA ESVs. Appendix H, Table H-10 presents the details of the MDC to OMZM ESV comparisons and Appendix H, Table H-11 presents the MDC to OMZA ESV comparisons for surface water in the unnamed tributary to Sand Creek. No surface water samples were collected during the historical ERA; therefore, no comparison to the historical results is possible.

7.3.3.7 Step 3A: Refinement of Integrated COPECs

Step 3A refines the list of integrated COPECs to determine if there are final COPECs requiring further evaluation in Level III or remediation to protect ecological receptors or if integrated COPECs can be eliminated from further consideration. This section applies and evaluates refinement factors to the integrated COPECs for the AOC. This evaluation is an important part of Level II and is adapted from USEPA Step 3A, outlined in the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997) and *Risk Assessment Handbook Volume II: Environmental Evaluation* (USACE 2010b). The purpose of Step 3A is stated as follows by the Army (BTAG 2005):

> "The results of Step 3A will be used to determine if threats to ecological receptors are negligible and an appropriate risk management decision may be made to end the ERA process, or potential threats are still indicated and a BERA should be initiated."

The evaluation and refinement factors used in Step 3A are as follows:

- Comparison of average (i.e., mean) concentration to ESV,
- Comparison of mean concentration to background concentration,
- Comparison of background concentration to ESV,
- Frequency of chemical occurrence relative to ESV,
- Magnitude of ESV exceedance (ratio of ESV to chemical concentrations),
- Discussion of Ohio EPA approved and preferred ESVs,
- Qualitative relationship of exposure area to general home range,
- Category of wetland quality inside the AOC,

- Geographical relationship of on-site wetlands to AOC exceedance area,
- Information about on-site migration of chemicals to on-site wetlands, and
- Evaluation of off-site migration of chemicals at biological/water quality stations.

There are 17 integrated COPECs in soil at Wet Storage Area. Aluminum, arsenic, cobalt, lead, mercury, zinc, benz(a)anthracene, benzo(a)pyrene, and chrysene are the nine integrated COPECs that exceeded their background concentrations and ESVs. Mercury is also a PBT compound. Four chemicals (4,4'-DDE; endrin; alpha-chlordane; and beta-BHC) have ratios below one but are integrated COPECs because they are PBT compounds. Four additional chemicals (3-nitrotoluene, nitrocellulose, carbazole, and dibenzofuran) are integrated COPECs by default (i.e., the chemicals do not have an ESV).

There are four integrated COPECs in sediment at Wet Storage Area: 2-methylnaphthalene, acenaphthylene, and benz(a)anthracene exceeded their ESVs, and manganese was an integrated sediment COPEC by default (i.e., the chemical does not have an ESV).

There are no integrated COPECs in surface water at Wet Storage Area.

Chemicals with no ESVs are discussed later in Step 3A and in the uncertainty section (Section 7.3.3.9). PBT compounds are discussed later in Step 3A. All integrated COPECs that have an MDC to ESV ratio greater than one are evaluated based on a series of evaluation or refinement factors. The first four evaluation and refinement factors are organized to compare key quantitative information. These factors are:

- Comparison of average or mean concentration to ESV,
- Comparison of mean concentration to background concentration,
- Comparison of background concentration to ESV, and
- Frequency of chemical occurrence relative to ESV.

Multiple evaluation factors can be used to define whether an integrated COPEC should be retained or eliminated from further consideration. There are two types of comparisons and associated decisions in the first steps of the refinement process (Table 7-16).

Comparing the background concentration to an ESV is also an important consideration in this part of the evaluation. Additionally, frequency of detection is provided. The evaluations are presented by type of decision on a COPEC-by-COPEC basis (Table 7-17). These evaluations are followed by the application of additional evaluation and refinement factors, when necessary.

Comparison of Mean Concentration to ESV – Five integrated COPECs [arsenic, cobalt, benz(a)anthracene, benzo(a)pyrene, and chrysene] in soil are eliminated in this step because the mean concentration is smaller than the ESV (Appendix H, Table H-12). Each eliminated integrated COPEC is discussed relative to the mean concentration being smaller than the ESV and the related evaluation and refinement factors. Table 7-17 shows the relevant data and various comparisons.

Arsenic. Arsenic was detected in all 22 ISM samples analyzed for inorganic chemicals at Wet Storage Area. Only nine samples had detections above the background concentration, and only two samples had arsenic concentrations exceeding the ESV (Table 7-17). Although the MDC for arsenic in surface soil exceeds the background concentration and ESV, the mean concentration is less than the ESV and background concentrations. Therefore, arsenic is eliminated from further consideration and will not be a final COPEC.

Cobalt. Cobalt was detected in all 22 ISM samples analyzed for inorganic chemicals at Wet Storage Area. Ten samples had detections above the background concentration, but only one sample had a cobalt concentration exceeding the ESV (Table 7-17). Although the MDC for cobalt in surface soil exceeds the background concentration and ESV, the mean concentration is less than the ESV and close to background concentration. Therefore, cobalt is eliminated from further consideration and will not be a final COPEC.

Benz(a)anthracene. Benz(a)anthracene was detected in five of six ISM samples. There is no background concentration for comparison, but only one sample had a concentration exceeding the ESV (Table 7-17). Although the MDC for benz(a)anthracene in surface soil exceeds the ESV, the mean concentration is less than the ESV. Therefore, benz(a)anthracene is eliminated from further consideration and will not be a final COPEC.

Benzo(a)pyrene. Benzo(a)pyrene was detected in all six ISM samples. There is no background concentration for comparison, but only one sample had a concentration exceeding the ESV (Table 7-17). Although the MDC for benzo(a)pyrene in surface soil exceeds the ESV, the mean concentration is less than the ESV. Therefore, benzo(a)pyrene is eliminated from further consideration and will not be a final COPEC.

Chrysene. Chrysene was detected in all six ISM samples. There was no background concentration for comparison, but only one sample had a concentration exceeding the ESV (Table 7-17). Although the MDC for chrysene in surface soil exceeds the ESV, the mean concentration is less than the ESV. Therefore, chrysene is eliminated from further consideration and will not be a final COPEC.

Of the nine integrated soil COPECs with MDCs exceeding the ESV, arsenic, cobalt, benz(a)anthracene, benzo(a)pyrene, and chrysene were eliminated from further consideration. Four remaining integrated COPECs with MDCs greater than the ESV (aluminum, lead, mercury, and zinc) in surface soil have mean concentrations larger than the ESV.

Comparison of Mean Concentration Above ESV to Background Concentration – One integrated COPEC in surface soil (aluminum) is eliminated in this step because the mean concentration is larger than the ESV but smaller than the background concentration. Aluminum is discussed relative to the various evaluation and refinement factors.

Aluminum. Aluminum in surface soil has a mean concentration less than the background concentration (Table 7-17). The background concentration is more than 350 times greater than the ESV, so the ESV can be considered conservative. Although aluminum was detected in all 22 ISM samples at concentrations above the ESV, only 1 sample had a detection exceeding the background concentration. Having only one sample exceed the background concentration suggests the concentration of aluminum in surface soil is not likely a concern. Additionally, aluminum is not likely a concern because the soil pH is too high to dissociate the chemical. A typical soil pH is 6–7 at one of the nearby load lines at Camp Ravenna (USACE 2004). Regarding aluminum chemistry and ecological risk in soil, the USEPA states, "aluminum is identified as a COPC only for soil with a pH less than 5.5" (USEPA 2003a). Therefore, because the mean concentration is less than the background concentration, the ESV is rather conservative, and the soil pH at Camp Ravenna is higher than the USEPA dissociation limit, aluminum is eliminated from further consideration and will not be a final COPEC.

Continued Evaluations. The remaining three integrated COPECs (lead, mercury, and zinc) in soil have mean concentrations greater than the ESV and the background concentration. Each remaining integrated COPEC is presented below and discussed relative to the first four and related evaluation and refinement factors.

Lead. Lead in soil has a mean concentration greater than the background concentration and ESV. It was detected above the background concentration in 5 of 22 ISM samples, but it was detected at concentrations above the ESV in all 22 samples (Table 7-17). This is because the ESV is lower than the background concentration, which indicates the ESV for lead may be conservative. Although the ESV may be conservative, the mean concentration for lead in surface soil exceeds the background concentration and ESV. Lead requires further evaluation as a COPEC.

Mercury. Mercury in surface soil has a mean concentration greater than the background concentration and ESV. Mercury was detected above the background concentration in 12 of 22 ISM samples, but it was detected at concentrations above the ESV in all 22 samples (Table 7-17). This is because the background concentration is 70 times greater than the ESV, suggesting the ESV may be very conservative. Although mercury has a very conservative ESV, it is a PBT compound, and the mean concentration exceeds both the background concentration and ESV. Mercury requires further evaluation as a COPEC.

Zinc. Zinc in surface soil has a mean concentration greater than the background concentration and ESV. It was detected above the background concentration in only 12 of 22 ISM samples, but it was detected at concentrations above the ESV in all 22 samples (Table 7-17). This is because the ESV is lower than the background concentration, which indicates the ESV for lead may be conservative. Because the mean concentration in surface soil exceeds the background concentration and the ESV, zinc requires further evaluation as a COPEC.

Additional Aspects of Continued Evaluations – The second refinement factor comparing the mean concentration to the background concentration evaluates how much higher the mean soil concentration is compared to the background concentration. Three COPECs (lead, mercury, and zinc) have mean concentrations higher than their background concentrations. If the degree of difference between the mean concentration and the background concentration is small, the integrated COPEC may not be considered a final COPEC. Table 7-18 shows that while the mean concentration exceeds the background concentration, the exceedance is small in two of three cases. For example, the mean concentration for lead is 26.6 mg/kg, while the background concentration is 26.1 mg/kg.

Additional Technical and Refinement Factors. The next three evaluation and refinement factors include:

- Magnitude of ESV exceedance (ratio of ESV to chemical concentrations);
- Discussion of Ohio EPA approved and preferred ESVs; and
- Qualitative relationship of exposure area to general home range.

Magnitude of ESV Exceedance. Although the mean concentration to ESV ratios for lead (2.4), mercury (914), and zinc (1.5) indicate a possibility of risk, two of the ratios are relatively small (Appendix H, Table H-12). The small ratios for lead and zinc indicate the potential for toxicity is relatively low, and this likely supports eliminating the integrated COPECs. The *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2008) states:

> "If only minor exceedances are detected and other evidence can substantiate, a claim may be made that some or all of the site-associated soils have not been impacted and no additional ecological investigation of the soils is warranted."

Comparison of Ohio EPA Approved and Preferred ESVs. The *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2008) gives specific guidance on selecting media screening values (ESVs) for Level II evaluation. For soil, three possible sources of ESV values are listed in order of preference: (1) USEPA EcoSSLs; (2) *Preliminary Remediation Goals for Ecological Endpoints* (DOE 1997); and (3) *Region 5 Ecological Screening Levels* (USEPA 2003). However, it is important to note the preferred source (EcoSSLs) can have up to four values per chemical: one for each receptor type (i.e., plants, soil invertebrates, birds, and mammals). Because Ohio EPA does not provide guidance on which value to select of these four, the most conservative (lowest) value was chosen for this ERA. It is possible that the chosen ESV is too conservative. Alternative ESVs are presented below for the remaining three integrated COPECs.

The Ohio EPA approved and preferred lead ESV used in this ERA is 11 mg/kg. This ESV is from the USEPA EcoSSLs (Appendix H, Table H-5). The lead ESV used in this ERA is the most conservative ESV of the USEPA EcoSSLs. Other EcoSSLs for lead include 56, 120, and 1,700 mg/kg (USEPA 2005). The ESV of 11 mg/kg is about four times lower than the ESV (40.5 mg/kg) from the next source of ESVs preferred by Ohio EPA (Appendix H, Table H-5) (DOE 1997). The preferred ESV used for lead is also lower than the background concentration of 26.1 mg/kg (Appendix H, Table H-8), while all of the other EcoSSLs and the alternate ESV are above the background concentration. This information indicates the Ohio EPA approved and preferred ESV for lead, and thus the selection of lead as a COPEC is very conservative.

The Ohio EPA approved and preferred mercury ESV used in this ERA is 0.00051 mg/kg (Appendix H, Table H-5). The ESV is lower than other ESVs for mercury (0.1 mg/kg), the ESV for methylmercury (0.0016 mg/kg) (USEPA 2003) (Appendix H, Table H-5), and the background concentration (0.036

mg/kg) (Appendix H, Table H-8). The *Preliminary Remediation Goals for Ecological Endpoints* labels the form of mercury as an “inorganic chemical” and notes that the ESV for mercury is “so low that it may often be within background soil concentrations” (DOE 1997). Although mercury can bioaccumulate in food chains as a PBT compound, the Ohio EPA approved and preferred ESV is very low; therefore, the selection of mercury as a COPEC is very conservative.

The Ohio EPA approved and preferred zinc ESV used in this ERA is 46 mg/kg. This value is from the USEPA EcoSSLs (Appendix H, Table H-5). The zinc ESV used in this ERA is the most conservative ESV of the USEPA EcoSSLs. Other EcoSSLs for zinc include 79, 120, and 160 mg/kg (USEPA 2007b). The ESV of 46 mg/kg is about five times greater than the ESV (8.5 mg/kg) from the next source of ESVs preferred by Ohio EPA (Appendix H, Table H-5) (DOE 1997). The preferred ESV used for zinc is also lower than the background concentration of 61.8 mg/kg (Appendix H, Table H-8), while all of the other EcoSSLs are above the background concentration. These factors indicate the Ohio EPA approved and preferred ESV for zinc is somewhat conservative; thus, the selection of zinc as a COPEC is somewhat conservative.

