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EMAIL AND ATTACHED REVISED COMMENTS ON THE DRAFT REMEDIAL INVESTIGATION REPORT FOR AREA OF CONCERN 6 (AOC 6) TNT SUBAREAS FISC WILLIAMSBURG VA
07/30/2015
CH2M HILL

From: Ivester, Marlene/VBO
Sent: Thursday, July 30, 2015 11:55 AM
To: Gehlhaus, Martin
Cc: 'Hoover, Gerald'; 'Jones, Angela CIV NAVFAC MIDLANT, EV'
Subject: RE: Cheatham Annex (CAX) - Draft Remedial Investigation (RI) Report for AOC 6 TNT Subareas

Martin,

In response to Jerry's email below, the files were not ready last week, but they are now and are attached. Again, this is related to edits we made to the RI based on your Comment 2 below. In the attached Word file of the Draft Final RI report, please see the Executive Summary, Section 5.3, and Section 8.1. Also attached are the supporting files (HHRA text, tables and figures) for the lead evaluation you requested. [Note: to avoid any confusion, the HHRA text also contains red-lines edits related to other, previously resolved comments; however, the edits related to your Comment 2 are easy to pick out.]

Should you have any questions, please let us know.

Regards,

Marlene

From: Hoover, Gerald [mailto:Hoover.Gerald@epa.gov]
Sent: Thursday, July 16, 2015 4:02 PM
To: Gehlhaus, Martin
Cc: Ivester, Marlene/VBO
Subject: Cheatham Annex (CAX) - Draft Remedial Investigation (RI) Report for AOC 6 TNT Subareas

Martin,
I'm working with the Navy to finalize the CAX RI Report for AOC 6 TNT Subareas. There is one outstanding issue based on your comment #2 and the Navy's response below. I'm out of the office next week, so I've asked Marlene Ivester of CH2M Hill if she would send you an electronic copy of the red-lined markup of the revised document for your review. It should come early next week. If you have time to take a quick look at it we would really appreciate it. I'll drop off a document review request form tomorrow so it's in the system.

Martin's Comment #2. *Lead was not identified as a COPC in Section H.6.2. Risk Assessment Results. This determination is correct using the mean concentration in soil and subsurface soil and the exposure parameters*
described in the Table 4s; however, the highest concentration observed, 1,100 mg/kg, was from a subsurface soil sample from within the Catch Box Ruins and was identified as an outlier using ProUCL 5.0. The next highest concentration, 580 mg/kg, was from a surface soil sample also within the Catch Box Ruins. Section H.6.4 addresses the possibility of lead as a hot spot but fails to provide a strategy moving forward. Recommend calculating human health risk of exposure to lead in surface and subsurface soils using concentrations within Catch Box Ruins (using sample Stations CAA06-SO01 and SO26).

Navy Response: Agree. We will evaluate risks associated with exposure to lead in the Catch Box

Ruins, using samples CAA06-SO01 and SO26. Risks associated with exposure to surface soil, and combined surface and subsurface soil from these samples, will be evaluated, based on the exposure scenarios presented in Appendix I Table 1 evaluated in the HHRA. The RI text (and Appendices H and I) will be updated as needed following this evaluation.

~~~~~~

Jerry Hoover
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Environmental Protection Agency, Region III
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(215) 814-2077
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Draft Final

AOC 6 TNT Subareas Remedial Investigation Report

Naval Weapons Station Yorktown, Cheatham Annex
Williamsburg, Virginia

Contract Task Order WE47

July 2015

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Mid-Atlantic

Under the

NAVFAC CLEAN 8012 Program
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Prepared by

CH2MHILL

Virginia Beach, Virginia

Executive Summary

This report presents the findings of the Remedial Investigation (RI) at the Area of Concern (AOC) 6 Trinitrotoluene (TNT) Graining House Sump and TNT Catch Box Ruins subareas (AOC 6 TNT Subareas), Naval Weapons Station (WPNSTA) Yorktown, Cheatham Annex (CAX), in Williamsburg, Virginia. Based on the results from previous investigations, the RI was conducted to characterize the nature and extent of contamination within soil and groundwater to assess the potential risks posed by exposure to contamination for human and ecological receptors. Surface water and sediment analytical data were previously collected at the AOC 6 TNT Subareas during the 2012 Site Inspection (SI) (CH2M HILL, 2012). However, since no potential human health or ecological risks were identified for sediment and surface water based on results of the SI, and since these media are currently being assessed as part of the Penniman Lake SI, they were not evaluated in this RI.

The objectives of the RI have been achieved – data gaps have been filled, the nature and extent of contamination have been sufficiently defined, the conceptual site model (CSM) has been updated to reflect the compilation of data from all investigation activities to-date, and human health and ecological risks have been assessed.

Soil and groundwater sampling at the AOC 6 TNT Subareas indicate that the extent of contamination within soil has been delineated and consists primarily of two separate areas to the immediate southeast and northeast of the foundation of the former TNT Graining House.

The sources of contamination at the AOC 6 TNT Subareas are considered to be potential sources of historical leakage or discharge from the former TNT Graining House Sump and/or TNT Catch Box Ruins. The former TNT Catch Box Ruins were used to separate TNT particles from wastewater. Historical leakage or discharge represent the only identified source of CERCLA-regulated contamination at the AOC 6 TNT Subareas. Based on the data evaluations presented in this RI, the following potentially site-related constituents of concern (COCs) posing risks to either human health or the environment were identified:

Risk Component	Medium		
	Surface Soil	Subsurface Soil	Groundwater
Human Health	2,4,6-trinitrotoluene (TNT), 2-nitrotoluene, arsenic, ~~and~~ hexavalent chromium, and lead*	TNT, 2-nitrotoluene, arsenic, and hexavalent chromium	Arsenic and iron
Ecological	TNT and lead	TNT and lead	No unacceptable risks to aquatic biota identified

*Unlike the other listed COCs, lead is not a COC when evaluating exposure to lead in soil across the full site; however, if only exposed to soil within the Catch Box Ruins, lead is a COC for Catch Box Ruins surface soil and combined surface and subsurface soil.

A Focused Feasibility Study (FFS) is recommended to develop and evaluate remedial alternatives to address potentially unacceptable human health or ecological risks associated with TNT and lead in soil at the AOC 6 TNT Subareas. Since the size of the AOC 6 TNT Subareas is relatively small (approximately 0.5 acre) and the approximate boundaries of the TNT and lead contamination in soil are defined, an FFS would allow for a more efficient evaluation of several selected potential remedial alternatives. No further action is recommended for arsenic and hexavalent chromium in soil. The arsenic concentrations are within the range of background. Hexavalent chromium was not detected in surface soil and in subsurface soil, the risk to a residential receptor would fall within the acceptable risk range for this constituent.

Since there was only one detection of the human health COC 2-nitrotoluene, the risks associated with exposure to it across the site are likely over-estimated, and since this one detection is within the approximate distribution of TNT contamination south of the former TNT Graining House Sump, it would be addressed as part of the FFS remedial alternatives associated with TNT in this area, such that no further action with respect to 2-nitrotoluene is warranted.

In addition, no further action is recommended for groundwater since the groundwater data evaluated during this RI indicate that the concentrations of arsenic and iron in groundwater are likely attributable to naturally occurring background conditions and not from historical leakage or discharge from the former TNT Graining House Sump and/or TNT Catch Box Ruins.

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Acronyms and Abbreviations

°C	degree Celsius
°F	degree Fahrenheit
µg/kg	microgram per kilogram
µg/L	microgram per liter
amsl	above mean sea level
AOC	area of concern
atm-m^3/M	atmosphere per cubic meter per mole
BCF	bioconcentration factor
bgs	below ground surface
CAX	Cheatham Annex
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-term Environmental Action—Navy
COC	constituent of concern
COPC	constituent of potential concern
CSM	conceptual site model
CTE	central tendency exposure
DI	deionized
DNT	dinitrotoluene
DO	dissolved oxygen
DoD	Department of Defense
DPT	direct-push technology
ER	environmental restoration
ERA	Ecological Risk Assessment
ERP	Environmental Restoration Program
ESV	ecological screening value
FFS	Focused Feasibility Study
f_{oc}	fraction of organic carbon
ft/day	foot per day
g/cm^3	gram per cubic centimeter
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
HSA	hollow-stem auger
ID	inside diameter
IDW	investigation-derived waste
K	hydraulic conductivity
K_d	distribution coefficient
K_h	horizontal hydraulic conductivity or Henry's Law Constant
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
MCL	maximum contaminant level
mg/kg	milligram per kilogram

mg/L	milligram per liter
ml/g	milliliter per gram
MS	matrix spike
mS/cm	milliSiemen per centimeter
MSD	matrix spike duplicate
mV	millivolt
NAVFAC	Naval Facilities Engineering Command
Navy	Department of the Navy
ORP	oxidation-reduction potential
PCB	polychlorinated biphenyl
PID	photoionization detector
ppm	part per million
PSLP	Penniman Shell Loading Plant
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RI	Remedial Investigation
RME	reasonable maximum exposure
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SI	Site Inspection
SOP	Standard Operating Procedure
SVOC	semivolatile organic compound
TNT	trinitrotoluene
TOC	total organic carbon
UCL	upper confidence level
USEPA	United States Environmental Protection Agency
UTL	upper tolerance limit
VDEQ	Virginia Department of Environmental Quality
VOC	volatile organic compound
WPNSTA	Naval Weapons Station

SECTION 1

1 Introduction

This Remedial Investigation (RI) report presents the data and findings obtained from the field activities conducted to characterize the nature and extent of contamination and assess potential risks to human health and the environment at Naval Environmental Restoration Program (ERP) Area of Concern (AOC) 6, Trinitrotoluene (TNT) Graining House Sump and TNT Catch Box Ruins subareas, Naval Weapons Station (WPNSTA) Yorktown, Cheatham Annex (CAX), Williamsburg, Virginia. Due to the geographic proximity of the AOC 6 TNT Graining House Sump and the AOC 6 TNT Catch Box Ruins, these two subareas were investigated together and are herein referred to as the AOC 6 TNT Subareas. This report was prepared for the Department of the Navy (Navy), Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic Division, under the Comprehensive Long-term Environmental Action—Navy (CLEAN) 8012 Contract N62470-11-D-8012, Contract Task Order WE47, for submittal to NAVFAC Mid-Atlantic, the United States Environmental Protection Agency (USEPA) Region III, and the Virginia Department of Environmental Quality (VDEQ). The Navy, USEPA, and VDEQ work jointly as the CAX Tier I Partnering Team.