The above information about alternative ESVs shows there are less conservative ESVs that could be chosen for the Level II work. Table 7-19 shows the ratio of ESV to mean concentration for the preferred ESV and an alternative ESV. This alternative ESV is the ESV with the closest concentration to the preferred ESV that is above the background concentration. For the three remaining integrated COPECs, using the alternative ESV would decrease the ratios for lead and zinc to less than one. Thus, if the alternative ESVs were used, lead and zinc would be eliminated from further consideration and would not be final COPECs.

Qualitative Relationship of Exposure Area to General Home Range. A majority of the highest lead, mercury, and zinc concentrations in surface soil (0–1 ft bgs) are located near the former igloos west of Wet Storage Area Road (Figures 5-2, 5-4, and 7-2). The highest concentrations are as follows:

- Lead: 97 mg/kg at WSAss-002M and 69 mg/kg at WSAss-001M.
- Mercury: 2.1 mg/kg at WSAss-010M and 2 mg/kg at WSAss-008M and WSAss-016M.
- Zinc: 140 mg/kg at WSAss-002M and 99 mg/kg at WSAss-010M.

Lead was detected in surface soil above its background concentration at 5 of 22 ISM sample locations. The two highest concentrations of lead were detected east of former igloos WS-2 and WS-2A in the area directly in front of the opening to each igloo (Figure 5-2). The remaining three detections of lead (40, 46, and 50 mg/kg) above its background concentration are located between former igloos WS-2 and WS-2A. The area of elevated lead concentrations in the vicinity of former igloos WS-2 and WS-2A is approximately 0.37 acres (Figure 7-2).

Mercury was detected in surface soil above its background concentration at 12 ISM locations. Of those, seven concentrations are greater than three times the background concentration and the alternative ESV (i.e., greater than 0.1 mg/kg). Four of the seven elevated mercury results are located near former igloos WS-2 and WS-2A (Figure 5-2). The remaining three elevated mercury results are located in an area between former igloos WS-1 and WS-1A (Figure 5-4). The area of elevated mercury in the vicinity of former igloos WS-2/WS-2A and WS-1/WS-1A is approximately 0.37 and 0.25 acres, respectively (Figure 7-2).

Zinc was detected in surface soil above its background concentration at 12 ISM locations. The four highest concentrations of zinc (ranging between 82 and 140 mg/kg) were detected in the vicinity of former igloos WS-2 and WS-2A (Figure 5-2). The remaining eight detections above its background concentration (ranging from 63–71 mg/kg) were just slightly above the background concentration of 61.8 mg/kg. The area of elevated zinc concentrations in the vicinity of former igloos WS-2 and WS-2A is approximately 0.37 acres.

The highest concentrations of these three COPECs occur in two relatively small areas of soil clustered near the former igloos. These areas range between approximately 0.25 and 0.37 acres (Figure 7-2) and are smaller than the usual 1-acre home range of a small bird or small mammal (USEPA 1993). A larger receptor that uses this area as a small part of its home range would, on average, be exposed to concentrations even lower than the mean concentration for lead (26.6 mg/kg), mercury (0.466 mg/kg), and zinc (69.7 mg/kg). Thus, the exposure of wildlife species to these areas would be relatively small and of limited consequence. This evaluation and refinement factor, along with corroborating evidence from the biological and water quality sampling stations, results in eliminating mercury as a final COPEC and provides supports evidence that lead and zinc should not be final COPECs.

Wetland Quality, Geographical Information, and On-site Migration of Chemicals. The next three evaluation and refinement factors are concerned with risk to wetlands. The three factors are:

- Category of wetland quality inside the AOC,
- Geographical relationship of on-site wetlands to AOC exceedance area, and
- Information about on-site migration of chemicals to on-site wetlands.

If the wetland quality is low, it is distant from the AOC exceedance area (i.e., high concentration area), or on-site migration is unlikely, it increases the likelihood that the remaining integrated COPECs (lead, mercury, and zinc) will not be of ecological concern and do not need to be evaluated as final COPECs.

The wetland complex is classified as a Category 3 wetland (with an ORAM score of 66). Category 3 indicates high wetland quality that is often forested. The wetland complex is a jurisdictional wetland. The other small jurisdictional wetlands, dispersed mostly along the ditches and roads at the AOC, do not have ORAM scores (Section 7.3.2.3).

The wetland complex is relatively small, with 1.2 acres inside the AOC (Figure 7-1). The other unscored, jurisdictional wetlands total 0.85 acres. Camp Ravenna contains about 1,970 acres of wetlands, and the 2.05 acres of wetlands inside the habitat boundary at Wet Storage Area represent 0.1% of the total area of Camp Ravenna (OHARNG 2014). The relatively small area and availability of many more wetland acres at Camp Ravenna lowers the importance of the wetlands at Wet Storage Area.

The wetland complex is located in the western part of Wet Storage Area along the unnamed tributary of Sand Creek, within a few hundred feet of the highest inorganic chemical concentrations near the former and current igloos. Very small wetlands exist along the drainage ditches near the former and current igloos.

Over a period of years, contaminants from the former and current igloos may have flowed westward toward the unnamed tributary to Sand Creek and northward to Sand Creek (Appendix H photographs). Soluble contaminants are likely to be discharged, dispersed, and diluted. Insoluble (immobile) chemicals are more likely to be retained. The small wetlands near the drainage ditches are considered an ecosystem sink during most seasons of the year. This subset of wetlands is located close to the former igloos where the high concentration areas are found, but receptor exposure is limited, as explained in the subsection detailing the qualitative relationship of exposure area to general home range (Figure 7-2). The wetland complex occurs along the unnamed tributary to Sand Creek where there is no evidence of soil COPECs migrating to sediment or surface water. This is based on the lack of detections or detections below background concentrations or ESVs in on-site sediment and surface water samples (Appendix H, Tables H-9 and H-10). Additionally, these COPECs are not detected above background concentrations in the two downstream sampling locations on Sand Creek (Section 5.3.4 and Table 5-10). The lack of on-site migration to the high quality wetland complex and off-site migration to downstream sample locations further reduces the concern about the remaining integrated COPECs.

Evaluation of Biological and Water Quality Sampling Stations – The last evaluation and refinement factor is:

- Evaluation of off-site migration of chemicals at biological/water quality stations.

Various biological measurements of macroinvertebrates and fish, as well as chemical and physical measurements of surface water and sediment, were taken and assessed for evidence of upgradient and downgradient contamination. These studies were published in the *Facility-wide Biological and Water Quality Study* (USACE 2005b). Monitoring stations are positioned in streams and ponds downgradient of several AOCs. Two sampling stations (S-2 and S-3) are upstream of Wet Storage Area, and one station (S-4) is downstream of the AOC. When the assessment attributes are positively rated (e.g., "good," "excellent," or "full attainment status"), this is evidence the downstream sampling station has not been impaired by upstream chemical conditions at the AOC.

The measurements taken at each station are sediment chemistry and conditions, surface water chemistry and conditions, fish community, benthic macroinvertebrate community, and habitat conditions. Also, a statement about attainment status is provided. Table 7-12 shows the results of the attributes for all three sampling stations (S-2, S-3, and S-4). Review of the *Facility-wide Biology and Water Quality Study* (USACE 2005b) data from the three sampling stations showed many positive metrics and no sign of aquatic impairment.

Table 7-12 shows the biological, sediment, and water quality attributes at the downstream location indicate little to no impairment (i.e., Full Attainment Status). No inorganic chemicals or SVOCs were detected above screening criteria (Section 7.3.2.3); therefore, chemicals at Wet Storage Area have not adversely affected downstream ecological conditions. This greatly reduces concern for the remaining COPECs (in soil and sediment) at Wet Storage Area.

Evaluation of Integrated COPECs in Sediment – Integrated COPECs in sediment were subjected to the same evaluation and refinement factors applied to integrated COPECs for surface soil (there were no integrated COPECs in surface water). Some factors, such as those concerning wetlands and off-site migration, apply to the whole AOC and have already been discussed. Other evaluation and refinement factors, such as the qualitative relationship of exposure area to general home range, do not apply.

The four integrated COPECs in sediment at Wet Storage Area are manganese, 2-methylnaphthalene, acenaphthylene, and benz(a)anthracene (Table 7-15). Manganese was conservatively identified as an integrated COPEC by default (i.e., the chemical did not have an ESV) and is discussed later in Step 3A and in the uncertainty section (Section 7.3.3.9). Three COPECs [benz(a)anthracene, 2-methylnaphthalene, and acenaphthylene] had an MDC that exceeded the ESV; these are discussed below.

Benz(a)anthracene. Benz(a)anthracene in sediment had a mean concentration below its ESV (Table 7-20). It was detected in two of two discrete samples. There was no background concentration for comparison, but only one sample had a concentration exceeding the ESV. Although the MDC for benz(a)anthracene in sediment exceeds the ESV, the mean concentration is less than the ESV. Therefore, benz(a)anthracene is eliminated from further consideration and will not be a final COPEC.

2-Methylnaphthalene. 2-Methylnaphthalene was detected in two of two discrete sediment samples, and one of these samples exceeded the ESV (Appendix H, Table H-9, Table 7-20). Because 2-methylnaphthalene also had a mean concentration that exceeded the ESV and does not have a background concentration for comparison, it was evaluated further. The magnitude of ESV exceedance was fairly low; the mean concentration to ESV ratio was 2.2 (Appendix H, Table H-13). The small ratio indicates risk to ecological receptors is relatively low, and this likely supports eliminating the integrated COPEC. 2-Methylnaphthalene has no alternative ESV approved by Ohio EPA (2008).

Acenaphthylene. Acenaphthylene was detected in one of two discrete sediment samples, and the single detection exceeded the ESV (Appendix H, Table H-9, Table 7-20). Because acenaphthylene does not have a background concentration for comparison, it was evaluated further. The magnitude of ESV exceedance was fairly low; the concentration to ESV ratio was 1.9 (Appendix H, Table H-9). The small ratio indicates risk to ecological receptors is relatively low, and this likely supports eliminating the integrated COPEC. Acenaphthylene has no alternative ESV approved by Ohio EPA (2008).

None of these three sediment COPECs were detected in surface water.

Evaluation of PBT Compounds and COPECs Without ESVs – As discussed in Level II, there are five chemicals that are PBT compounds and four chemicals that are integrated COPECs by default (i.e., the chemicals did not have ESVs) in surface soil and one COPEC by default in sediment at Wet Storage Area. These chemicals are briefly evaluated below.

PBT Compounds. The *Guidance for Conducting Ecological Risk Assessments* (Ohio EPA 2008) includes a PBT compound screen in the Level II ERA. This screen is necessary because not all ESVs account for bioaccumulation; instead, they are derived based primarily on toxicity to endpoint receptors exposed by direct contact (e.g., plants and soil-dwelling invertebrates) or ingestion of soil or water (e.g., mammals and birds). For AOCs that move to a Level III BERA, PBT compounds are evaluated in the wildlife food chains. Ohio EPA allows PBTs to be screened out in Level II if the "method used to derive the screening value considered exposure to higher trophic level organisms in the development of the screening value" (Ohio EPA 2008).

For the first two sources of soil ESVs preferred by Ohio EPA (EcoSSLs and PRGs), bioaccumulation in higher trophic levels is considered in developing the ESV. According to EcoSSL guidance, "wildlife receptors may be exposed to contaminants in soil by two main pathways: incidental ingestion of soil while feeding, and ingestion of food items that have become contaminated due to uptake from soil" (USEPA 2007b). Deriving EcoSSL values includes uptake equations that account for direct ingestion and food chain bioaccumulation (USEPA 2007a). The same is true of PRGs: "the 90th percentile of the soil-to-biota uptake factor was used as a conservative estimate of the chemical concentrations in wildlife food types (earthworms, plants, or small mammals)," and "the model accounts for the ingestion of soil as well as food" (DOE 1997). It is also important to note that both sources often derive values for multiple receptors, and the most conservative (lowest) value is chosen. Thus, for soil ESVs from these two sources, PBT compounds that have ratios less than one can be dismissed as final COPECs. For this ERA, this includes 4,4'-DDE.

USEPA Region 5 ESLs (USEPA 2003) are an Ohio EPA-approved source for soil, sediment, and surface water ESVs (see Appendix H, Tables H-8 to H-10 for hierarchies); they are a source of screening values for some PBT compounds not covered in the EcoSSLs or PRGs. The ESLs also account for bioaccumulation in the food chain, as "development of ESLs focused on mammalian or avian species and identified those chemicals that have the potential for significant bioaccumulation or biomagnification" (USEPA 1999). Thus, development of ESLs included bioaccumulation in higher tropic levels as a standard component in the equations, and PBT compounds with ESVs in soil, sediment, and surface water from this source that have ratios less than one can be dismissed as final COPECs. For this ERA, this includes endrin, alpha-chlordane, and beta-BHC in surface soil.

PBT compounds at Wet Storage Area are 4,4'-DDE; endrin; alpha-chlordane; beta-BHC; and mercury in surface soil. Mercury is the only PBT COPEC that exceeded its ESV. Because all three sources of soil ESV include bioaccumulation, the four PBT compounds below their ESVs (4,4'-DDE; endrin; alpha-chlordane; and beta-BHC) are dismissed and will not be final COPECs. Mercury in surface soil was previously evaluated in Step 3A, and it will not be a final COPEC because the size of the exposure areas is small when compared to a receptor's home range.

COPECs without ESVs. The *Guidance for Conducting Ecological Risk Assessments* specifies chemicals without screening benchmark values should be retained as COPECs (Ohio EPA 2008). While Ohio EPA allows the use of additional screening benchmark values, such values need to be approved prior to submitting the report. For Wet Storage Area, a search for (and subsequent approval of) additional values was not deemed necessary. Rather, to mitigate concern for the uncertainties associated with COPECs that lack ESVs, a limited additional evaluation was conducted for each medium, focusing on frequency of detection, relationship to background concentration, and other chemical-specific refinement factors.

For soil at Wet Storage Area, the integrated COPECs without ESVs are 3-nitrotoluene, nitrocellulose, carbazole, and dibenzofuran. 3-Nitrotoluene was detected in 1 of 22 samples. Carbazole and dibenzofuran were detected in one of three samples. Thus, exposure to these chemicals would be limited. While nitrocellulose was detected in two of three samples, it is essentially non-toxic (USEPA 1987), and this chemical is also not expected to be an ecological concern.

For sediment, manganese was the only identified integrated COPEC without an ESV. It was detected in two of two sediment samples; however, the mean concentration (1,990 mg/kg) is essentially the same as the background concentration (1,950 mg/kg). Manganese is not considered an ecological concern in sediment.

Summary of Findings in Step 3A – Of the 17 integrated COPECs in surface soil at Wet Storage Area, 4 were eliminated as COPECs because they did not have ESVs and had low frequency of detection or little to no toxicity. Four PBT compounds (4,4'-DDE; endrin; alpha-chlordane; and beta-BHC) were eliminated using ESVs that accounted for bioaccumulation because they had ratios less than one. Additional integrated COPECs were eliminated from further consideration because the mean concentration is smaller than the ESV [arsenic, cobalt, benz(a)anthracene, benzo(a)pyrene, and chrysene] or the mean concentration is smaller than the background concentration (aluminum). The remaining three integrated COPECs in soil (lead, mercury, and zinc) have a combination of the following factors that together eliminated them from further consideration.

- Most mean concentrations are only slightly higher than background concentrations.
- Most mean concentration-to-ESV ratios of exceedance are near one.
- Ohio EPA guidance allows alternative ESVs that are less conservative than the ESVs used in this ERA. These alternate ESVs (unlike the preferred ESV) are above background concentrations. If these alternate ESVs were used in lieu of the current ones, ratios for lead and zinc would be below one and the ratio for mercury would be fairly low (4.7).
- Samples with highly elevated concentrations are limited to relatively small areas, and wildlife receptors are exposed to rather low frequencies of detections above the alternative ESVs.
- The wetlands are relatively small, and on-site migration is unlikely.
- Off-site downstream sampling station indicates a healthy environment.

No final COPECs in surface soil were identified for Wet Storage Area.

Of the four integrated COPECs in sediment, manganese has no ESV. It was eliminated as a COPEC because the detection is similar to the background concentration. Benz(a)anthracene was eliminated because the average concentration was lower than the ESV. 2-Methylnaphthalene and acenaphthylene were eliminated due to relatively low risk to ecological receptors (mean-to-ESV ratios of 2.2 and 1.9, respectively), lack of sediment COPECs in surface water, and positive conditions in the downstream environments. There were no integrated COPECs in surface water. No final COPECs in sediment and surface water were identified for Wet Storage Area.

7.3.3.8 Consideration of Human Health Driven Remediation

The HHRA does not identify any COCs and recommends no further action for surface soil, sediment, and surface water at Wet Storage Area. Thus, there would be no remediation implemented to further protect human health that would also protect ecological resources at Wet Storage Area.

7.3.3.9 Uncertainties and Mitigations

Uncertainties or unknowns are present in both exposure data and effects data. To mitigate uncertainty in exposure data, the MDCs of all available and appropriate data were used in Level I. In Level II, the MDC and mean COPEC concentrations were used to mitigate uncertainty concerning exposure data for receptors in the AOC. To mitigate uncertainty in effects information, a site visit for habitat condition was conducted, and the latest INRMP of rare species sightings and jurisdictional wetlands was used (OHARNG 2014). In addition, the ORAM was applied to the wetland complex. Conservative ESVs, which are typically based on concentrations observed to have no effect on test species in laboratory studies, were used in Level II to mitigate uncertainty concerning effects on receptors in the AOC. There are some COPECs because they do not have ESVs. These COPECs are assumed to have limited toxicity given the lack of cause-effect laboratory tests and field-observed effects in scientific literature.

In Level II, to mitigate uncertainty concerning effects on receptors in the AOC, the ESVs for COPECs are compared to background concentrations. Using ESVs that are lower than background concentrations indicates the conservative nature of the evaluation. Conservative ESVs are appropriate for use as screening thresholds in Level I and II (i.e., soil constituents with an MDC below the ESV need no further consideration in Level II).

7.3.3.10 Summary and Recommendations of Screening Level Ecological Risk Assessment

Integrated COPECs were identified in surface soil and sediment at Wet Storage Area. Most of the soil COPECs identified in the historical ERA were also identified during screening of PBA08 RI data. Three historical COPECs were not identified during the PBA08 RI, and a few new COPECs were identified due to additional sampling data. Because no comparable historical sediment and surface water data were available, only PBA08 RI sediment and surface water data were considered. Those chemicals retained after screening historical and PBA08 RI data were termed integrated COPECs.

Seventeen integrated soil COPECs and four integrated sediment COPECs were further evaluated in Step 3A with technical and refinement factors. All integrated soil and sediment COPECs were determined to be of no ecological concern. None require remediation or further evaluation. Consequently, the ERA for Wet Storage Area can conclude with a Level II that no further action is necessary to be protective of important ecological receptors.

7.3.4 Conclusions

There is chemical contamination present in surface soil and sediment at Wet Storage Area. This contamination was identified using historical and PBA08 RI data. Temporarily flooded forest alliances consisting of green ash/American elm/hackberry; dry, mid-successional, cold-deciduous shrubland; and mixed-deciduous, successional forest habitat were observed on the 36 acres of the AOC. Wetlands and an unnamed tributary to Sand Creek are important and significant ecological resources near contamination in the AOC. These findings invoked a Level II assessment.

The Level II assessment evaluated soil, sediment, and surface water using historical and PBA08 RI data, identified integrated COPECs, and evaluated the integrated COPECs using technical and refinement factors in Step 3A. The factors in Step 3A showed there is no further evaluation necessary for integrated COPECs, and there is no ecological concern requiring remediation. Consequently, the ERA for Wet Storage Area can conclude with a Level II that no further action is necessary to be protective of important ecological receptors.

Table 7–1. Risk Assessment Data Set for Surface Soil (0-1 ft bgs): ISM Samples

Location	Sample ID	Date	Depth (ft bgs)
WSAss-001M	WSAss-001M-SO	10/27/2004	0–1
WSAss-002M	WSAss-002M-SO	10/26/2004	0–1
WSAss-003M	WSAss-003M-SO	10/26/2004	0–1
WSAss-004D[a]	WSAss-004D-SO	10/26/2004	0–1
WSAss-004M	WSAss-004M-SO	10/26/2004	0–1
WSAss-005M	WSAss-005M-SO	10/27/2004	0–1
WSAss-006M	WSAss-006M-SO	10/27/2004	0–1
WSAss-007M	WSAss-007M-SO	10/27/2004	0–1
WSAss-008M	WSAss-008M-SO	10/29/2004	0–1
WSAss-009M	WSAss-009M-SO	10/29/2004	0–1
WSAss-010M	WSAss-010M-SO	10/28/2004	0–1
WSAss-011D[a]	WSAss-011D-SO	11/1/2004	0–1
WSAss-011M	WSAss-011M-SO	11/1/2004	0–1
WSAss-012M	WSAss-012M-SO	10/29/2004	0–1
WSAss-013M	WSAss-013M-SO	10/29/2004	0–1
WSAss-014M	WSAss-014M-SO	10/27/2004	0–1
WSAss-015M	WSAss-015M-SO	10/27/2004	0–1
WSAss-016M	WSAss-016M-SO	10/27/2004	0–1
WSAss-017M	WSAss-017M-SO	10/27/2004	0 – 1
WSAss-020M	WSAss-020M-SO	12/3/2004	0–1
WSAss-033M	WSAss-033M-5645-SO	3/24/2010	0–1
WSAss-034M	WSAss-034M-5646-SO	3/24/2010	0–1
WSAss-035M	WSAss-035M-5648-SO	3/24/2010	0–1
WSAss-036M	WSAss-036M-5647-SO	3/24/2010	0–1
WSAss-030[b]	WSAss-030-5653-SO	3/24/2010	0–1

Table 7–1. Risk Assessment Data Set for Surface Soil (0-1 ft bgs): ISM Samples (continued)

Location	Sample ID	Date	Depth (ft bgs)
WSAss-031[b]	WSAss-031-5654-SO	3/24/2010	0–1
WSAss-032[b]	WSAss-032-5655-SO	3/24/2010	0–1

[a] Discrete sample taken in ISM area for determining volatile organic compounds.

[b] Chromium speciation samples used to evaluate the presence of hexavalent chromium. WSAss-030 collected at ISM area WSAss-001M; WSAss-031 collected between ISM areas WSAss-008M and WSAss-009M; and WSAss-032 collected at ISM area WSAss-003M.

bgs = Below ground surface.
ft = Feet.
ID = Identification.
ISM = Incremental sampling methodology.

Table 7–2. Risk Assessment Data Set for Subsurface Soil: Discrete Samples

Location	Sample ID	Date	Depth (ft bgs)
WSAsb-021	WSAsb-021-5612-SO	3/23/2010	1–4
WSAsb-022	WSAsb-022-5616-SO	3/23/2010	1–4
WSAsb-023	WSAsb-023-5620-SO	3/23/2010	1–4
WSAsb-024	WSAsb-024-5624-SO	3/24/2010	1–4
WSAsb-026	WSAsb-026-5630-SO	3/23/2010	1–4
WSAsb-027	WSAsb-027-5634-SO	3/23/2010	1–4
WSAsb-028	WSAsb-028-5638-SO	3/23/2010	1–4
WSAsb-029	WSAsb-029-5642-SO	3/24/2010	1–4
WSAsb-021	WSAsb-021-5613-SO	3/23/2010	4–7
WSAsb-022	WSAsb-022-5617-SO	3/23/2010	4–7
WSAsb-023	WSAsb-023-5621-SO	3/23/2010	4–7
WSAsb-024	WSAsb-024-5625-SO	3/24/2010	4–7
WSAsb-026	WSAsb-026-5631-SO	3/23/2010	4–7
WSAsb-027	WSAsb-027-5635-SO	3/23/2010	4–7
WSAsb-028	WSAsb-028-5639-SO	3/23/2010	4–7
WSAsb-029	WSAsb-029-5643-SO	3/24/2010	4–7
WSAsb-024	WSAsb-024-5626-SO	3/24/2010	7–13
WSAsb-026	WSAsb-026-5632-SO	3/23/2010	7–13.
WSAsb-028	WSAsb-028-5640-SO	3/23/2010	7–13

bgs = Below ground surface.
ft = Feet.

Table 7–3. Risk Assessment Data Set for Surface Water

Location	Sample ID	Date
WSAsw-037	WSASW-037-5656-SW	3/23/2010
WSAsw-038	WSASW-038-5657-SW	3/23/2010

ID = Identification.

Table 7–4. Risk Assessment Data Set for Sediment

Location[a]	Sample ID	Date Sampled	Depth (ft bgs)
WSAsd-037	WSASD-037-5649-SD	3/23/2010	0–0.5
WSAsd-038	WSASD-038-5650-SD	3/23/2010	0–0.5

[a] Discrete sediment samples co-located with surface water samples.

bgs = Below ground surface.

Table 7–5. Summary of SRCs

SRC	Surface Soil (0-1 ft bgs)[a]	Subsurface Soil (1-13 ft bgs)[b]	Surface Water	Sediment
Inorganic Chemicals				
Aluminum	X	--	--	--
Antimony	--	--	X	X
Arsenic	X	X	--	--
Barium	X	--	--	--
Beryllium	X	--	--	X
Cadmium	X	X	--	X
Chromium	X	--	--	--
Cobalt	X	X	--	--
Copper	X	--	--	--
Lead	X	--	X	--
Manganese	--	--	--	X
Mercury	X	--	--	--
Nickel	X	--	X	--
Selenium	--	--	X	--
Silver	X	X	--	X
Thallium	X	--	--	--
Vanadium	--	--	X	--
Zinc	X	--	--	--
Explosives				
3-Nitrotoluene	X	--	--	--
Nitrocellulose	X	--	--	--
Pesticides				
4,4-DDE	X		--	--
4,4-DDT	--	X	--	--
Endosulfan sulfate	X	--	--	--
Endrin	X	--	--	--
alpha-Chlordane	X	--	--	--
beta-BHC	X	--	--	--
Semi-Volatile Organic Chemicals				
2-Methylnaphthalene	X	--	--	X
Acenaphthene	X	X	--	--
Acenaphthylene	X	--	--	X
Anthracene	X	X	--	X
Benz(a)anthracene	X	X	--	X
Benzenemethanol	X	--	--	--
Benzo(a)pyrene	X	X	--	X
Benzo(b)fluoranthene	X	X	--	X
Benzo(ghi)perylene	X	X	--	X
Benzo(k)fluoranthene	X	X	--	X
Bis(2-ethylhexyl)phthalate	--	X	--	--
Carbazole	X	--	--	--
Chrysene	X	X	--	X
Di-n-butyl phthalate	--	X	--	--
Dibenz(a,h)anthracene	X	X	--	--
Dibenzofuran	X	--	--	--
Fluoranthene	X	X	--	X
Fluorene	X	X	--	--
Indeno(1,2,3-cd)pyrene	X	X	--	X

Table 7–5. Summary of SRCs (continued)

SRC	Surface Soil (0-1 ft bgs)[a]	Subsurface Soil (1-13 ft bgs)[b]	Surface Water	Sediment
Naphthalene	X	X	--	X
Phenanthrene	X	X	--	X
Phenol	X	--	--	--
Pyrene	X	X	--	X
Volatile Organic Chemicals				
2-Butanone	--	--	--	X
Toluene	--	X	--	--

[a]Surface soil characterized using incremental sampling methodology sampling.
[b]Deep surface and subsurface soil characterized using discrete sampling.
bgs = Below ground surface.
BHC = Hexachlorocyclohexane.
DDE = Dichlorodiphenyldichloroethylene.
DDT = Dichlorodiphenyltrichloroethane.
ft = Feet.
SRC = Site-related contaminant.
X = Chemical is an SRC in this medium.
-- = Compound not identified as an SRC in this medium.