The RI field activities discussed in this report were conducted in September through October 2013, June 2014, and August 2014. The purpose of the RI was to fill data gaps remaining following earlier investigations, to further characterize the nature and extent of contamination, and to support an assessment of potential environmental and human health risks associated with exposure to contaminants in site media at the AOC 6 TNT Subareas. The field activities were conducted in accordance with the Uniform Federal Policy – Sampling and Analysis Plan (SAP) titled *Tier II Sampling and Analysis Plan, AOC 6 TNT Graining House Sump and TNT Catch Box Ruins Subareas Remedial Investigation, Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia* (AOC 6 TNT Subareas SAP) (CH2M HILL, 2013).

1.1 Objectives and Approach

The objectives of the RI are to characterize the nature and extent of potential contamination in soil and groundwater and to assess the potential risks posed by this contamination to human health and the environment.

- The activities completed to support the objectives of the RI activities were as follows:
- Collection of surface and subsurface soil samples from the AOC 6 TNT Subareas
- Installation of six shallow monitoring wells at the AOC 6 TNT Subareas
- Completion of a groundwater elevation survey and collection of groundwater samples from all new monitoring wells at the AOC 6 TNT Subareas
- Completion of single-well, hydraulic conductivity (K) ”slug” tests in monitoring wells at the AOC 6 TNT Subareas
- Installation of a staff gauge in Penniman Lake to determine the Penniman Lake water surface elevation for comparison to the water table elevation in the surficial aquifer at the AOC 6 TNT Subareas
- Quantitative assessment of the potential human health and ecological risks associated with exposure to contaminated site media, where identified

1.2 Site Background

This subsection provides a general summary of background information for CAX and the AOC 6 TNT Subareas, including site descriptions and environmental history.

1.2.1 CAX

CAX consists of 2,300 acres of land on the York-James Peninsula, northwest of WPNSTA Yorktown (**Figure 1-1**). CAX was the location of the former Penniman Shell Loading Plant (PSLP), a large powder and shell loading facility operated by DuPont during World War I. The facility closed in 1918, and the property was used for farming or remained idle until CAX was commissioned in 1943 as a satellite unit of the Naval Supply Depot to provide bulk storage facilities and serve as an assembly and overseas shipping point throughout World War II. In 1987, CAX was designated the Hampton Roads Navy Recreational Complex. Today, the mission of CAX includes supplying Atlantic Fleet ships and providing recreational opportunities to military and civilian personnel, with outdoor recreational facilities including cabins, camping sites, an 18-hole golf course, swimming pool, ball fields, freshwater and saltwater fishing areas, boating, wildlife watching, and hunting.

CAX is bordered by Queen Creek to the north, the Colonial National Historical Park to the south, the York River to the east, King Creek to the southeast, and the Queens Lake subdivision to the west; the City of Williamsburg is southwest of CAX. The majority of CAX is undeveloped and heavily wooded. Major surface water features at CAX are Youth Pond, Cheatham Pond, Jones Pond, and Penniman Lake. Potable water supply at CAX is provided by Newport News Waterworks (ASTDR, 2004).

In October 1998, control of CAX was transferred from the Fleet and Industrial Supply Center to WPNSTA Yorktown. Comprehensive environmental restoration (ER) activities at CAX began in 1984 under the Navy Assessment and Control of Installation Pollutants program and the ERP. On January 2, 2001, CAX was added to the National Priorities List, which required all subsequent ER activities to be conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Navy, Commonwealth of Virginia (through VDEQ), and USEPA executed a Federal Facilities Agreement in March 2005, which identified a total of 12 Sites and seven AOCs to be addressed under CERCLA (USEPA et al., 2005).

1.2.2 AOC 6 TNT Subareas

Five non-contiguous subareas comprise AOC 6, each less than 1 acre in size, and all related to the former PSLP. The PSLP was an explosives manufacturing facility operated during World War I by the E.I. DuPont de Nemours & Company on what is now CAX and adjacent properties. This facility operated as a TNT manufacturing plant beginning in approximately 1916, and subsequently added the loading of artillery shells for the war effort in 1918. Between 1918 and 1925, following the end of the war, this facility was demolished and reverted to farmland or left idle until CAX was commissioned in 1943 as a satellite unit of the Naval Supply Depot to provide bulk storage facilities and serve as an assembly and overseas shipping point throughout World War II.

In August 2000, the USEPA and Navy agreed to investigate five subareas related to the former PSLP (1918 Drum Storage Area, Ammonia Settling Pits, TNT Graining House Sump, TNT Catch Box Ruins, and Waste Slag Material). These subareas comprise AOC 6 (Penniman AOC), and are located within the vicinity of the former shell loading area, south of Sanda Avenue (formerly DuPont's “G” plant) on Navy property (Weston, 1999) (**Figure 1-2**). The AOC 6 TNT Subareas, combined, are approximately 0.5 acre in size and are located along the southwest bank of Penniman Lake (**Figure 1-2**). The AOC 6 TNT Subareas are the only subareas investigated as part of this RI; the other three AOC 6 subareas were evaluated separately.

The history of the AOC 6 TNT Subareas is largely unknown. Roy F. Weston, Inc. identified these subareas as potential waste sources through a review of historical aerial photographs, engineering drawings, and site reconnaissance visits (Weston, 1999). The TNT Graining House Sump subarea includes the concrete footprint of the former TNT Graining House as well as the concrete-lined, open top pit believed to be the sump pit for the TNT Graining House. The TNT Catch Box Ruins subarea consists of an earthen, brick-lined depression located immediately east and adjacent to the TNT Graining House. The TNT Catch Box was used to separate TNT particles from wastewater. Potential historical leakage or discharge from the former TNT Graining

House sump and/or TNT Catch Boxes are the sole known or suspected sources of contamination at the AOC 6 TNT Subareas (**Figure 1-3**).

1.3 Summary of Previous Investigations

This section presents a summary of the findings from previous investigations conducted prior to the RI field activities. While the results of the previous investigations are briefly mentioned in this section, only the 2012 Site Inspection (SI) analytical data were combined with the current RI data for evaluation in this report, and are discussed in greater detail in Section 4.

1.3.1 AOC 6 TNT Subareas Previous Investigations

Previous investigations that helped characterize potential contamination at the AOC 6 TNT Subareas are the 1999 SI (Weston, 1999) and the 2012 SI (CH2M HILL, 2012).

1.3.1.1 1999 Site Inspection

In January 1999, one waste sample was collected from each of the TNT subareas to assess potential sources of contamination associated with the former PSLP and to support hazard ranking system (HRS) evaluations. The waste samples were analyzed for Target Compound List organic compounds (volatile organic compounds [VOCs], semivolatile organic compounds [SVOCs], pesticides, and polychlorinated biphenyls [PCBs]), Target Analyte List inorganic constituents, cyanide, and explosives constituents. The analytical results indicated that detections of one explosive and several inorganic constituents exceeded the 1999 USEPA Region III risk-based concentrations, as summarized in the *Final Site Inspection Narrative Report for the Penniman Shell Loading Plant* (Weston, 1999), and these data were further reviewed as part of the 2012 SI Work Plan (CH2M HILL, 2008).

1.3.1.2 2012 Site Inspection

In 2008, SI field activities were conducted that included surface and subsurface soil sampling, groundwater sample collection via direct-push technology (DPT), and surface water and sediment (surface and subsurface) sampling from nearby Penniman Lake. The soil and sediment samples were analyzed for SVOCs, explosives, inorganic constituents, and cyanide; the groundwater and surface water samples were analyzed for SVOCs, explosives, inorganic constituents (total and dissolved), cyanide (total and dissolved), and hardness (surface water only). Since VOCs, SVOCs, pesticides, and PCBs were not found to be constituents of potential concern (COPCs) during the 1999 SI, these analyses were not carried forward to the 2012 SI, with the exception of SVOCs, which were added at the request of the USEPA. The sampling results were evaluated as part of the SI Report (CH2M HILL, 2012) and indicated that potentially unacceptable human health and/or ecological risks were associated with exposure to explosives and inorganic constituents in soil and inorganic constituents in groundwater; therefore, an RI was recommended. Because no potential human health or ecological risks were identified for sediment and surface water, and since these media are being evaluated as part of the Penniman Lake SI, no further action with respect to the AOC 6 Ammonia Settling Pits and TNT Subareas was recommended for sediment and surface water (CH2M HILL, 2012).