Table 7–6. Summary of COPCs

COPC	Surface Soil (0-1 ft bgs)[a]	Subsurface Soil (1-13 ft bgs)[b]	Surface Water	Sediment
Inorganic Chemicals				
Aluminum	X	--	--	--
Arsenic	X	X	--	--
Chromium	X	--	--	--
Cobalt	X	X	--	--
Manganese	--	--	--	X
Semi-Volatile Organic Chemicals				
Benz(a)anthracene	X	--	--	--
Benzo(a)pyrene	X	X	--	X
Benzo(b)fluoranthene	X	--	--	--
Benzo(k)fluoranthene	X	--	--	--
Dibenz(a,h)anthracene	X	--	--	--
Indeno(1,2,3-cd)pyrene	X	--	--	--

[a]Surface soil characterized using incremental sampling methodology sampling.
[b]Subsurface soil characterized using discrete sampling.
bgs = Below ground surface.
COPC = Chemical of potential concern.
X = Chemical is a COPC in this medium.
-- = Chemical is not identified as a COPC in this medium.

Table 7–7. FWCUGs Corresponding to an HQ of 1 and TR of 1E-05 for COPCs in Soil and/or Sediment

COPC	Critical Effect or Target Organ	FWCUG (mg/kg)	
		HQ = 1	TR = 1E-05
Aluminum	Neurotoxicity in offspring	73,798	--
Arsenic	Skin	20.2	4.25[c]
Chromium, hexavalent[b]	Stomach ulcer, liver/kidney	199	1,874
Chromium, trivalent	NOAEL	81,473	--
Cobalt	Not specified	1,313	8,030
Manganese	Central nervous system	2,927[c]	--
Benz(a)anthracene	NA	--	2.21
Benzo(a)pyrene	NA	--	0.221
Benzo(b)fluoranthene	NA	--	2.21
Benzo(k)fluoranthene	NA	--	22.1
Dibenz(a,h)anthracene	NA	--	0.221
Indeno(1,2,3-cd)pyrene	NA	--	2.21

[a]Resident FWCUGs are the smaller of the Adult or Child values for each COPC and endpoint (non-cancer and cancer).

[b]FWCUG for hexavalent chromium was calculated using a cancer unit risk factor developed for a chromate mixture consisting of 1/7 hexavalent chromium and 6/7 trivalent chromium.

[c]Risk-based FWCUG is less than the background screening values for arsenic in surface soil (15.4 mg/kg), subsurface soil (19.8 mg/kg), and sediment (19.5 mg/kg) and for manganese in surface soil (1,450 mg/kg), subsurface soil (3,030 mg/kg), and sediment (1,950 mg/kg).

COPC = Chemical of potential concern.
FWCUG = Facility-wide cleanup goal.
HQ = Hazard quotient.
mg/kg = Milligrams per kilogram.
NA = Not applicable
NOAEL = No observable adverse effect level.
TR = Target risk.
-- = No value available.

Table 7–8. Total and Hexavalent Chromium Soil Sample Results

ISM Sample Results		Discrete Chromium Speciation Sample Results			
ISM Sample Location	Total Chromium (mg/kg)	Discrete Sample Location[a]	Total Chromium (mg/kg)	Hexavalent Chromium (mg/kg)	Percent Hexavalent Chromium (%)
WSAss-001M	22	WSAss-030	21.8	ND	NA
WSAss-008M/ WSAss-009M	18/18	WSAss-031	16.5	0.52J	3.2
WSAss-003M	26	WSAss-032	20.6	ND	NA

[a]Discrete sample location is located within the corresponding ISM sample location (for WSAss-030 and WSAss-032) or between the two corresponding ISM sample locations (for WSAss-031).

ISM = Incremental sampling methodology.
mg/kg = Milligrams per kilogram.
NA = Not applicable; hexavalent chromium not detected in sample.
ND = Not detected.
J = Estimated concentration.

Table 7–9. Comparison of Surface Soil (0−1 ft bgs) Results for ISM and Discrete Samples at Wet Storage Area

Analyte (mg/kg)	CAS Number	ISM Sample Results		Discrete Sample Results		Maximum Detected Concentration in ISM or Discrete Sample
		Freq of Detect	Maximum Detect	Freq of Detect	Maximum Detect	
Metals and Anions						
Aluminum	**7429-90-5**	**22/ 22**	**27100**	**8/ 8**	**12,000**	**ISM**
Antimony	7440-36-0	5/ 22	0.52	7/ 8	0.19	ISM
Arsenic	**7440-38-2**	**22/ 22**	**21**	**8/ 8**	**21.5**	**Discrete**
Barium	7440-39-3	22/ 22	110	8/ 8	89.8	ISM
Beryllium	7440-41-7	22/ 22	1.3	8/ 8	0.7	ISM
Cadmium	7440-43-9	4/ 22	0.19	8/ 8	0.5	Discrete
Calcium	7440-70-2	22/ 22	5,900	8/ 8	3,860	ISM
Chromium[d]	**7440-47-3**	**22/ 22**	**26**	**8/ 8**	**18.7**	**ISM**
Cobalt	**7440-48-4**	**22/ 22**	**14**	**8/ 8**	**12.2**	**ISM**
Copper	7440-50-8	22/ 22	21	8/ 8	22.1	Discrete
Iron	7439-89-6	22/ 22	32,000	8/ 8	33,600	Discrete
Lead	7439-92-1	22/ 22	97	8/ 8	47.7	ISM
Magnesium	7439-95-4	22/ 22	3,900	8/ 8	3,820	ISM
Manganese	7439-96-5	22/ 22	1,130	8/ 8	812	ISM
Mercury	7439-97-6	22/ 22	2.1	4/ 8	0.73	ISM
Nickel	7440-02-0	22/ 22	32	8/ 8	30	ISM
Potassium	7440-09-7	22/ 22	2,230	8/ 8	1,090	ISM
Selenium	7782-49-2	6/ 22	1.4	8/ 8	1.2	ISM
Silver	7440-22-4	1/ 22	0.035	ND	ND	ISM
Sodium	7440-23-5	22/ 22	430	8/ 8	45.1	ISM
Thallium	7440-28-0	8/ 22	0.31	8/ 8	0.18	ISM
Vanadium	7440-62-2	22/ 22	28	8/ 8	19.3	ISM
Zinc	7440-66-6	22/ 22	140	8/ 8	114	ISM
Explosives						
3-Nitrotoluene	99-08-1	1/ 22	0.08	ND	ND	ISM
Nitrocellulose	9004-70-0	2/ 3	1.1	ND	ND	ISM
Tetryl	479-45-8	ND	ND	1/ 8	0.026	Discrete
SVOCs						
2-Methylnaphthalene	91-57-6	2/ 3	0.058	1/ 2	0.022	ISM
Acenaphthene	83-32-9	3/ 6	1.5	4/ 8	0.77	ISM
Acenaphthylene[e]	208-96-8	1/ 6	0.016	ND	ND	ISM
Anthracene	120-12-7	4/ 6	2.9	5/ 8	2.1	ISM
Benz(a)anthracene	**56-55-3**	**5/ 6**	**8.2**	**6/ 8**	**3.9**	**ISM**
Benzenemethanol	100-51-6	1/ 3	0.62	ND	ND	ISM
Benzo(a)pyrene	**50-32-8**	**6/ 6**	**5.5**	**6/ 8**	**3.6**	**ISM**
Benzo(b)fluoranthene	**205-99-2**	**6/ 6**	**7.3**	**6/ 8**	**4**	**ISM**
Benzo(ghi)perylene[e]	191-24-2	5/ 6	3.7	6/ 8	2.2	ISM
Benzo(k)fluoranthene	**207-08-9**	**5/ 6**	**3.2**	**6/ 8**	**2.2**	**ISM**
Bis(2-ethylhexyl)phthalate	117-81-7	ND	ND	1/ 2	0.084	Discrete
Carbazole	86-74-8	1/ 3	1.4	2/ 2	0.65	ISM
Chrysene	218-01-9	6/ 6	7.8	6/ 8	3.5	ISM
Dibenz(a,h)anthracene	**53-70-3**	**4/ 6**	**0.94**	**4/ 8**	**0.49**	**ISM**
Dibenzofuran	132-64-9	1/ 3	0.54	2/ 2	0.19	ISM
Fluoranthene	206-44-0	6/ 6	18	7/ 8	11	ISM
Fluorene	86-73-7	4/ 6	1.3	4/ 8	0.73	ISM

Table 7–9. Comparison of Surface Soil (0-1 ft bgs) Results for ISM and Discrete Samples at Wet Storage Area (continued)

Analyte (mg/kg)	CAS Number	ISM Sample Results		Discrete Sample Results		Maximum Detected Concentration in ISM or Discrete Sample
		Freq of Detect	Maximum Detect	Freq of Detect	Maximum Detect	
Indeno(1,2,3-cd)pyrene	**193-39-5**	**5/ 6**	**3.4**	**6/ 8**	**1.9**	**ISM**
Naphthalene	91-20-3	5/ 6	0.081	1/ 8	0.039	ISM
Phenanthrene[e]	85-01-8	5/ 6	12	6/ 8	7.5	ISM
Phenol	108-95-2	1/ 3	0.028	ND	ND	ISM
Pyrene	129-00-0	6/ 6	17	7/ 8	8.1	ISM
Pesticides						
4,4'-DDE	72-55-9	1/ 3	0.0004	ND	ND	ISM
Endosulfan sulfate	1031-07-8	1/ 3	0.0026	ND	ND	ISM
Endrin	72-20-8	1/ 3	0.00069	ND	ND	ISM
alpha-Chlordane	5103-71-9	1/ 3	0.0021	ND	ND	ISM
beta-BHC	319-85-7	1/ 3	0.0034	ND	ND	ISM

bgs = Below ground surface.
BHC = Hexachlorocyclohexane.
CAS = Chemical Abstract Service.
DDE = Dichlorodiphenyldichloroethylene.
ft = Feet.
ISM = Incremental sampling methodology.
mg/kg = Milligrams per kilogram.
ND = Not detected.
SVOC = Semi-volatile organic compound.
-- = No value available.
Bold = Chemical is a chemical of potential concern.

Table 7–10. Environmental Concentrations of PAHs Measured in Background Surface Soil Samples at RVAAP

Analyte	% Detects		Reported Concentration (mg/kg)	
			Minimum	Maximum
Acenaphthene	1/15	7%	0.88	0.88
Acenaphthylene	1/15	7%	0.07	0.07
Anthracene	2/15	13%	0.12	1
Benz(a)anthracene	10/15	67%	0.044	4.1
Benzo(a)pyrene	8/15	53%	0.058	3.7
Benzo(b)fluoranthene	10/15	67%	0.062	4.8
Benzo(ghi)perylene	6/15	40%	0.046	1.3
Benzo(k)fluoranthene	6/15	40%	0.053	2.6
Chrysene	10/15	67%	0.057	4
Dibenz(a,h)anthracene	2/15	13%	0.11	0.37
Indeno(1,2,3-cd)pyrene	5/15	33%	0.054	1.5

mg/kg = Milligrams per kilogram.
PAH = Polycyclic aromatic hydrocarbon.
RVAAP = Ravenna Army Ammunition Plant.

Table 7–11. Concentrations of Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, and Dibenz(a,h)anthracene in Soil from Various Environmental Studies

Study	Number of Samples	Geometric Mean or Median	Minimum	95th Percentile[a]	Maximum
Benz(a)anthracene					
CA/T Project[b]	872	0.33	0.045	19	250
LSPA Project[b]	490	0.563	ND	--	796
Watertown[b]	17	0.411	0.021	6.04	6.05
Worcester[b]	68	--	ND	3.8	15
New England[c]	62	0.672	ND	1.86	15
Illinois[d] Urban	--	--	--	1.8	--
Illinois[d] Rural	--	--	--	0.72	--
ATSDR[e] Urban	--	--	0.169	--	59
ATSDR[e] Rural	--	--	0.005	--	0.02
ATSDR[e] Agricultural	--	--	0.056	--	0.11
NYSDEC Rural Near Roads[f]	28	--	ND	1.2	2.9
NYSDEC Rural Distant Roads[f]	118	--	ND	0.16	2.6
Benzo(a)pyrene					
CA/T Project[b]	873	0.3	0.031	17	230
LSPA Project[b]	489	0.44	ND	--	222
Watertown[b]	17	0.95	0.6	4.77	6.08
Worcester[b]	67	--	ND	3.3	9.7
New England[c]	62	0.686	ND	1.82	13
Illinois[d] Urban	--	--	--	2.1	--
Illinois[d] Rural	--	--	--	0.98	--
ATSDR[e] Urban	--	--	0.165	--	0.22
ATSDR[e] Rural	--	--	0.002	--	1.3
ATSDR[e] Agricultural	--	--	0.0046	--	0.9
NYSDEC Rural Near Roads[f]	28	--	ND	1.1	2.4
NYSDEC Rural Distant Roads[f]	118	--	ND	0.12	3.4
Benzo(b)fluoranthene					
CA/T Project[b]	873	0.68	0.045	18	270
NYSDEC Rural Distant Roads[f]	118	--	ND	--	0.23
LSPA Project[b]	486	--	ND	--	250
Watertown[b]	17	1.4	0.6	6.79	7.08
Worcester[b]	--	--	--	--	--
New England[c]	62	0.722	ND	1.97	12
Illinois[d] Urban	--	--	--	2	--
Illinois[d] Rural	--	--	--	0.7	--
ATSDR[e] Urban	--	--	15	--	62
ATSDR[e] Rural	--	--	0.02	--	0.03
ATSDR[e] Agricultural	--	--	0.058	--	0.22
NYSDEC Rural Near Roads[f]	28	--	ND	1.2	3.3
NYSDEC Rural Distant Roads[f]	118	--	ND	0.36	4.6
Dibenz(a,h)anthracene					
CA/T Project[b]	866	0.17	0.045	2.1	39
LSPA Project[b]	--	--	--	--	--
Watertown[b]	17	0.195	0.155	0.604	0.64
Worcester[b]	68	--	ND	--	1.6
New England[c]	62	0.245	ND	--	2.9
Illinois[d] Urban	--	--	--	0.42	--
Illinois[d] Rural	--	--	--	0.15	--

Table 7–11. Concentrations of Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, and Dibenz(a,h)anthracene in Soil from Various Environmental Studies (continued)

Study	Number of Samples	Geometric Mean or Median	Minimum	95th Percentile[a]	Maximum
ATSDR[e]	--	--	--	--	--
NYSDEC Rural Near Roads[f]	28	--	--	--	--
NYSDEC Rural Distant Roads[f]	118	--	ND	--	0.23

[a] Lognormal 95th percentile value for all studies except: (1) New England value is 95% upper confidence limit and (2) NYSDEC values are distribution-free 95th percentile.

[b] Data reported by Massachusetts Department of Environmental Protection (MADEP 2002) are from the following data sets:
CA/T = Data collected by Mass Highway Department as part of the Central Artery/Tunnel (CA/T) project.
LSPA = Preliminary data compiled by the Massachusetts Licensed Site professional Association (LSPA) from data submitted by its members in 2001.
Water Town and Worcester Site-specific samples.

[c] Data from three New England locations from Bradley et al. 1994.

[d] Concentrations of polycyclic aromatic hydrocarbons (PAHs) in Illinois metropolitan statistical areas (urban) and non-metropolitan statistical areas (rural) as reported by Illinois Environmental Protection Agency (IEPA 2005).

[e] Data published by the Agency for Toxic Substances and Disease Registry (ATSDR) in PAHs August 1995.

[f] Distribution-free 95th percentile values for near roads (less than 10 ft from roads and pavement) and not near roads (more than 15 ft from roads and pavement) from New York State Brownfield Cleanup program Development of Soil Cleanup Objectives Technical Support Document (September 2006), Appendix D.

ND = Not detected.
NYSDEC = New York State Department of Environmental Conservation.
-- = No value reported for this source.

Table 7–12. Summary of Historical COPECs per the Characterization of 14 AOCs

Group	COPEC	Shallow Soil	Sediment	Surface Water
Inorganic Chemicals	Arsenic	X	--	--
	Chromium	X	--	--
	Iron	X	--	--
	Lead	X	--	--
	Mercury	X	--	--
	Nickel	X	--	--
	Zinc	X	--	--
Pesticides	Beta-BHC	X	--	--
SVOCs	Benz(a)anthracene	X	--	--
	Benzo(a)pyrene	X	--	--
	Carbazole	X	--	--
	Chrysene	X	--	--
	Dibenzofuran	X	--	--
Explosives	3-Nitrotoluene	X	--	--
Propellants	Nitrocellulose	X	--	--

Adapted from Table WSA-5 from the Characterization of 14 AOCs (MKM 2007).
AOC = Area of concern.
BHC = Hexachlorocyclohexane.
SVOC = Semi-volatile organic compound.
COPEC = Chemical of potential ecological concern.
-- = Chemical not identified as a COPEC in this data set.
X = Quantitative COPEC, exceeds ecological screening value.

Table 7–13. Comparison of Five Assessment Attributes at Sampling Stations near Wet Storage Area

Attribute	Attribute Rating S-2 (RM 5.9) (upstream)	Attribute Rating S-3 (RM 4.84) (upstream)	Attribute Rating S-4 (RM 4.5) (downstream)	Comments
Sediment quality	Excellent	Good	Excellent	Downstream station rating is equivalent to upstream stations, suggesting no negative impacts from Wet Storage Area.
Water quality	Excellent	Excellent	Excellent	Downstream station rating is equivalent to upstream stations, suggesting no negative impacts from Wet Storage Area.
Fish community (IBI)[a]	Good	Good	Good	Downstream station rating is equivalent to upstream stations, suggesting no negative impacts from Wet Storage Area.
Macroinvertebrate community (ICI)[b]	Excellent	Good	Good	Downstream station rating is equivalent to upstream station S-3 and minor deviation from rating of upstream station S-2, suggesting no negative downstream impacts from Wet Storage Area.
Habitat (QHEI)[c]	Excellent	Good	Excellent	Downstream station rating is equivalent to upstream stations, suggesting no negative impacts from Wet Storage Area.
Use Attainment Status [d]	Full	Full	Full	Downstream station rating is equivalent to upstream stations, suggesting no negative impacts from Wet Storage Area.

[a] Fish communities -range from 0-60, with <18 being “very poor,” 18-26 being “poor,” 28-34 being “fair,” 36-48 being “good,” and 50-60 being “excellent” (Ohio EPA 1988).

[b] Macroinvertebrate communities range from 0-60, with <2 being “very poor,” 2-12 being “poor,” 14-32 being “fair,” 34-46 being “good,” and 48-60 being “excellent” (Ohio EPA 1988).

[c] Habitat ranges from 20 to <100, with <20 being “very poor,” 30-44 being “poor,” 45-59 being “fair,” 60-74 being “good,” and 75-100 being “excellent” (Ohio EPA 2009).

[d] Full-attainment means all of the applicable indices meet the Ohio EPA biocriteria (USACE 2005b).

IBI = Index of Biotic Integrity.
ICI = Invertebrate Community Index
QHEI = Qualitative Habitat Evaluation Index.
RM = River mile
< = Less than.

Table 7–14. Survey of Proximity to the AOC of Various Ecological Resources

Natural Resource	Natural Resources Inside Habitat Area	Proximity Within or Near the AOC	Distances to Nearest Resources of the AOCs[a]
Wetlands (Planning Level Survey and Jurisdictional)	A small, high quality (Category 3) wetland complex; wetlands associated with drainage ditches and natural conveyances	The small high quality wetland is along the eastern border; other wetlands occur throughout AOC, adjacent to former igloos and existing roadways	Other wetlands are in vicinity of AOC (Figure 7-1)
Rare species	No known sightings	None	325 ft to the south/southeast 500 ft to the north/northeast 800 ft to the north/northeast[b] (See text for species names)
Beaver dams	None	None	3,200 ft north 3,700 ft southwest
100-year floodplain	Floodplain along unnamed tributary to the west	Sand Creek floodplain to the north	100-year floodplain to Sand Creek located within the AOC
Stream sampling[c]	None	Stream sampling stations 600 ft to the southwest on unnamed tributary to Sand Creek and 600 ft to the northeast on Sand Creek	Additional stream sampling station approximately 4,000 ft upstream of the AOC
Pond sampling[c]	None	None	Approximately 6,600 ft south (George’s Pond)

[a] Measurements of distance and direction are taken from the nearest boundary of the AOC to the resource being measured.

[b] The butternut is a federal species of concern, which is not an officially listed status with legal protection.

[c] Stream and pond sampling refers to *Facility-wide Biological and Water Quality Study 2003* (USACE 2005b).

AOC = Area of concern.

ft = Feet.

Table 7–15. Summary of Integrated COPECs for Surface Soil

COPEC	MDC (mg/kg)	ESV (mg/kg)	Ratio of MDC to ESV	Comments
Aluminum	27,100	50	542	Second highest ratio at 542x
Arsenic	21	18	1.2	None
Cobalt	14	13	1.1	None
Lead	97	11	8.8	None
Mercury	2.1	0.00051	4,118	Highest ratio at more than 4100x; PBT Compound
Zinc	140	46	3.0	None
3-Nitrotoluene	0.08	No ESV	--	None
Nitrocellulose	1.1	No ESV	--	None
Benz(a)anthracene	8.2	5.21	1.6	None
Benzo(a)pyrene	5.5	1.52	3.6	None
Carbazole	1.4	No ESV	--	None
Chrysene	7.8	4.73	1.7	None
Dibenzofuran	0.54	No ESV	--	None
4,4’-DDE	0.0004	0.021	0.02	PBT Compound
Endrin	0.00069	0.0101	0.07	PBT Compound
alpha-Chlordane	0.0021	0.224	0.01	PBT Compound
beta-BHC	0.0034	0.00398	0.85	PBT Compound

Table excludes nutrients.
BHC = Hexachlorocyclohexane.
COPEC = Chemical of potential ecological concern.
DDE = Dichlorodiphenyldichloroethylene.
ESV = Ecological screening value.
MDC = Maximum detected concentration.
PBT = Persistent, bioaccumulative, and toxic
x = Multiplier.
-- = Not applicable, no ESV is available for comparison.

Table 7–16. Summary of Integrated COPECs in Sediment

COPEC	MDC (mg/kg)	ESV (mg/kg)	Ratio of Maximum to ESV	Comments
Manganese	2,230	No ESV	--	None
2-Methylnaphthalene	0.08	0.0202	4	Highest ratio at 4x
Acenaphthylene	0.011	0.00587	1.9	Second highest ratio at almost 2x
Benz(a)anthracene	0.12	0.108	1.1	None

Table excludes nutrients.
COPEC = Chemical of potential ecological concern.
ESV = Ecological screening value.
MDC = Maximum detected concentration.
-- = Not applicable, no ESV available.
x = Multiplier

Table 7–17. Application and Decisions of Selected Evaluation Factors to Integrated COPECs for Surface Soil from Level II

Action	Condition for Decision to Dismiss or Retain COPEC	Outcome
Compare mean concentration to ESV	(A) Mean concentration smaller than or equal to the ESV	COPEC is not a candidate to be a final COPEC. Evaluation ceased.
	(B) Mean concentration larger than the ESV	Continue evaluation of chemical.
Compare mean concentration above ESV to background concentration	(A) Mean concentration smaller than the background concentration	COPEC is not a candidate to be a final COPEC. Evaluation ceased.
	(B) Mean concentration larger than background concentration	Continue evaluation of chemical.

COPEC = Chemical of potential ecological concern.
ESV = Ecological screening value.

Table 7–18. Summary of Data for Step 3A Refinement of Integrated COPECs in Surface Soil at Wet Storage Area

COPEC	Mean Concentration (mg/kg)	ESV (mg/kg)	Mean Concentration > ESV? (Yes/No)	Background Concentration (mg/kg)	Mean Concentration > Background Concentration? (Yes/No)	ESV > Background Concentration? (Yes/No)	Frequency of Detections[a] > ESV	Frequency of Detections[a] > Background Concentration	Further Evaluation in Level II Required? (Yes/No)
COPEC with Mean Concentration < ESV									
Arsenic	15.3	18	No	15.4	No	Yes	2/22	9/22	No
Cobalt	10.6	13	No	10.4	Yes	Yes	1/22	10/22	No
Benz(a)anthracene	1.41	5.21	No	0	Yes	Yes	1/5	5/5	No
Benzo(a)pyrene	0.957	1.52	No	0	Yes	Yes	1/6	6/6	No
Chrysene	1.35	4.73	No	0	Yes	Yes	1/6	6/6	No
COPEC with Mean Concentration > ESV and Mean Concentration < Background Concentration									
Aluminum	12,400	50	Yes	17,700	No	No	22/22	1/22	No
COPEC with Mean Concentration > ESV and Mean Concentration > Background Concentration									
Lead	26.6	11	Yes	26.1	Yes	No	22/22	5/22	Yes
Mercury	0.466	0.00051	Yes	0.036	Yes	No	22/22	12/22	Yes
Zinc	69.7	46	Yes	61.8	Yes	No	22/22	12/22	Yes

[a] Frequency of detection refers to the subset of detections relative to ESV or background concentration as opposed to the standard frequency of detections of total samples taken.

COPEC = Chemical of potential ecological concern.
ESV = Ecological screening value.
mg/kg = Milligrams per kilogram.
< = Less than.
> = Greater than.

Table 7–19. Summary of Mean Concentrations and Background Concentrations of Remaining Integrated Soil COPECs in the Refinement Factors

COPEC	Mean Concentration (mg/kg)	Background Concentration (mg/kg)	Ratio of Mean Concentration to Background Concentration	Qualitative Assessment of Mean to Background Concentration
Surface Soil				
Lead	26.6	26.1	1.02	Concentrations are similar
Mercury	0.466	0.036	12.9	Mean concentration is larger than the background concentration
Zinc	69.7	61.8	1.13	Concentrations are similar

COPEC = Chemical of potential ecological concern.
mg/kg = Milligrams per kilogram.

Table 7–20. Comparison of Alternative ESV to Mean Concentration for Remaining Integrated COPECs

COPEC	Background Concentration (mg/kg)	Preferred ESV (mg/kg)	Alternative ESV[a] (mg/kg)	Ratio of Preferred ESV to Mean Concentration	Ratio of Alternative ESV to Mean Concentration
Lead	26.1	11	40.5	2.4	0.7
Mercury	0.036	0.00051	0.1	913.7	4.7
Zinc	61.8	46	79	1.5	0.9

[a] The Alternative ESV is the ESV with the closest concentration to the preferred ESV that is above the background concentration.

COPEC = Chemical of potential ecological concern.
ESV = Ecological screening value.
mg/kg = Milligrams per kilogram.