As part of the SI that began in 2008, a geophysical survey was conducted in April 2010 around the AOC 6 Ammonia Settling Pits, TNT Graining House Sump, and TNT Catch Box Ruins subareas to address USEPA's concerns as to whether the buildings in these areas had underground piping connecting them to each other or to other former PSLP buildings for the transfer of explosives materials. The results of the geophysical survey showed no evidence of underground piping at any of the three subareas (CH2M HILL, 2012).

1.4 Report Organization

The RI report is organized as follows:

- **Section 1** – Introduction
- **Section 2** – Field Investigation Methods
- **Section 3** – Physical Characteristics

- **Section 4** – Nature and Extent of Contamination
- **Section 5** – Human Health Risk Assessment
- **Section 6** – Ecological Risk Assessment
- **Section 7** – Chemical Fate and Transport
- **Section 8** – Conclusions and Recommendations
- **Section 9** – References

Tables and figures are provided at the end of each respective section. Appendixes are included at the end of the report.

SECTION 2

2 Field Investigation Methods

This section describes the approach and methodology for the field activities conducted as part of the RI at the AOC 6 TNT Subareas. Field activities for the AOC 6 TNT Subareas included surface and subsurface soil sampling, monitoring well installation, groundwater monitoring and sampling, K testing, a field inspection of the TNT Graining House Sump, and installation of a staff gauge in Penniman Lake. Specific details of the sampling rationale and objectives for the AOC 6 TNT Subareas field activities are provided in the AOC 6 TNT Subareas SAP (CH2M HILL, 2013).

Table 2-1 summarizes all of the environmental data that were evaluated during this RI, including the number of samples collected, sample nomenclature, the media sampled, the sample collection methods, and the analyses performed. **Figure 2-1**[1] depicts the locations of all samples collected during the RI in various environmental media.

The investigation activities were implemented to support:

- Development of the hydrogeologic conceptual model for the AOC 6 TNT Subareas (**Section 3**)
- Assessment of the nature, extent, fate, and transport of contamination, potential sources of contamination, and development of a contaminant transport conceptual site model (CSM) (**Sections 4 and 7,** respectively)
- Assessment of potential risks to human health and the environment (**Sections 5 and 6,** respectively)
- Information to be utilized for the potential completion of a future Focused Feasibility Study (FFS) (**Section 8**)

2.1 AOC 6 TNT Subareas Field Investigation Activities

2.1.1 Pre-Investigation Activities

Prior to the RI field activities, underground utility clearance was conducted at the AOC 6 TNT Subareas on September 12, 2013, by Accumark, Inc., of Ashland, Virginia.

In addition, vegetation clearance was conducted on September 17, 2013, by Parratt-Wolff of East Syracuse, New York, utilizing a Terex skid-steer loader.

2.1.2 Soil Sampling

Surface (0 to 6 inches below ground surface [bgs]) and subsurface (6 to 24 inches bgs) soil samples were collected to better define the extent of soil contamination and evaluate potential risks associated with exposure to soil at the AOC 6 TNT Subareas. The soil samples were divided into three groups:

- Surface and subsurface soil samples collected in the vicinity of the AOC 6 TNT Subareas to provide expanded spatial coverage to adequately characterize this medium
- Surface and subsurface soil samples collected from areas where elevated chromium concentrations were detected during the 2012 SI

[1] The "berm boundary" on Figure 2-1 represents the remnants of an earthern berm that was installed during construction of the former PSLP and assumed to provide some protection should an explosion occur. Berms [or "bunkers" as they are referred to on historic drawings (Weston, 1999)] were constructed of various configurations (either completely surrounding or horseshoe- or L- shaped) around several of the former PSLP buildings where an unexpected detonation of explosive materials could occur. The berm is located outside of the footprint of the TNT Subareas; therefore, no sampling of this area is necessary.

- Three-point composite surface and subsurface soil samples collected from the surface depression at the AOC 6 TNT Catch Box Ruins to account for the potential variability of contaminant concentrations within this area and to address the potential for contamination above the water table

The soil sampling activities were conducted in accordance with the Standard Operating Procedure (SOP) entitled *Shallow Soil Sampling* (CH2M HILL, 2013). Surface soil samples, collected with a hand auger, were obtained from a depth of 0 to 6 inches bgs while subsurface soil samples, also collected with a hand auger, were obtained from a depth of 6 to 24 inches bgs, as outlined in the approved AOC 6 TNT Subareas SAP. Following sample collection, organic vapors emanating from each soil sample were monitored with a photoionization detector (PID). Any responses from the PID were noted in the field logbook; no soil samples registered a PID reading above 0.00 part per million.

2.1.2.1 Soil Sampling in the vicinity of the AOC 6 TNT Subareas

Co-located surface and subsurface soil samples were collected from 12 locations (**Figure 2-1** – sample locations CAA06-SO28 through CAA06-SO39) surrounding the AOC 6 TNT Graining House Sump and AOC 6 TNT Catch Box Ruins to supplement the 2012 SI data in order to determine the extent of soil contamination and evaluate potential risks to human health and the environment. Thirteen sample locations were initially proposed in the AOC 6 TNT Subareas SAP. However, based on the actual site conditions, the CAX Partnering Team verbally agreed on September 12, 2013, to eliminate one of the proposed locations since the existing berm prohibited sampling native soil in the intended area. In addition, the remaining RI soil samples, plus soil samples from the 2012 SI, provide adequate soil sample coverage to the north, west, and east of the AOC 6 TNT Subareas (which is limited in size). The CAX Partnering Team agreed to re-locate soil sample location CAA06-SO28 to the southwest in order to collect a representative sample of native soil since its proposed location, at the time, had standing water from a rain event.

In accordance with the approved AOC 6 TNT Subareas SAP, soil samples were analyzed for explosives, 2,4-dinitrotoluene[2](DNT), inorganic constituents, total organic carbon (TOC), pH, and grain size (surface soil samples only) (**Table 2-1**). After collection in sampling containers, the samples were packed on ice and shipped to the laboratory (TriMatrix Laboratories of Grand Rapids, Michigan) for analyses, in accordance with the SOP entitled *Packaging and Shipping Procedures for Low-Concentration Samples* (CH2M HILL, 2013).

2.1.2.2 Hexavalent Chromium Sampling

Two co-located surface and subsurface soil samples (CAA06-SS/SB26 and CAA06-SS/SB27) were collected from those locations where elevated chromium concentrations were detected during the 2012 SI (CAA06-SO03 and CAA06-SO01, respectively) in order to refine the Human Health Risk Assessment (HHRA) for the AOC 6 TNT Subareas by determining the ratio of trivalent chromium to the more toxic hexavalent chromium. In accordance with the approved AOC 6 TNT Subareas SAP (CH2M HILL, 2013), these soil samples were analyzed for total and hexavalent chromium (**Table 2-1**). After collection in sampling containers, the samples were packed on ice and shipped to the laboratory (Columbia Analytical Services of Rochester, New York) for analyses, in accordance with the SOP entitled *Packaging and Shipping Procedures for Low-Concentration Samples* (CH2M HILL, 2013).

2.1.2.3 Three-point Composite Soil Sampling at the AOC 6 TNT Catch Box Ruins

Co-located surface and subsurface, three-point composite soil samples (CAA06-SO26-000H [0 to 6 inches bgs] and CAA06-SO26-0H02 [6 to 24 inches bgs]) were collected from the lowest portion and center of the AOC 6 TNT Catch Box Ruins. The center of the three collection points was within the vicinity of the 2012 SI location CAA06-SO01, where the highest detections of explosives and inorganic constituents were observed

[2] Since 2,4-DNT was the only SVOC constituent detected in soil during the 2012 SI, the RI soil samples were submitted for analysis of 2,4-DNT. However, the laboratory method for analyzing this constituent also provided results for 2,6-DNT and nitrobenzene.

in surface and subsurface soil; the two other collection points were located 18 inches to the north and south of the center collection point.

In accordance with the approved AOC 6 TNT Subareas SAP (CH2M HILL, 2013), the three-point composite soil samples were analyzed for 2,4-DNT[1], explosives, inorganic constituents, TOC, pH, and grain size (three-point composite surface soil sample only) (**Table 2-1**). After collection in sampling containers, the samples were packed on ice and shipped to the laboratory (TriMatrix Laboratories of Grand Rapids, Michigan) for analysis, in accordance with the SOP entitled *Packaging and Shipping Procedures for Low-Concentration Samples* (CH2M HILL, 2013).

2.1.3 Groundwater Sampling

2.1.3.1 Monitoring Well Installation

Six shallow monitoring wells (CAA06-MW01 through CAA06-MW06) were installed within the Columbia (surficial) aquifer to depths up to 20 feet bgs (**Figure 2-1**). Each monitoring well was installed in accordance with the SOP entitled *General Guidance for Monitoring Well Installation* (CH2M HILL, 2013). The monitoring well construction details are summarized in **Appendix A**.