Table 7–21. Summary of Data for Step 3A Refinement of Integrated COPECs in Sediment at Wet Storage Area

COPEC	Mean Conc. (mg/kg)	ESV (mg/kg)	Mean Conc. > ESV? (Yes/No)	Background Conc. (mg/kg)	Mean Conc.> Background Conc.? (Yes/No)	ESV > Background Conc.? (Yes/No)	Frequency of Detections[a] > ESV	Frequency of Detections[a] > Background Conc.	Further Evaluation in Level II Required? (Yes/No)
COPEC with Mean Concentration < ESV									
Benz(a)anthracene	0.066	0.108	No	0	Yes	Yes	1/2	2/2	No
COPEC with Mean Concentration > ESV and Mean Concentration > Background Concentration									
2-Methylnaphthalene	0.0442	0.0202	Yes	0	Yes	Yes	1/2	2/2	Yes
Acenaphthylene	0.02	0.00587	Yes	0	Yes	Yes	1/1	1/1	Yes

[a] Frequency of detection refers to the subset of detections relative to ESV or background concentration as opposed to the standard frequency of detections of total samples taken.

Conc. = Concentration

COPEC = Chemical of potential ecological concern.

ESV = Ecological screening value.

mg/kg = Milligrams per kilogram.

< = Less than.

> = Greater than.

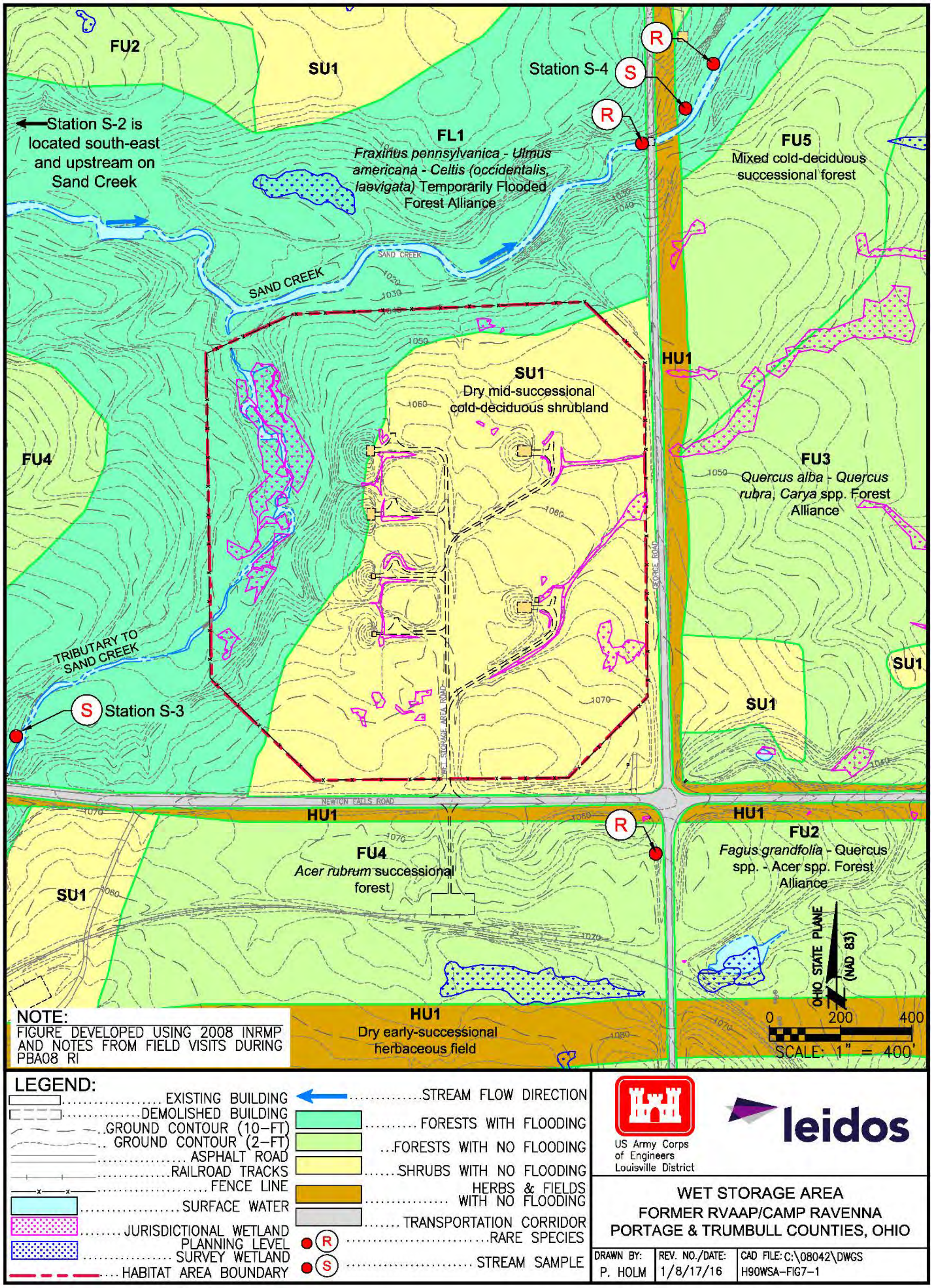


Figure 7–1. Natural Resources Inside and Near Habitat Area at Wet Storage Area

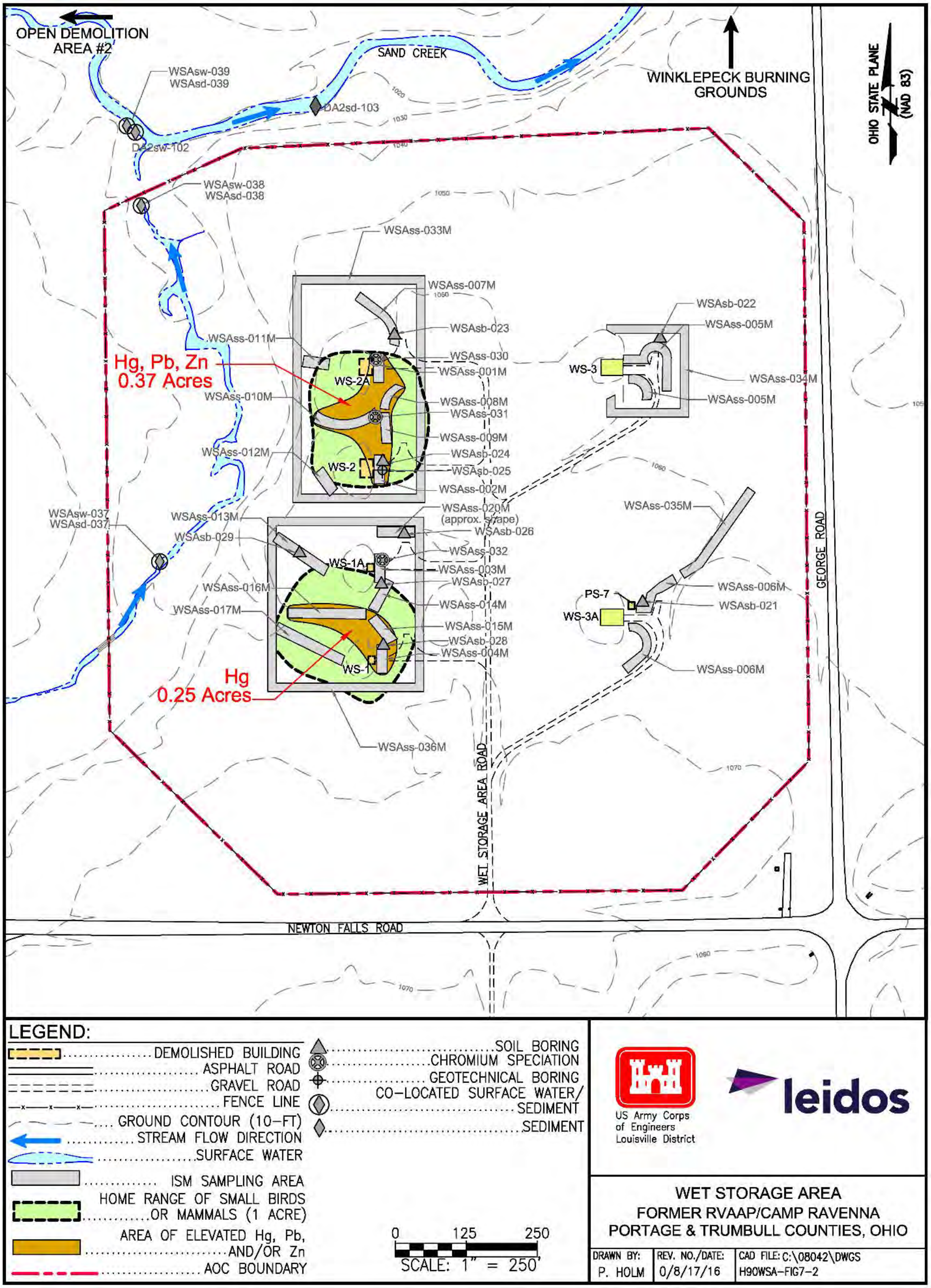


Figure 7–2. The Relationship of Areas of Highest Concentration to General Home Range

8.0 REMEDIAL INVESTIGATION CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

This RI Report for Wet Storage Area presents a detailed analysis of historical and newly acquired environmental data. The following sections summarize the major findings of the nature and extent of contamination, contaminant fate and transport modeling, HHRA, and ERA. A CSM incorporating all available information is presented to integrate results of prior investigations and the PBA08 RI. The CSM denotes, based on available data where source areas occur, the mechanisms for contaminant migration from source areas to receptor media (e.g., surface water and groundwater), exit pathways from the AOC, and if COCs occur that may require further evaluation in an FS. This section concludes with recommendations for any further characterization under the RI phase of work and, for each of the media evaluated in the RI, whether to proceed to the FS phase of the RI/FS process.

8.2 SUMMARY OF DATA USED IN THE REMEDIAL INVESTIGATION

Quality-assured sample data from the Building T-5301 IRA, ODA2 Phase II RI, Characterization of 14 AOCs report (MKM 2007) and 2010 PBA08 RI were used to evaluate nature and extent of contamination at Wet Storage Area. These investigations used discrete and ISM sampling methods.

All available sample data collected at the locations were evaluated to determine suitability for use in various key RI data screens and evaluations (i.e., nature and extent, fate and transport, and risk assessment). Evaluation of the data's suitability for use in the PBA08 RI involved two primary considerations: whether the data represented current AOC conditions and sample collection methods (e.g., discrete vs. ISM).

Surface water and sediment samples outside the AOC from the ODA2 Phase II RI and the 2000 Building T-5301 IRA were considered with respect to contaminant migration. Samples from the Characterization of 14 AOCs data set were evaluated to determine if conditions had changed substantively between earlier characterization efforts and the 2010 PBA08 RI. The samples collected in 2004–2005 were collected within ditch lines adjacent to former buildings and in areas encompassing, but also extending substantially beyond the footprint of the former buildings. Therefore, both data sets were considered representative of current conditions within and surrounding the footprints of the former buildings/igloos at Wet Storage Area.

Data collected in 2010 as part of the PBA08 RI focused on delineating the extent of contaminants identified in surface soil (0–1 ft bgs), subsurface soil (1–13 ft bgs), sediment, and surface water. The PBA08 RI sampled locations with the greatest likelihood of contamination (e.g., adjacent to production buildings or within sediment accumulation areas, such as ditches) and analyzed for chemicals identified in historical investigations. Additionally, sediment and surface water samples were collected from drainage ditches and streams exiting the AOC.

8.3 SUMMARY OF NATURE AND EXTENT

Nature and extent of contamination in surface soil (0–1 ft bgs), subsurface soil (greater than 1 ft bgs), sediment, and surface water was evaluated in the RI. Data from the RIs (2004 Characterization of 14 AOCs and 2010 PBA08 RI) effectively characterize the nature and extent of the contamination at the AOC. Surface water and sediment samples outside the AOC from the 2002 ODA2 Phase II RI and the 2000 Building T-5301 IRA were considered with respect to contaminant migration but were not used in the Wet Storage Area data screening process. Figure 4-6 shows the sample locations used to conduct this RI. To support the evaluation of nature and extent of contamination, SRC concentrations were compared to SLs corresponding to the lowest FWCUG for the Resident Receptor (Adult and Child) and National Guard Trainee at a target HQ of 0.1 or TR of 1E-06, as presented in the FWCUG Report (USACE 2010a) (herein referred to as the FWCUG Report). It can be concluded that the vertical and horizontal extent of contamination is defined, and no further sampling is needed to evaluate Wet Storage Area.

8.3.1 Surface Soil

The predominant SRCs in surface soil at Wet Storage Area were inorganic chemicals and SVOCs, the majority of which were PAHs. Fourteen inorganic chemicals were identified as SRCs in surface soil. The maximum concentrations for inorganic SRCs were not concentrated in any one location, and two ISM samples with the most maximum detections for surface soil were WSAss-002M and WSAss-033M. The highest density of samples with inorganic chemicals above background concentrations was located in the vicinity of the former igloos in the northwestern portion of Wet Storage Area. Aluminum, arsenic, and cobalt concentrations exceeded their respective SLs and were considered COPCs; however, only arsenic concentrations at nine ISM locations exceeded the respective Resident Receptor (Adult and Child) at a TR of 1E-05, HQ of 1. The arsenic exceedance does not appear to be concentrated in any particular area of the AOC.

All 21 SVOC SRCs were detected at 2004 ISM sample location WSAss-004M, located adjacent to one of the southwestern igloos, with maximum detections for all 21 of the SVOC SRCs observed in this sample. Thirteen SVOCs were detected at WSAss-036M, which delineates the area containing WSAss-004M, at concentrations typically two orders of magnitude lower than those observed at WSAss-004M. Although SVOC detections in surface soil occur throughout the AOC, the samples with the highest concentrations generally occur adjacent to the former and extant igloo locations and are effectively delineated by the PBA08 RI data. Five of the six PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] that exceeded the SLs at WSAss-004M were detected at concentrations greater than their respective Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. Benzo(a)pyrene also exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1 at discrete PBA08 RI sample locations WSAsb-022, WSAsb-024, WSAsb-027, and WSAsb-028. Benz(a)anthracene, benzo(b)fluoranthene, and dibenz(a,h)anthracene also exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1 at discrete PBA08 RI sample locations WSAsb-024 and WSAsb-028.