Parratt-Wolff, Inc., of Hillsborough, North Carolina, provided hollow-stem auger (HSA) well drilling and installation services using a 4.25-inch-inside-diameter (ID) HSA. During the lithologic logging of soil cores (collected using 4-foot-long Macro Core sampler), soil descriptions, including grain size, color, moisture content, relative density, consistency, soil structure, mineralogy, and other relevant information such as possible evidence of contamination, were recorded. Soil boring logs are included in **Appendix A**.

New monitoring wells were constructed with flush-threaded, 2-inch-ID Schedule 40 polyvinyl chloride (PVC) casing and well screen (**Appendix A**). In accordance with the SOP entitled *Installation of Shallow Monitoring Wells* (CH2M HILL, 2013), the well screens were 10 feet long with 0.010-inch slot sizes. A silica sand filter pack was placed around the annular space of the well screen from the bottom of the boring and well screen to a depth of approximately 2 feet above the top of the screen. A bentonite layer (approximately 1 to 2 feet) was placed at the top of the sand pack. After the bentonite was allowed to hydrate for at least 24 hours, a cement-bentonite grout was placed in the remaining annular space to the surface. All monitoring wells were completed with steel stick-up protective casings and surrounded by four protective bollards. A locking, watertight cap was placed on the top of each casing, and the well identification numbers were clearly marked on the well with etched well identification tags.

2.1.3.2 Monitoring Well Development

Prior to sampling, all monitoring wells were developed in order to restore the permeability of the aquifer material surrounding the well, which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well during installation. Monitoring well development was performed after the grout used to construct the new monitoring wells was allowed to adequately set (at least 24 hours or more) to prevent grout contamination of the screened interval. Monitoring wells were developed using a submersible pump and a combination of surging and pumping throughout the well screen.

Between 18 and 40 gallons of water were evacuated from each well, with a total of 182 gallons of water purged during the entire monitoring well development event. During monitoring well development, in accordance with the SOP entitled *Installation of Shallow Monitoring Wells* (CH2M HILL, 2013), water quality parameters (pH, oxidation-reduction potential [ORP], temperature, conductivity, turbidity, and dissolved oxygen [DO]) were recorded approximately every 5 minutes using a YSI water-quality meter. The YSI instrument was calibrated daily, and calibration results were recorded in the field notebook.

Generally, development continued until at least three well volumes were removed and the water produced was free of turbidity, sand, and silt (to the maximum extent practicable) or the monitoring well was purged dry. A YSI water-quality meter was used to determine when the turbidity was low (preferably less than 20 Nephelometric Turbidity Units). If turbidity continued to decrease after the removal of three well volumes, development was continued until turbidity readings stabilized (that is, until turbidity readings were within 10 percent of each other for three consecutive readings). In addition, development typically ended once three successive measurements of pH, specific conductivity, and temperature within 10 percent of each other were achieved.

2.1.3.3 Groundwater Elevation Measurements and Installation and Survey of Staff Gauge in Penniman Lake

A groundwater elevation survey was conducted at all six monitoring wells prior to sampling on October 2, 2013, and additional rounds of groundwater elevation measurements were collected on June 18, 2014, and August 22, 2014. An electronic water-level meter was used to measure the depth to water from the marking on the top of casing to the nearest 0.01 foot.

To determine the potential for Penniman Lake to be recharging groundwater in the surficial aquifer at the AOC 6 TNT Subareas and influencing groundwater flow directions, a staff gauge was installed on August 22, 2014, near the overflow inlet near Penniman Lake dam (**Figure 2-1**). Immediately following the staff gauge installation, the staff gauge was surveyed by ECLS of Angier, North Carolina (a Virginia-licensed and registered surveyor), and an additional round of groundwater level measurements was collected from each of the six monitoring wells in the AOC 6 TNT Subareas. **Table 2-2** summarizes the water-level measurements from each round of groundwater measurements at the CAX AOC 6 TNT Subareas monitoring wells, as well as the measured surface water elevation at the Penniman Lake staff gauge (PL-SG01).

2.1.3.4 Groundwater Sampling

Groundwater samples were collected from all monitoring wells in accordance with the SOP entitled *Low-Flow Groundwater Sampling from Monitoring Wells – EPA Region I and III* (CH2M HILL, 2013) in order to minimize drawdown and to obtain samples representative of groundwater conditions in the surrounding geologic formation. Prior to groundwater sample collection, monitoring wells were purged in order to remove any stagnant water that may have accumulated within the well. Groundwater samples were collected from monitoring wells using a peristaltic pump and disposable tubing. Groundwater quality parameters comprising pH, conductivity, turbidity, DO, temperature, and ORP were measured during the purging of each well using a YSI water-quality meter and a flow-through cell to prevent the purged groundwater from contacting the atmosphere during parameter measurement.

Purging continued until water quality readings collected five minutes apart stabilized to within 10 percent of one another. Following parameter stabilization, CHEMet test kits were used to confirm DO readings measured by the YSI water-quality meters (both Model Number 600XLM), as well as to measure ferrous iron concentrations. Once DO reading confirmation was obtained, the flow-through cell was disconnected and samples were collected directly into laboratory-prepared, pre-preserved sample bottles. The final set of groundwater quality measurements recorded before sample collection for each monitoring well is presented in **Table 2-3**.

Groundwater samples were analyzed for total and dissolved inorganic constituents and natural attenuation parameters comprising alkalinity, chloride, methane, nitrate, nitrite, pH, sulfate, sulfide, and TOC. Groundwater for the analytical samples was pumped through tubing directly into the appropriate laboratory-provided bottleware, with the exception of samples to be analyzed for dissolved inorganic constituents. Groundwater collected for dissolved inorganic constituents analysis was pumped through a 0.45-micrometer filter and then directly into the sample bottleware. After collection in sampling containers, and at the end of each day, the samples were packed on ice and shipped via overnight service to the laboratory for analysis in accordance with the SOP entitled *Packaging and Shipping Procedures for Low-Concentration Samples* (CH2M HILL, 2013).

2.1.3.5 Hydraulic Conductivity Testing

Aquifer K at the site was evaluated using single-well K tests, commonly referred to as "slug tests." Due to the limited area of influence achieved during a test, the slug test data provide a rough estimate of the hydrogeologic parameters of the aquifer unit proximal to the individual monitoring wells. The slug tests were conducted in the following steps:

Static Water-Level Measurement: The static (pre-test) water level in the well was measured using an electronic water-level meter with a graduated tape.

Pressure Transducer Placement: A pressure transducer was set 1 foot above the bottom of each well. The pressure transducer was secured to the well to minimize disturbance during testing. The pressure transducer was connected to a data logger programmed to collect a water-level measurement every second for the duration of the test.

Falling Head Test: A slug (consisting of a 5.3-foot-long, 1.5-inch-diameter cylinder made of solid plastic) was lowered until the base of the slug was near the top of the water, and then dropped into the water, causing displacement of water in the well, which was manifested by an almost instantaneous rise in the water level within the well. The water level in the well was monitored as it equilibrated by the pressure transducer and manual measurements until the water level within the well returned at least 90 percent of the way to the originally measured static water level.

Rising Head Test: After the falling head test was completed, the slug was quickly removed from the well, causing an almost instantaneous drop in the water level. The water level in the well was monitored as it equilibrated by the pressure transducer and manual measurements until the water level returned at least 90 percent of the way to the originally measured static water level.

Tests were conducted on October 4, 2013, in all permanent monitoring wells to provide data across the aquifers at the site and to generate estimates of the K of the aquifer.

2.1.3.6 Surveying

The surveyor, ECLS of Angier, North Carolina (a Virginia-licensed and registered surveyor), conducted a survey of the new monitoring wells and the soil sample locations. Each of the monitoring wells was surveyed for vertical and horizontal control to an accuracy of ±0.01 foot and ±0.1 foot, respectively (**Appendix B**). Monitoring wells were surveyed at the top of the PVC casing (where marked) and at the ground surface. The vertical elevations were referenced to National Geodetic Vertical Datum 88 to remain consistent with the existing WPNSTA Yorktown vertical datum. Horizontal coordinates conformed to North American Datum 83 with ties to the Virginia State Plane Coordinate System. The survey also included the footprint of the former TNT Graining House and Sump, the TNT Catch Box Ruins, and the maximum elevation of the berm directly north of the former TNT Graining House, as show in the survey exhibit plat in **Appendix B**.

2.1.4 TNT Graining House Sump Field Inspection

On September 19, 2013, the former TNT Graining House sump, located within the footprint of the TNT Graining House (**Figure 1-3**), was inspected. The concrete sump compartment measured 8 feet long, 2.5 feet wide, and 3.6 feet in depth, and water was observed at 2.2 feet above the bottom of the sump. Leaves, roots, and less than two inches of organic material, plus flakes of scraped concrete, were recovered via a three-inch auger bucket, but no residual material from the former ordnance plant processes was present. Therefore, per the AOC 6 TNT Subareas SAP (CH2M HILL, 2013), no residual material sample was collected.

2.2 Quality Assurance and Quality Control

Samples collected for the RI were analyzed using SW-846 Program methods with Level IV quality assurance (QA)/quality control (QC), as identified in the AOC 6 TNT Subareas SAP (CH2M HILL, 2013). For definitive data, sample results were reported by the laboratories with the equivalent of USEPA Contract Laboratory Program Level IV QA/QC.

Field QA/QC samples were collected during the sampling program. These samples were obtained to:

- Ensure that disposable and reusable sampling equipment were free of contaminants
- Evaluate field methodology

- Establish ambient field background conditions
- Evaluate whether cross-contamination occurred during sampling and/or shipping

Several types of field QA/QC samples were collected and analyzed in accordance with the AOC 6 TNT Subareas SAP (CH2M HILL, 2013). They are defined as follows:

- **Equipment Rinsate Blank (decontaminated equipment):** Equipment blanks were collected at the frequency noted in Section 2.4 or Worksheet #12 of the AOC 6 TNT Subareas SAP (one per medium per day of sampling). These samples were obtained by running laboratory-grade deionized (DI) water over or through sample collection equipment after the equipment was decontaminated. These samples were used to determine whether decontamination procedures for reusable equipment were adequate.
- **Equipment Rinsate Blank (disposable equipment):** Equipment blanks were collected at the frequency noted in Worksheet #12 of the AOC 6 TNT Subareas SAP (once per lot). These samples were obtained by running laboratory-grade DI water over or through sample collection equipment prior to the equipment's use. These samples were used to determine whether disposable, one-time-use equipment was contaminant-free prior to use.
- **Duplicate Sample:** Duplicate samples were collected at the same time and under identical conditions as their respective associated sample, at the frequency noted in Section 2.4 or Worksheet #12 of the AOC 6 TNT Subareas SAP (one per 10 field samples of similar matrix). These samples were collected to evaluate the field and laboratory reproducibility of sample results, and are one way to evaluate field methodology.

In addition to samples collected to monitor field QC, samples were also collected to monitor quality within the laboratory. These included the following:

- **Matrix Spike (MS):** An aliquot of a matrix (that is, soil, groundwater, and so forth) was spiked with known quantities of analytes of interest and subjected to the entire analytical procedure. By measuring the recovery of these spiked quantities, the appropriateness of the method for the matrix was demonstrated.
- **Matrix Spike Duplicate (MSD):** These samples were collected as second aliquots of the same matrix as the MS to determine the precision of the method.

One MS sample and one MSD sample were collected for every 20 environmental samples collected (or greater than or equal to 5 percent of the samples collected) per medium.

2.3 Decontamination Procedures

All decontamination activities were conducted in accordance with the SOPs entitled *Decontamination of Personnel and Equipment* and *Decontamination of Drilling Rigs and Equipment*, as applicable (CH2M HILL, 2013). Disposable sampling equipment and personal protective equipment, such as Masterflex tubing and nitrile gloves, were not decontaminated after use and instead were disposed as non-hazardous solid waste. After use, disposable equipment was placed in plastic contractor bags and disposed in an onsite trash dumpster. Non-disposable sampling equipment, such as hand augers, was decontaminated prior to each use.

Reusable, heavy equipment, such as drilling rods and augers, was decontaminated before and in between the collection of each sample using a high-pressure steam cleaner with potable-grade water. Pressure-washing was conducted at the temporary decontamination pad, which had been constructed prior to the start of drilling activities. The decontamination pad consisted of a raised wood frame lined with a high-density polyethylene tarp, which acted as a basin to collect fluids. These fluids were then pumped into approved 55-gallon drums to await characterization and disposal. All heavy equipment decontamination procedures were conducted in accordance with the SOP entitled *Decontamination of Drilling Rigs and Equipment* (CH2M HILL, 2013).

Water generated during decontamination of sampling equipment was collected and transferred to an approved 55-gallon drum to await characterization and disposal.

2.4 Investigation-derived Waste Management

Investigation-derived waste (IDW) generated during the AOC 6 TNT Subareas RI included soil cuttings, well development groundwater, groundwater sampling purge-water, as well as decontamination rinse-water from all non-disposable sampling equipment and heavy equipment. The IDW was containerized in approved 55-gallon drums that were properly labeled and stored on secondary containment at ER Site 7, the approved IDW staging location. In total, eight drums of solid IDW and eight drums of aqueous IDW were generated during the AOC 6 TNT Subareas RI field activities.

Prior to disposal, CH2M HILL field staff collected one composite sample from all aqueous IDW drums and one composite sample from all solid IDW drums. The IDW samples were analyzed for full Toxicity Characteristic Leachate Procedure analyses (VOCs, SVOCs, pesticides, and inorganic constituents), ignitability, reactive cyanide, reactive sulfide, and corrosivity. Based on the analytical results, all IDW was identified as non-hazardous and disposed by Clearfield, MMG, at the company’s approved disposal facility located in Chesapeake, Virginia, within 90 days of generation.

All IDW management activities were conducted in accordance with Section 3.2.1 of the AOC 6 TNT Subareas SAP. An analytical summary for the IDW samples is provided in **Table 2-4**. Laboratory analytical data for the IDW samples are presented in **Appendix C**. All IDW handling and disposal information is included in **Appendix D.**

2.5 Data Quality Evaluation

The data quality evaluation and validation is a multi-tiered approach. The process begins with an internal laboratory review, continues with an independent review by a third-party validator, and ends with an overall review by the CH2M HILL project chemistry team. The results of the data quality evaluation are included as **Appendix E**.

SECTION 3

3 Physical Characteristics

This section presents an evaluation of the AOC 6 TNT Subareas physical characteristics pertaining to the conceptual hydrogeology of the site. The physical settings of CAX and the AOC 6 TNT Subareas, including meteorology, topography, land and groundwater use, hydrogeology, and ecological resources, are summarized in this section. This information provides the basis for the hydrologic and hydrogeologic conceptual model of the AOC 6 TNT Subareas, which in turn is a foundational element of the overall CSM for these sites. A detailed hydrologic and hydrogeologic conceptual model is important to describe the primary mechanisms that control the fate and migration of contaminants. The information concerning the physical characteristics of the AOC 6 TNT Subareas also supports the HHRA and Ecological Risk Assessment (ERA).

3.1 Climate

The climate of the Virginia Peninsula is influenced by the moderating effects of the Atlantic Ocean, resulting in mild winters and long, warm summers. High humidity occurs frequently along the coast and less frequently inland. The average relative humidity in mid-afternoon is approximately 60 percent. Humidity is higher at night, and the average humidity at dawn is approximately 80 percent. Ground fog is a frequent weather occurrence in late summer, especially during early morning hours.

Freezing temperatures occur intermittently from October through March. The average monthly temperatures in the area range from approximately 38.8 degrees Fahrenheit (°F) in January to 77.4°F in July (Baker, 2003).

Because of its location near the coastline, the vicinity of CAX is subject to easterly storms throughout late summer and early fall, which cause high tides and coastal flooding. Intense tropical hurricanes occasionally sweep the coast. Winter storms that move along the eastern seaboard are often associated with high winds and precipitation, occasionally in the form of snow, ice pellets, or rain; however, the snow is seldom prolonged or heavy. The average annual precipitation is approximately 44 inches, with the summer months being the wettest and the winter months being the driest (Baker, 2003).

Spring is a period of contrasting weather, particularly during March. Spring and autumn are periods of occasional frost. Summer is warm and humid with occasional showers and afternoon thunderstorms. Autumn is a season of comfortable temperatures (average temperature 60˚F to 81˚F) and generally pleasant weather (Baker, 2003).

Winds are highly variable in the area of CAX. Prevailing winds are usually from the south-southwest, but north-northeasterly winds are common in some months. Onshore winds predominate during the spring and summer (Baker, 2003).

3.2 Topography and Surface Drainage Features

The topography at CAX is characterized by gently rolling terrain dissected by ravines and stream valleys trending predominantly northeastward toward the York River. Ground elevations at CAX vary from sea level along the eastern boundary, which borders the York River, to a maximum elevation of approximately 50 feet above mean sea level (amsl) on a few scattered hills in the western portion of the base. Valleys consisting of 40- to 60-foot ravines with steep slopes (slopes exceeding 1:1) occur along the major creeks draining CAX (Baker, 2003).

CAX is bordered on the west by Cheatham Pond, on the north by the mouth of Queen Creek, on the east by the York River, and on the south by King Creek. In 1943, dams were constructed to create the 108-acre Cheatham Pond from a tributary of Queen Creek, as well as the 43-acre Penniman Lake from a tributary of King Creek. Both creeks are tidally influenced; however, Cheatham Pond and Penniman Lake are not.

Damming a portion of the Cub Creek watershed formed Jones Pond, a 69-acre freshwater, non-tidally-influenced pond enclosed by several wooded ravines and located in the southwestern section of CAX. Numerous small creeks flow through wooded ravines throughout CAX and drain into tidal creeks that join the York River. In most areas, forests extend to the marsh and lake margins. The tributaries of CAX all drain into the York River (Baker, 2003).

The AOC 6 TNT Subareas are wooded and moderately vegetated with shrubs. In general, the topography of the AOC 6 TNT Subareas is gently undulating with a somewhat abrupt topographic descent along the shoreline of Penniman Lake. Surficial runoff from the AOC 6 TNT Subareas flows primarily east toward Penniman Lake and southeast toward King Creek (**Figure 3-1**).

3.3 Land Use

CAX is a secure military installation that occupies 2,300 acres. The area encompassing the AOC 6 TNT Subareas is approximately 0.5 acre in size and located within the confines of CAX where access by the general public is restricted. Navy and Department of Defense (DoD) personnel do have access to the AOC 6 TNT Subareas for the pursuit of recreational activities such as jogging, hunting, and fishing. Future land use at the AOC 6 TNT Subareas is not expected to change and will likely continue as recreational in the foreseeable future.