An explosive (3-nitrotoluene), propellant (nitrocellulose), and five pesticides (4,4'-DDE; endosulfan sulfate; endrin; alpha-chlordane; and beta-BHC) were identified as SRCs in the surface soil at Wet Storage Area. None of the detected concentrations exceeded their respective SLs. VOCs and PCBs were not detected in the surface soil.

8.3.2 Subsurface Soil

Four inorganic chemicals (arsenic, cadmium, cobalt, and silver) were identified as SRCs, although no spatial or vertical trend is apparent for the distribution of inorganic chemicals in subsurface soil, and concentrations only marginally exceeded their applicable background concentrations. Seventeen SVOCs were identified as SRCs, with soil boring location WSAsb-024 (located adjacent to one of the former igloos in the northwest portion of the AOC) containing the greatest number and highest concentrations of SVOCs. Benzo(a)pyrene was detected at 1–4 ft bgs at WSAsb-024 at a concentration that exceeded its SL of 0.022 mg/kg; thus, benzo(a)pyrene was identified as a COPC. The benzo(a)pyrene concentration was detected below the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. No SVOCs were detected at 4–7 or 7–13 ft bgs at WSAsb-024. The majority of SVOC SRCs were PAHs which were identified as SRCs in surface soil as well.

One VOC (toluene) and one pesticide (4,4'-DDT) were identified as SRCs, although they occurred at low, estimated concentrations in different depth intervals of soil boring WSAsb-028. Explosives, propellants, and PCBs were not detected in the subsurface soil.

8.3.3 Sediment

The greatest number and highest magnitude of the identified SRCs in sediment samples were detected in the most upstream location within the unnamed tributary to the west of Wet Storage Area. The predominant SRCs in sediment were inorganic chemicals and PAHs. SRC concentrations generally followed a clear longitudinal trend, exhibiting decreasing numbers and concentrations with downstream distance. However, location WSAsd-037, which exhibits the highest and most PAH and inorganic detections, is in a location that is upstream relative to potential surface water contributions from Wet Storage Area; therefore, it is not influenced by runoff from the AOC. Two of the inorganic chemicals (antimony and manganese) were not identified as SRCs in surface soil at Wet Storage Area and occurred in sediment at upstream location WSAsd-037 at concentrations twice or more of the maximum concentrations observed in surface soil at the AOC. Manganese concentrations at WSAsd-037 exceeded the Resident Receptor (Adult and Child) FWCUG at a TR of 1E-05, HQ of 1. One VOC (2-butanone) was detected in sediment sample WSAsd-037 upstream of the AOC. Chloromethane and the pesticide dieldrin were detected in sediment in one historical sample in Sand Creek, downstream of the AOC. Explosives, propellants, pesticides, and PCBs were not detected in sediment samples at Wet Storage Area.

8.3.4 Surface Water

Surface water at Wet Storage Area is present within the unnamed tributary on the west side of the AOC, which then enters into Sand Creek to the north. Within the former operational area at Wet Storage Area, surface water only occurs as storm water runoff either overland or within discontinuous ditch lines immediately adjacent to intra-AOC access roads. While five inorganic SRCs were identified in surface water, these inorganic chemicals did not have established background concentrations, and all detections were at concentrations below laboratory screening criteria. Explosives, propellants, SVOCs, pesticides, and PCBs were not detected in surface water samples at Wet Storage Area. Nitrocellulose, bis(2-ethylhexyl)phthalate, acetone, carbon disulfide, and chloroform were each detected once at locations outside the AOC.

8.4 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

All SRCs identified in the surface soil, subsurface soil, and sediment at Wet Storage Area were evaluated through the stepwise contaminant fate and transport evaluation. The evaluation included analyzing leaching and migration from soil and sediment to groundwater and determining whether contamination present in soil and sediment may potentially impact groundwater quality at the site.

Maximum concentrations of SRCs identified in surface and subsurface soil were evaluated using a series of generic screening steps to identify initial CMCOPCs. Initial CMCOPCs for soil were further evaluated using the SESOIL model to predict leaching concentrations and identify final CMCOPCs based on RVAAP facility-wide background concentrations and the lowest risk-based screening criteria among USEPA MCLs, USEPA tap water RSLs, or RVAAP groundwater FWCUGs for the Resident Receptor Adult. A sediment screening analysis was performed for sediment samples at the AOC. The sediment screening analysis for this AOC assumed that the sediment concentration and the recharging groundwater concentration were in equilibrium and that there was no dilution in groundwater. The resulting groundwater concentrations were compared against RVAAP facility-wide background concentrations and the lowest risk-based screening criteria to identify the final sediment CMCOPC. These final CMCOPCs were evaluated using the AT123D model to predict groundwater concentrations beneath source areas and at the nearest downgradient groundwater receptor to the AOC (e.g., stream).

The evaluation of modeling results with respect to current AOC groundwater data and model limitations identified the following CMCOPCs for soil and sediment:

- Arsenic and naphthalene in soil were predicted to exceed the screening criteria in groundwater beneath the source area; however, none of these constituents were predicted to exceed screening criteria at the downgradient receptor location.
- Manganese, benz(a)anthracene benzo(b)fluoranthene, and naphthalene in sediment were predicted to exceed the screening criteria in groundwater beneath the source area; however, none of these constituents were predicted to exceed screening criteria at the downgradient receptor location.

A qualitative assessment of the sample results and considerations of the limitations and assumptions of the models were performed to identify if any CMCOCs are present in soil and sediment at Wet Storage Area that may impact the groundwater at Wet Storage Area beneath the source or at the downstream receptor location. This qualitative assessment concluded that there were no CMCOCs present in soil and sediment that may impact the groundwater beneath the source or at the downstream receptor location. No further action is required of soil and sediment at Wet Storage Area for the protection of groundwater.

8.5 SUMMARY AND CONCLUSIONS OF THE HUMAN HEALTH RISK ASSESSMENT

The HHRA identified COCs and conducted risk management analysis to determine if COCs pose unacceptable risk to the Resident Receptor (Adult and Child). Since the risk management analysis determined there were no unacceptable risks to the Resident Receptor (Adult and Child), it can be concluded that there is no unacceptable risk to the National Guard Trainee and Industrial Receptor.

Media of concern at Wet Storage Area are surface soil, subsurface soil, surface water, and sediment. Soil data associated with Wet Storage Area were aggregated into surface and subsurface soil. Sediment and surface water were evaluated from the unnamed tributary at the ingress of the tributary onto Wet Storage Area and approximately 100 ft upstream of the confluence with Sand Creek.

No COCs were identified for the Resident Receptor (Adult and Child) in subsurface soil, sediment, or surface water. Arsenic and five PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were identified as COCs for the Resident Receptor (Adult and Child) in surface soil.

Arsenic (21 mg/kg) exceeded the FWCUG (4.25 mg/kg) and surface (15.4 mg/kg) and subsurface (19.8 mg/kg) background criteria in surface soil ISM sample WSAss-020M, collected near igloo WS-1A. The reported arsenic concentration in the larger ISM sample (WSAss-036M) collected in 2010 to delineate the southwest portion of Wet Storage Area (which surrounds the approximate location of WSAss-020M) was 14.8 mg/kg. Regional studies indicate arsenic may be naturally occurring in Ohio soils at greater than 20 mg/kg. Arsenic appears to be present at Wet Storage Area at naturally occurring concentrations and there is no known operational source of arsenic at Wet Storage Area. Based on this evaluation, arsenic does not represent a hot spot and was not identified as a COC for potential remediation in surface soil.

Five PAHs [benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were identified as surface soil COCs exceeding their FWCUGs and contributing to an SOR greater than one in Wet Storage Area surface soil at ISM sample location WSAss-004M. Because ISM samples represent an average concentration across the area sampled, no statistical analysis of ISM data was conducted (i.e., the detected concentration in each ISM sample was compared directly to FWCUGs). WSAss-004M is 0.02 acres and represents the parking area at the end of the driveway in front of former igloo WS-1. The acreage of WSAss-004M alone is too small to represent a residential EU. ISM sample WSAss-036M was collected in March 2010 to define the lateral extent of contamination around igloos WS-1 and WS-1A, including the area of sample WSAss-004M. The PAH concentrations reported in WSAss-036M (ranging from not detected to 0.033 mg/kg) are more representative of the larger EU area and are below FWCUGs for the Resident (Adult and Child). Due to the low PAH concentrations reported in surrounding sample WSAss-036M and absence of an identified source of PAHs other than roads, vehicle exhaust, and building debris, PAHs were not identified as COCs for potential remediation in surface soil at Wet Storage Area.

Based on the risk management analysis, no COCs were identified to be carried forth in an FS for the Resident Receptor (Adult and Child) in any of the media of concern; therefore, no other receptors were evaluated and no further action is necessary to be protective of human health receptors.

8.6 SUMMARY AND CONCLUSIONS OF THE ECOLOGICAL RISK ASSESSMENT

The Level I ERA presents important ecological resources on or near the AOC and evaluates the potential for current contamination to impact ecological resources. There is chemical contamination present in surface soil and sediment at Wet Storage Area. This contamination was identified using historical and PBA08 RI data. Various forest communities, shrubland, and other ecological resources were observed on the 36 acres in the AOC. There are important and significant ecological resources in the AOC. Specifically, wetlands and surface water (unnamed tributary to Sand Creek) are present and near contamination. These findings invoked a requirement of a Level II ERA.

The Level II ERA evaluated soil and sediment COPECs. Seventeen integrated COPECs were identified for soil. Four integrated COPECs were identified for sediment. The integrated soil and sediment COPECs were further evaluated with technical and refinement factors in Step 3A. The factors in Step 3A showed there are no integrated COPECs that are of ecological concern requiring remediation or further evaluation. Consequently, the Level II Screening ERA for Wet Storage Area concludes with a recommendation that no further action is necessary to be protective of important ecological receptors.

8.7 UPDATED CONCEPTUAL SITE MODEL

The updated CSM is presented in this section to incorporate results of this RI. Elements of the CSM include:

- Primary and secondary contaminant sources and release mechanisms,
- Contaminant migration pathways and discharge or exit points,
- Potential receptors of risk, and
- Data gaps and uncertainties.

The following sections describe each of the above elements of the CSM for Wet Storage Area and the CSM is presented on Figure 8-1. In addition, figures contained in earlier sections of the report that illustrate AOC features, topography, groundwater and surface water flow directions, and nature and extent of SRCs are cited to assist in visualizing key summary points of the CSM.

8.7.1 Primary and Secondary Contaminant Sources and Release Mechanisms

No primary contaminant sources (e.g., operational facilities or retention basins) remain at Wet Storage Area. All previously stored materials were removed as of 1945. Four igloos with lead-lined floors along the west side of the AOC were demolished in 2004. Two igloos (concrete floored) on the east side of the AOC (WS-3 and WS-3A) remain intact; one was refurbished for administrative use. Remnant contamination in soil is considered a secondary source of contamination.

Sites where explosives were identified as potential contaminants from previous use were thoroughly evaluated, including around former process buildings and across the AOC as a whole. Explosives were not detected in any of the environmental media sampled (i.e., surface soil, subsurface soil, sediment, and surface water).

Small drainage ditches within the AOC convey storm water runoff on an intermittent basis. No perennial drainage conveyances exist within the AOC; however, an unnamed tributary to Sand Creek lies about 100 ft to the west and Sand Creek lies about 400 ft to the north.

The primary mechanisms for release of contaminants from secondary sources at the AOC are:

- Eroding soil matrices with sorbed chemicals and mobilization in overland surface water storm runoff during heavy rainfall conditions,
- Dissolving soluble chemicals and transport in perennial surface water conveyances and intermittent surface water runoff,
- Re-suspending contaminated sediment during periods of high flow with downstream transport within the surface water system, and
- Leaching contaminants to groundwater.

8.7.2 Contaminant Migration Pathways and Exit Points

8.7.2.1 Surface Water Pathways

Migration of contaminants from soil sources via surface water occurs primarily by particle-bound contaminants moving in surface water runoff and dissolved constituents being transported through surface water. Upon reaching portions of surface water conveyances where flow velocities decrease, particle-bound contaminants will settle out as sediment accumulation. Sediment-bound contaminants may become re-suspended and migrate during storm events, or may partition to dissolved phase in surface water. As noted in Section 3.0, natural and engineered storm water drainage conveyances exit the AOC, which ultimately discharge into the unnamed tributary along the west boundary of the AOC and directly to Sand Creek (Figure 3-1). Further, sediment at the downstream sample location within the unnamed tributary west of the AOC contained notably lower concentration of SRCs than the upstream location, indicating minimal contributions from Wet Storage Area by soil erosion pathways.

8.7.2.2 Groundwater Pathways

The estimated direction of groundwater flow at Wet Storage Area is to the north toward Sand Creek based on RVAAP facility-wide potentiometric data. The groundwater table occurs within unconsolidated glacial overburden at an estimated depth range of 10–20 ft bgs, based on PBA08 RI subsurface soil boring data and 2010 water level data from a nearby facility-wide background well (Section 3.4.2). Groundwater discharge to surface water features (e.g., via base flow to streams or springs) does not occur within the AOC boundary. Rather, the closest potential groundwater discharge location is Sand Creek located along the northern AOC boundary.

The FWGWMP was initiated in 2005 and involves quarterly sampling of selected wells within the former RVAAP. Between 2012–2013, samples were collected from monitoring well FWGmw-013 in four different sampling events under the FWGWMP.