3.4 Water Use

Between approximately 1943 and October 2002, Jones Pond was the drinking water source for CAX (ATSDR, 2004). In addition, groundwater from the Yorktown-Eastover aquifer was historically the drinking water source for older individual homes within the vicinity of CAX and was used as a backup water supply for CAX itself. In 2002, the source of drinking water for CAX switched from Jones Pond to water[3] distributed by the City of Newport News Waterworks (ATSDR, 2004). Therefore, groundwater at CAX is not a current or anticipated future source of drinking water at the installation. Furthermore, drinking water is publically available through the City of Newport News Waterworks to all domestic homes located within the vicinity of CAX. The Commonwealth of Virginia does not employ groundwater use classifications; therefore, groundwater at CAX is considered to be of potential beneficial use. There are no fresh surface water bodies within the vicinity of the AOC 6 TNT Subareas that could feasibly be used as a potable water supply.

3.5 Hydrogeology

3.5.1 Geology

CAX is located in the Atlantic Coastal Plain Physiographic Province, which is underlain by multiple layers of unconsolidated sediment of Quaternary, Tertiary, and Cretaceous ages (**Figure 3-2**). The primarily granitic rock formations of the Appalachian Mountains to the west were eroded over millennia and sediment was transported from the mountains by rivers and streams to the coast, building up layers of sediment that fanned out onto the Atlantic continental shelf. Successive sea level rises deposited fluvial estuarine and marine sediment further, building the Coastal Plain. Widely fluctuating sea levels sculpted the Coastal Plain into river terraces of different elevations bounded by scarp features that resulted from shoreline erosion. The Coastal Plain in the vicinity of CAX includes four terraces: Lackey Plain, Croaker Flat, Huntington Flat, and Grafton Plain (from highest to lowest), and three scarps: Kingsmill, Lee Hall, and Camp Peary. As shown on **Figure 3-3**, CAX is located within the Lackey Plain and Croaker Flat terraces, separated by the Camp Peary scarp located along the York River (Brockman et al., 1997), with the AOC 6 TNT Subareas located within the Croaker Flat.

[3] The Chickahominy River is the primary source of drinking water for the City of Newport News, with groundwater from deep wells in the Lee Hall area serving as a secondary source of water (Newport News Waterworks, 2013)

A total of 10 geologic formations have been identified (Brockman et al., 1997) beneath CAX. The uppermost geologic formations consists of alluvial, colluvial, and marsh deposits composed of silt, sand, and pebbles with some clay. In terms of the overlying soils, the AOC 6 TNT Subareas are located within Soil Association Group 2, one of the four soil association groups identified at CAX during a 1985 soil survey report for CAX prepared by the Soil Conservation Service. Soils in Soil Association Group 2, the Dogue, Pamunkey, and Uchee Association (**Figure 3-4**), were formed on river terraces and are deep, well- to poorly drained soils with clayey and loamy subsoils (Baker, 2003). A more detailed description of the soils within Soil Association Group 2 can be found in the 2003 CAX Background Investigation report (Baker, 2003).

The uppermost subsurface geology in the area of the AOC 6 TNT Subareas consists of the Pleistocene (Quaternary) Shirley formation and the Pliocene (Tertiary) Yorktown formation (Mixon et al., 1989). The Shirley formation is relatively thin, only occurs within topographically higher areas located adjacent to the site, and consists of sand, gravel, silt, clay, and trace amounts of organic material. The uppermost portion of the Yorktown formation (Yorktown confining unit) is defined by Brockman and Richardson (1992) as the silt or clay of the Morgarts Beach Member of the Yorktown formation and consists of clay, clayey silt, sandy clay, or silty clay with or without some shell hash or sand stringers (Brockman et al., 1997). Within the Croaker Flat, the Yorktown confining unit impedes the vertical flow of groundwater between the Columbia (surficial) and Yorktown-Eastover aquifers (Brockman et al., 1997). Soil boring data from both the SI (CH2M HILL, 2012) and the RI (**Appendix A**) indicate that the subsurface lithology at the AOC 6 TNT Subareas consists (in descending order) primarily of a thin layer of topsoil underlain by dark and light colored silty sands that are interlayered with fine clays, which are then underlain by a greenish-grey fat clay.

3.5.2 Hydrostratigraphy

Each Coastal Plain geologic unit was grouped into hydrostratigraphic units based upon hydrologic characteristics (Lazniak and Meng, 1988; Brockman et al., 1997). Based upon the hydraulic characteristics of the geologic units present, the uppermost eight (Cobham Bay Member of the Eastover formation through the Tabb formation) of the 10 geologic formations have been identified as the York County Shallow Aquifer System. As shown on **Figure 3-2**, the following five hydrogeologic units make up the York County Shallow Aquifer System at CAX (in descending order):

- Columbia aquifer (consisting of the Windsor through Tabb formations)
- Cornwallis Cave confining unit (consisting of the Bacons Castle formation)
- Cornwallis Cave aquifer (consisting of the upper Moore House Member of the Yorktown formation and the Sedley formation)
- Yorktown confining unit (consisting of the upper Morgarts Beach and lower Moore House Members of the Yorktown formation)
- Yorktown-Eastover aquifer (consisting of the Cobham Bay through Rushmere Members of the Yorktown formation)

Beneath the AOC 6 TNT Subareas, the Camp Peary Scarp truncates portions of the York County Shallow Aquifer System; the Cornwallis Cave Confining Unit and Cornwallis Cave aquifer are not present at this site. The first encountered groundwater occurs within silty sands of the Columbia aquifer that are interlayered with fine clays. The Columbia aquifer is unconfined at the site, approximately 11 to 15 feet thick (**Appendix A**), and is recharged by the infiltration of precipitation. The Yorktown confining unit underlies the Columbia aquifer at the AOC 6 TNT Subareas. Based on a geohydrological study of WPNSTA Yorktown, the Yorktown confining unit is generally 14 feet thick (Brockman et al., 1997).

3.5.3 Aquifer Properties

Aquifer “slug” testing was performed at each of the six new AOC 6 TNT Subareas monitoring wells in October 2013 to collect rising-head and falling-head test data to estimate the K of the Columbia aquifer in the vicinity of the wells. The slug test data were analyzed using both the Hvorslev Method (Hvorslev, 1951) and the Bouwer and Rice Method (Bouwer and Rice, 1976). The K values were reported for both rising- and falling-head methods when the static water-level occurred within the riser pipe portion of the monitoring well (that is, above the screen interval). **Table 3-1** summarizes the results of the testing. The slug test data analyses were performed utilizing AQTESOLV software; the data plots are provided in **Appendix F**, and the average calculated horizontal hydraulic conductivity or Henry's Law Constant (K_h) value of 0.962 foot per day (ft/day) is included in **Table F-1** in **Appendix F**. While the Hvorslev solution is generally intended for confined aquifers and the Bouwer-Rice solution is generally intended for unconfined aquifers, a study by Brown et al. (1995) determined that the Hvorslev and Bouwer-Rice solutions are applicable to unconfined and confined aquifers in many cases. Therefore, although the Columbia aquifer is unconfined at the AOC 6 TNT Subareas, the overall maximum and minimum K values calculated from the falling- and rising-head test data were chosen independent of the method used to calculate the K value.

The K values in the Columbia aquifer were estimated to be between 0.130 and 2.234 ft/day. These values fall within or near the reported range of 0.4 to 8 ft/day for this aquifer (Brockman, et. al., 1997).

Slug test results, by their nature, are limited in their ability to accurately estimate the K of an aquifer, in part because of impacts from the filter pack placed around the well during installation. They are generally considered to represent an "order-of-magnitude" level of precision and accuracy in estimating K.

3.5.4 Groundwater Flow

The first encountered groundwater at the AOC 6 TNT Subareas is within the Columbia aquifer, and the groundwater elevations on August 22, 2014, ranged from 4.38 feet amsl at CAA06-MW04 to 6.35 feet amsl at CAA06-MW01 (**Table 2-2**). The Penniman Lake surface water elevation at staff gauge PL-SG01 was measured concurrently with the groundwater elevations at the AOC 6 TNT Subareas monitoring wells. The surface water elevation at PL-SG01, at 8.06 amsl, was 1.71 to 3.67 feet above the groundwater elevations, indicating that Penniman Lake is recharging the surficial aquifer at the AOC 6 TNT Subareas and influencing the directions of groundwater flow. The groundwater elevation data indicate that the primary groundwater flow direction at the AOC 6 TNT Subareas is southward, away from Penniman Lake and toward King Creek (**Figure 3-5**).

The average hydraulic gradient (I) along the flow path from CAA06-MW06 to CAA06-MW05 is 0.007[4]. Based on the average calculated K value of 0.962 ft/day within the Columbia aquifer (**Appendix F, Table F-1**), an assumed effective porosity (n) of 0.3[5], and the average horizontal hydraulic gradient calculated from the groundwater contour map (0.007), the average lateral groundwater velocity[6] at the AOC 6 TNT Subareas is estimated to be 0.022 ft/day.

3.6 Ecological Resources

Characterization of the terrestrial, wetland, and biological resources at CAX is adapted from the Initial Assessment Study (C.C. Johnson & Associates, Inc., and CH2M HILL, 1984).