Contaminant leaching pathways from soil and sediment to the water table are through silty loam/clay loam unconsolidated soil. Conservative transport modeling indicated two chemicals may leach from soil (arsenic and naphthalene) and four chemicals may leach from sediment (manganese, benz(a)anthracene, benzo(b)fluoranthene, and naphthalene) and migrate to the groundwater table at concentrations exceeding MCLs/RSLs beneath their respective sources; however, none of these constituents are predicted to migrate laterally and reach the nearest surface water receptor (Sand Creek located along the northern boundary of Wet Storage Area) at a concentration exceeding MCL/RSLs. These chemicals were not detected in monitoring well FWGmw-013 in samples collected from 2012–2013 above their respective groundwater criteria; therefore, this evaluation concludes that the model-predicted concentrations are conservative. A qualitative assessment of the sample results was performed and the limitations and assumptions of the models were considered to identify if any CMCOCs are present in soil or sediment at Wet Storage Area that may potentially impact groundwater. This qualitative assessment concluded that CMCOCs are not adversely impacting groundwater quality based on current data and are not predicted to have future impacts. No further action is required of soil or sediment to be protective of groundwater.

8.7.3 Potential Receptors

In February 2014, the Army and Ohio EPA amended the risk assessment process to address changes in the RVAAP restoration program. The Technical Memorandum identified three Categorical Land Uses and Representative Receptors to be considered during the RI phase of the CERCLA process. These three Land Uses and Representative Receptors are presented below.

1. Unrestricted (Residential) Land Use – Resident Receptor (Adult and Child) (formerly called Resident Farmer).
2. Military Training Land Use – National Guard Trainee.
3. Commercial/Industrial Land Use – Industrial Receptor (USEPA Composite Worker).

Unrestricted (Residential) Land Use is considered protective for all three Land Uses at Camp Ravenna. Therefore, if an AOC meets the requirements for Unrestricted (Residential) Land Use, the AOC is also considered to have met the requirements of the other Land Uses (i.e., Commercial/Industrial and Military Training), and the other Land Uses do not require evaluation. The HHRA did not identify Resident Receptor COCs to be carried forward for potential remediation; therefore, Wet Storage Area is considered protective for all potential human health receptors.

Camp Ravenna has a diverse range of vegetation and habitat resources. Habitats present within the facility include large tracts of closed-canopy hardwood forest, scrub/shrub open areas, grasslands, wetlands, open-water ponds and lakes, and semi-improved administration areas. An abundance of wildlife is present on the facility: 35 species of land mammals, 214 species of birds, 41 species of fish, and 34 species of amphibians and reptiles have been identified. The ERA Level I presents important ecological resources on or near the AOC and evaluates the potential for current contamination to impact ecological resources. There is chemical contamination present in soil and sediment at Wet Storage Area, and there are important and significant ecological resources in the AOC. The Level II ERA and the factors in Step 3A showed there are no integrated COPECs that are of ecological concern requiring remediation or further evaluation. Consequently, the Level II Screening ERA concluded that no further action is necessary to be protective of ecological resources.

8.7.4 Uncertainties

Uncertainties are inherent in the CSM depending on the density and availability of data. The CSM for Wet Storage Area is overall well defined using existing data, and major data gaps do not remain to be resolved. However, some uncertainties for the CSM for Wet Storage Area include:

- Surface water characterization within the drainage ditches on the AOC is subject to some uncertainty due to the intermittent occurrence of surface water originating within the AOC during precipitation events. Discharge of surface water from the AOC is generally via ditches at the AOC.
- Removing primary contaminant sources (e.g., buildings/igloos), grading, and continuing vegetation succession within those areas likely have resulted in a lower overall degree of soil erosion and contaminant migration from the former operations area.
- While this RI addresses soil, sediment, and surface water, additional ongoing investigations are being conducted for the Facility-wide Groundwater AOC. During implementation of the 2010 PBA08 RI, there were no groundwater wells at Wet Storage Area. Subsequent to the RIs, monitoring well FWGmw-013 was installed in 2012 within Wet Storage Area, northeast of Building WS-3.

8.8 RECOMMENDATION OF THE REMEDIAL INVESTIGATION

Based on the investigation results, Wet Storage Area has been adequately characterized and the recommended path forward is no further action for soil, sediment, and surface water at Wet Storage Area to attain Unrestricted (Residential) Land Use. Further investigation is not warranted at this AOC for the following reasons: Further investigation is not warranted at this AOC for the following reasons: (1) the current nature and extent of impacted media has been sufficiently characterized; (2) the fate and transport modeling did not identify soil CMCOCs requiring further evaluation or remediation to protect groundwater; (3) there are no CERCLA release-related human health COCs identified in soil, sediment, or surface water requiring further evaluation in an FS or additional remediation; and (4) remedial actions to protect ecological resources are not warranted.

The next step in the CERCLA process is to prepare a PP to solicit public input with respect to no further action for soil, sediment, and surface water. The PP will briefly summarize the history, characteristics, risks, and basis for no further action. Comments on the PP received from state and federal agencies and the public will be considered in preparing a ROD to document the final remedy. The ROD will also include a responsiveness summary addressing comments received on the PP.

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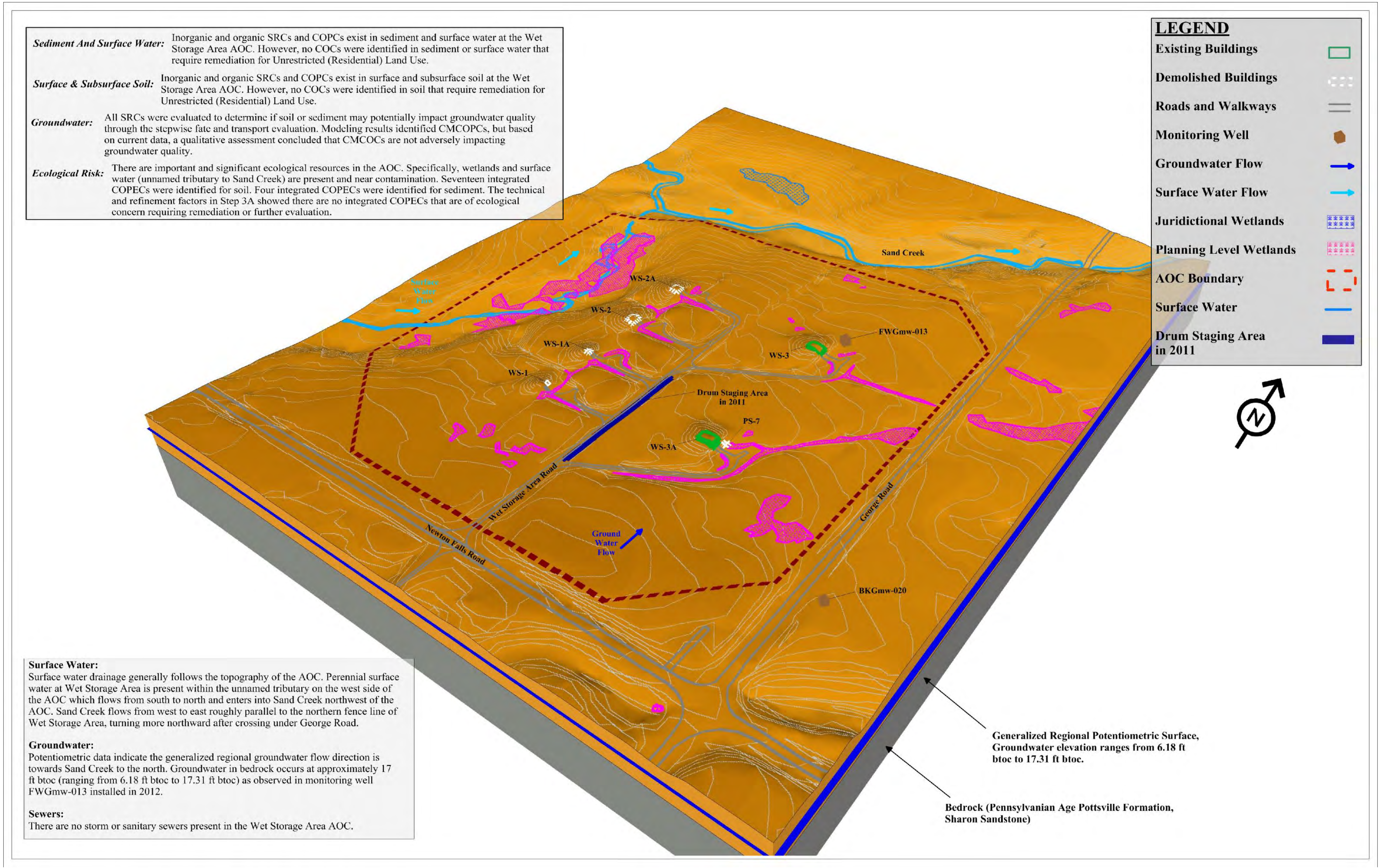

Sediment And Surface Water: Inorganic and organic SRCs and COPCs exist in sediment and surface water at the Wet Storage Area AOC. However, no COCs were identified in sediment or surface water that require remediation for Unrestricted (Residential) Land Use.

Surface & Subsurface Soil: Inorganic and organic SRCs and COPCs exist in surface and subsurface soil at the Wet Storage Area AOC. However, no COCs were identified in soil that require remediation for Unrestricted (Residential) Land Use.

Groundwater: All SRCs were evaluated to determine if soil or sediment may potentially impact groundwater quality through the stepwise fate and transport evaluation. Modeling results identified CMCOPCs, but based on current data, a qualitative assessment concluded that CMCOCs are not adversely impacting groundwater quality.

Ecological Risk: There are important and significant ecological resources in the AOC. Specifically, wetlands and surface water (unnamed tributary to Sand Creek) are present and near contamination. Seventeen integrated COPECs were identified for soil. Four integrated COPECs were identified for sediment. The technical and refinement factors in Step 3A showed there are no integrated COPECs that are of ecological concern requiring remediation or further evaluation.

Surface Water:
Surface water drainage generally follows the topography of the AOC. Perennial surface water at Wet Storage Area is present within the unnamed tributary on the west side of the AOC which flows from south to north and enters into Sand Creek northwest of the AOC. Sand Creek flows from west to east roughly parallel to the northern fence line of Wet Storage Area, turning more northward after crossing under George Road.

Groundwater:
Potentiometric data indicate the generalized regional groundwater flow direction is towards Sand Creek to the north. Groundwater in bedrock occurs at approximately 17 ft btoc (ranging from 6.18 ft btoc to 17.31 ft btoc) as observed in monitoring well FWGmw-013 installed in 2012.

Sewers:
There are no storm or sanitary sewers present in the Wet Storage Area AOC.

Generalized Regional Potentiometric Surface, Groundwater elevation ranges from 6.18 ft btoc to 17.31 ft btoc.

Bedrock (Pennsylvanian Age Pottsville Formation, Sharon Sandstone)

Figure 8–1. Wet Storage Area CSM

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9.0 AGENCY COORDINATION AND PUBLIC INVOLVEMENT

The Army is the lead agency responsible for executing the CERCLA process and ultimately completing an approved ROD for soil, sediment, and surface water at Wet Storage Area. This section reviews actions that have been conducted and presents activities that are planned to ensure the regulatory agencies and members of the public have been provided with appropriate opportunities to stay informed of the progress of Wet Storage Area environmental investigation, restoration efforts, and the recommendation of no further action for these media.

9.1 STATE ACCEPTANCE

State acceptance considers comments received from agencies of the state of Ohio on the recommendation for no further action. Ohio EPA is the lead regulatory agency for supporting decisions regarding Wet Storage Area. This RI Report has been prepared in consultation with the Ohio EPA.

Ohio EPA has provided input during the ongoing investigation and report development to ensure the recommendation for Wet Storage Area meets the needs of the state of Ohio and fulfills the requirements of the DFFO (Ohio EPA 2004). Ohio EPA provided comments on this RI Report and will provide comments on the subsequent PP and ROD. The Army will obtain Ohio EPA concurrence prior to the final selection and decision for soil, sediment, and surface water at Wet Storage Area.

9.2 COMMUNITY ACCEPTANCE

Community acceptance considers comments provided by community members. CERCLA 42 U.S.C. 9617(a) emphasizes early, constant, and responsive community relations. The Army has prepared a *Community Relations Plan for the Ravenna Army Ammunition Plant Restoration Program* (Vista 2015) to facilitate communication between the former RVAAP and the community surrounding Ravenna, Ohio during environmental investigations and potential remedial action. The plan was developed to ensure the public has convenient access to information regarding project progress. The community relations program interacts with the public through news releases, public meetings, public workshops, and Restoration Advisory Board meetings with local officials, interest groups, and the general public.

CERCLA 42 U.S. Code 9617(a) requires an Administrative Record to be established “at or near the facility at issue.” Relevant documents regarding the former RVAAP have been made available to the public for review and comment.

The Administrative Record for this project is available at the following location:

Camp Ravenna
Environmental Office
1438 State Route 534 SW
Newton Falls, OH 44444

Access to Camp Ravenna is restricted but can be obtained by contacting the environmental office at (614) 336-6136. In addition, an Information Repository of current information and final documents is available to any interested reader at the following libraries:

Reed Memorial Library
167 East Main Street
Ravenna, Ohio 44266

Newton Falls Public Library
204 South Canal Street
Newton Falls, Ohio 44444-1694

Additionally, RVAAP has an online resource for restoration news and information. This website is available at www.rvaap.org.

Comments will be received from the community upon issuing the RI Report and the PP. As required by the CERCLA regulatory process and the Community Relations Plan (Vista 2015), the Army will hold a public meeting and request public comments on the PP for Wet Storage Area. These comments will be considered prior to the final selection of no further action. Responses to these comments will be addressed in the responsiveness summary of the ROD.

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