Terrestrial flora at CAX consists predominantly of woodland species. The following three types of forest are present:

- Pine stands composed primarily of Loblolly and Virginia pines
- Mixed hardwood stands
- Mixed pine and hardwood stands

[4] Average hydraulic gradient was calculated between monitoring wells CAA06-MW03 and CAA06-MW05, whereby I (average hydraulic gradient) = (6.10-5.67 feet)/60 feet = 0.007

[5] Effective porosity of 0.30 used based on analyses of Cenomanian and Albian Age sands (Upper and Middle Potomac aquifer) in the Norfolk, Virginia, area (Brown and Silvey, 1997)

[6] Average groundwater velocity (ft/day) = (K x I)/n

Elevated areas are the predominant locations of pine stands, while hardwood stands are found on slopes and in ravines. Native tree species found at CAX include beech, black cherry, red maple, sweet gum, various pines, white ash, and white oak. The woodland's understory is composed of various seedling trees and vine species, such as Virginia creeper, briars, and honeysuckle. Ferns are found in many moist, shaded areas. Ornamental trees and shrubs have been planted in the improved areas and along major roadways. None of the plant species that occur at CAX are listed on the federal or Commonwealth endangered species lists.

Small, undeveloped tracts of land at CAX support a variety of indigenous wildlife species. Whitetail deer, beaver, skunk, bobcat, red and gray fox, squirrel, raccoon, opossum, and rabbit are present. Game birds, such as wild turkey, quail, duck, and pheasant, are also resident. Songbirds common to the eastern Virginia area are in abundance at CAX, along with a raptor population consisting of small hawks, owls, and osprey. Carrion-feeding birds such as crows and turkey vultures are also common. The southern bald eagle (federally and state protected) is known to nest nearby at WPNSTA Yorktown. Suitable habitat exists for roosting and perching at CAX, but only occasional sightings of eagles have been made there.

Wetlands are mainly found along principal tributaries to the York River and along the York River shoreline at CAX. The following four major marsh types exist along these margins:

- Saltmarsh cordgrass communities
- Big cordgrass communities
- Cattail communities
- Brackish water mixed communities

Freshwater wetlands are also present within the interior, non-tidal areas of the installation. Salinities in the York River estuary bordering CAX can be characterized as mesohaline (from 15 to 20 parts per thousand), and can fluctuate depending on seasonal impacts, runoff, and rainfall. Of the 295 fish species known from the Chesapeake Bay, only 32 are year-round residents. Nursery areas, foraging areas, and spawning ground attract the remaining species from the Atlantic Ocean and freshwater tributaries each year. In the York River, resident fish include hogchoker, weakfish, and oyster toadfish. Spot and croaker are common in nursery and foraging areas in the summer and numerous anadromous and catadromous fish use the area during migration, including the alewife, American eel, American shad, blueback herring, striped bass, and white perch. Commercially and recreationally important species from the York River include American shad, bay anchovy, blue crab, bluefish, croaker, spot, striped bass, summer flounder, and weakfish. The York River in the vicinity of CAX is a designated crab pot fishery from March through November of each year; immediately north of CAX is a spawning and nursery ground for blue crabs. Several species of endangered sea turtles (namely the green, hawksbill, leatherback, loggerhead, and Kemp's Ridley) are known to feed in the Chesapeake Bay and occasionally forage in the York River, including the vicinity of CAX, during the summer.

The York River is designated as Essential Fish Habitat for three species of fish managed by the Mid-Atlantic Fishery Management Council—summer flounder, bluefish, and butterfish. Though both bluefish and butterfish use the more open, pelagic waters characteristic of the river, juvenile summer flounder often use unvegetated, nearshore sandy bottoms and salt marsh creeks as nursery areas. Other species likely to use salt marsh creeks include anchovies, blue crabs, juveniles of migratory species, hard- and soft-shell clams, killifish, minnows, mummichogs, oysters, silversides, and weakfish.

No known federally or state-listed endangered or threatened species are currently using CAX habitats. Suitable habitat exists at CAX for both the red-cockaded woodpecker (federally endangered) and the bald eagle (formerly federally threatened and still protected by the Bald and Golden Eagle Protection Act and state threatened/endangered). Bordering the CAX property is the York River, which provides seasonal habitat for federally and state endangered Kemp's Ridley sea turtles and federally threatened loggerhead sea turtles. The shoreline along the York River may also provide habitat for federally threatened piping plovers. Rare resources and communities identified at CAX in the Virginia Department of Conservation and Recreation Natural Heritage Program database and the CAX Natural Heritage Inventory include a significant great blue heron colony, low salt marsh and salt scrub habitats, coastal plain depression ponds, non-riverine wet hardwood forests, and coastal plain calcareous seepage swamps.

SECTION 4

4 Nature and Extent of Contamination

This section presents an evaluation of the nature and extent of contamination within soil and groundwater at the AOC 6 TNT Subareas. Environmental samples were collected to characterize the vertical and horizontal extents of contamination in order to determine whether remedial action is warranted at these subareas.

The conservative screening values used to evaluate the sampling data at the AOC 6 TNT Subareas are the values presented in the AOC 6 TNT Subareas SAP (CH2M HILL, 2013):

- Soil – USEPA adjusted Residential Soil Regional Screening Levels (RSLs)[7] (USEPA, 2013) and site-specific literature-based ecological screening values (ESVs) for plants and soil invertebrates (if soil is within the first 2 feet of the ground surface)
- Groundwater – USEPA adjusted Tapwater RSLs[6] (USEPA, 2013) and the federal maximum contaminant levels (MCLs)

The background screening values used to evaluate the soil and groundwater sampling data are the surface and subsurface soil background 95 percent upper tolerance limits (UTLs) (CH2M HILL, 2011) and groundwater concentrations from monitoring wells CAA06-MW01 and CAA06-MW06[8], respectively. Since CAX background concentrations for groundwater are not available for the Columbia aquifer, background/upgradient groundwater quality for CERCLA sites overlying the Columbia aquifer was evaluated on a site-specific basis in accordance with the Final Background Study Work Plan, Naval Weapons Station Yorktown, Yorktown, Virginia and Cheatham Annex, Williamsburg, Virginia (CH2M HILL, 2009). Monitoring wells CAA06-MW01 and CAA06-MW06 are located upgradient of where historic site activities occurred at the AOC 6 TNT subareas; therefore, the groundwater analytical data from these two monitoring wells best represent groundwater background conditions.

Independent of any comparison to background concentrations, all data that exceed conservative screening values are included in the assessments of potential risks to human health and/or ecological receptors. The quantitative assessments of risks to human health and ecological receptors are included in **Sections 5 and 6** of this report, respectively.

This evaluation includes data collected in 2008 during the recent SI field activities (CH2M HILL, 2012) and this RI. The results from a total of 21 discrete surface soil samples, one three-point composite surface soil sample, 21 discrete subsurface soil samples, one three-point composite subsurface soil sample, and six groundwater samples that were collected from the AOC 6 TNT Subareas were used for this evaluation (**Table 2-1**). Four DPT groundwater samples were also collected during the 2012 SI and the analytical data were used to site the six monitoring wells installed during the RI. However, since the DPT groundwater samples were collected from temporary monitoring wells, the data may not be representative of current groundwater concentrations; consequently, these data were not evaluated in the RI and the monitoring well sampling data were used instead. Additionally, the surface water and sediment data from the 2012 SI (from Penniman Lake) were not evaluated as part of this RI since no potential human health or ecological risks were identified; in addition, these media are being assessed as part of the Penniman Lake SI. Laboratory analytical results used in this evaluation for the AOC 6 TNT Subareas are summarized by medium and analyte class in **Tables 4-1** through **4-3**. Laboratory analytical reports are included in **Appendix G**.

[7] The RSLs for those constituents that pose potential cancer risks were not adjusted, while the RSLs for noncarcinogens were adjusted by dividing by 10 to account for multiple chemicals contributing to potential noncancer risks.

[8] CAX background concentrations for groundwater are not available for the Columbia aquifer; therefore, groundwater concentrations in the site-specific upgradient monitoring wells CAA06-MW01 and CAA06-MW06 were used for comparison purposes during the risk assessments.

4.1 Soil

A total of 21 discrete and one three-point composite surface soil samples (**Table 4-1**) and 21 discrete and one three-point composite subsurface soil samples (**Table 4-2**) were collected from and around the AOC 6 TNT Subareas during the 2012 SI and the RI and the results evaluated to determine the nature and extent of site-related contamination (**Figure 4-1**):

- Surface and subsurface soil samples collected in the vicinity of the AOC 6 TNT Subareas to provide expanded spatial coverage to adequately characterize this medium
- Surface and subsurface soil samples collected from areas with elevated chromium concentrations during the SI
- three-point composite surface and subsurface soil samples collected from the surface depression at the AOC 6 TNT Catch Box Ruins to account for the potential variability of contaminant concentrations within this area and to address the potential for soil contamination above the water table

During the 2012 SI, soil samples were analyzed for SVOCs, explosive constituents, total inorganic constituents, cyanide, pH and TOC. Based on the results of the SI, soil samples collected during the RI were analyzed only for those constituent groups determined to be potentially site-related based on earlier results (explosive constituents[9] and total inorganic constituents). In addition, the soil samples collected during the RI were analyzed for pH, TOC, and grain size (surface soil samples only) to supplement the ERA, and two discrete, co-located surface and subsurface soil samples were analyzed for total and hexavalent chromium to supplement the HHRA.

4.1.1 Organic Compounds

4.1.1.1 SVOCs

The SVOC 2,4-DNT, was detected in surface and subsurface soil within the center of the TNT Catch Box Ruins at a concentration exceeding the adjusted residential RSL; the 2,4-DNT concentration also exceeded the ESV in subsurface soil (**Figure 4-2 and Figure 4-3**). The 2,4-DNT concentration exceeded the residential RSL (1,600 micrograms per kilogram [µg/kg]) in discrete surface soil sample CAA06-SS01-1008 at an estimated concentration of 6,300 L µg/kg in 2008. However, it was not detected in the three-point composite surface soil sample (CAA06-SO26-000H-0913) collected from the center area of the TNT Catch Box Ruins during the RI. The concentration of 2,4-DNT at the center of the TNT Catch Box Ruins exceeded the adjusted residential RSL during the 2012 SI in discrete subsurface soil sample CAA06-SB01-1008 (1,700 µg/kg) and the adjusted residential RSL and ESV during the RI in the three-point composite subsurface soil sample CAA06-SO26-0H02-0913 (12,000 µg/kg).

The 2,4-DNT constituent is a synthetic substance used in the production of TNT (ATSDR, 2013). Since the TNT Catch Box was used to separate TNT particles from wastewater, the 2,4-DNT detection is a CERCLA-regulated release likely attributable to historical activities at this subarea. The three-point composite subsurface soil sample CAA06-SO26-0H02-0913 was collected at the center of the TNT Catch Box Ruins and at two locations 18 inches from the center point, as well as directly above the water table. Since 2,4-DNT was not detected at concentrations exceeding screening criteria in any other subsurface soil samples, the horizontal and vertical extents of 2,4-DNT contamination in soil have been delineated at the AOC 6 TNT Subareas.

[9] The constituent 2,4-DNT was the only SVOC that exceeded risk screening criteria in the 2012 SI soil samples and the exceedances occurred at only one sample location (CAA06-SO01). It was included as a constituent in the explosives analysis during the RI. However, to maintain consistency during reporting, the 2,4-DNT analytical results are listed under the SVOC compounds in Tables 4-1 and 4-2 since this is where this compound was listed during the recent SI.

4.1.1.2 Explosive Constituents

Five explosive constituents in surface soil and three explosive constituents in subsurface soil were detected at the AOC 6 TNT Subareas at concentrations exceeding their respective adjusted residential soil RSL, and in some samples, also the ESV (**Figure 4-2 and Figure 4-3**).

- In surface soil, the concentrations of 1,3-dinitrobenzene, 2,4,6-trinitrotoluene (TNT), 2-amino-4,6-DNT, 2-nitrotoluene, and 4-amino-2,6-DNT exceeded the adjusted residential RSL in at least seven samples, and TNT concentrations exceeded the ESV in at least six samples.
  - The maximum-detected concentrations of 1,3-dinitrobenzene (2,500 µg/kg) and TNT (14,000,000 µg/kg) were detected in the three-point composite sample CAA06-SO26-000H-0913; the maximum-detected concentrations of 2-amino-4,6-DNT (16,000 J µg/kg), 2-nitrotoluene (48,000 J µg/kg), and 4-amino-2,6-DNT (17,000 µg/kg) were detected in sample CAA06-SS02-1008.
- In subsurface soil, the concentrations of 1,3-dinitrobenzene, TNT, and 4-amino-2,6-DNT exceeded the adjusted residential RSL in at least six samples, and TNT concentrations exceeded the ESV in at least five samples.
  - The maximum-detected concentrations of TNT (9,300,000 µg/kg), 1,3-dinitrobenzene (1,600 J µg/kg), and 4-amino-2,6-DNT (30,000 µg/kg) were detected in samples CAA06-SO26-0H02-0913 (a three-point composite sample), CAA06-SB01-1008, and CAA06-SB13-1108, respectively.

All of the detections of explosive constituents exceeding screening criteria in surface and subsurface soil were located in the vicinity of the TNT Catch Box Ruins or immediately southeast of the former TNT Graining House, and are attributable to historical activities at these subareas (**Figure 4-2 and Figure 4-3**).

4.1.2 Inorganic Constituents

Eight inorganic constituents in surface soil (**Figure 4-2**) and nine inorganic constituents in subsurface soil (**Figure 4-3**) were detected at the AOC 6 TNT Subareas at concentrations exceeding their respective adjusted residential RSL and/or ESV.

- In surface soil, aluminum, arsenic, chromium, cobalt, iron, lead, thallium, and vanadium concentrations exceeded the adjusted residential RSL or ESV in at least one sample. These detected concentrations also exceeded their respective Base background 95 percent UTL at one or more sample locations, except for thallium, which does not have a 95 percent UTL.
  - Arsenic concentrations in surface soil were detected above the adjusted residential RSL (0.61 milligram per kilogram [mg/kg]) (but not the ESV) and Base background 95 percent UTL (6.36 mg/kg) in two of the 20 surface soil samples analyzed for inorganic constituents (CAA06-SS01-1008 and CAA06-SS03-1008).
  - Aluminum, chromium, and vanadium concentrations exceeding the 95 percent UTLs were only detected in one out of 20 surface soil samples (CAA06-SS03-1008). Lead concentrations exceeding the 95 percent UTL were only detected in two out of 20 surface soil samples (CAA06-SS01-1008 and three-point composite sample CAA06-SO26-000H-0913). Iron concentrations exceeding the 95 percent UTL were only detected in three out of 20 surface soil samples (CAA06-SS01-1008, CAA06-SS03-1008, and three-point composite sample CAA06-SO26-000H-0913).
  - Thallium concentrations in surface soil were detected above the adjusted residential RSL (0.078 mg/kg) in 11 of 20 surface soil samples.
- In subsurface soil, aluminum, arsenic, hexavalent chromium, chromium, cobalt, iron, lead, thallium, and vanadium concentrations exceeded the adjusted residential RSL or ESV in at least one sample. In addition, these detected concentrations also exceeded their respective Base background 95 percent UTL in at least one sample location, except for hexavalent chromium and thallium, neither of which have a 95 percent UTL.

- Arsenic concentrations in subsurface soil were detected above the adjusted residential RSL (0.61 mg/kg) and Base background 95 percent UTL (5.54 mg/kg) in six of the 20 subsurface soil samples analyzed for inorganic constituents. The maximum concentration of 20.9 J mg/kg was detected in sample CAA06-SB01-1008, where this concentration also exceeded the ESV.
- Iron, lead, and vanadium concentrations exceeding the 95 percent UTLs were only detected in one out of the 20 subsurface soil samples. Chromium concentrations exceeding the 95 percent UTLs were only detected in two out of 20 subsurface soil samples (CAA06-SB01-1008 and CAA06-SB03-1008). Aluminum concentrations exceeding the 95 percent UTLs were only detected in five out of 20 subsurface soil samples CAA06-SB36-0H02-0913, CAA06-SB02-1008, CAA06-SB03-1008, CAA06-SB13-1108, and CAA06-SB31-0H02-0913).
- Hexavalent chromium concentrations in subsurface soil were detected above the adjusted residential RSL (0.3 mg/kg) at 0.31 J mg/kg and 0.94 mg/kg in two out of two subsurface soil samples, CAA06-SB26P-0H02-0913 and CAA06-SB27-0H02-0913, respectively.
- Thallium concentrations in surface soil were detected above the adjusted residential RSL (0.078 mg/kg) in 12 of 20 subsurface soil samples.

The detections of inorganic constituents exceeding screening criteria in surface and subsurface soil were distributed throughout the AOC 6 TNT Subareas and are not concentrated within the TNT Catch Box Ruins or immediately southeast of the former TNT Graining House (**Figure 4-2 and Figure 4-3**).

4.2 Groundwater

A total of six groundwater samples (CAA06-GW01 through CAA06-GW06) were collected from the AOC 6 TNT Subareas (**Table 4-3**) during the RI to evaluate groundwater conditions and to assess the potential for human health or environmental risks associated with this medium (**Figure 4-4**). Four DPT groundwater samples were also collected during the 2012 SI, analyzed for SVOCs, total and dissolved inorganic constituents, cyanide, and explosives, and the analytical data were used to site the six RI monitoring well locations. However, since the SI groundwater samples were collected from temporary monitoring wells, the DPT data may not be representative of current groundwater concentrations; consequently, these data were not evaluated in the RI. During the RI, groundwater samples were collected from the newly installed permanent monitoring wells and analyzed for potentially site-related contaminants based on earlier results (total/dissolved inorganic constituents) and monitored natural attenuation parameters (pH, alkalinity, chloride, nitrate, nitrite, sulfate, sulfide, TOC, ferrous iron, and DO).

A summary of the groundwater sampling results is presented as follows; a discussion of the results and significance of each natural attenuation parameter and more details regarding aquifer geochemical conditions within groundwater are presented in **Section 7.**

4.2.1 General Groundwater Geochemistry

Measurements of DO, ORP, pH, temperature, conductivity, and turbidity were collected at each monitoring well following purging and immediately prior to sampling (**Table 2-3**). The DO readings collected during purging activities, which provide an indication of the potential for aerobic or anaerobic biodegradation, ranged between 0.0 milligram per liter (mg/L) and 1.32 mg/L. Temperature readings ranged between 18.91 degrees Celsius (°C) and 21.86°C. The ORP values, which indicate the potential for redox conditions in groundwater, ranged between -179.1 millivolts (mV) and -53.0 mV, and pH values were generally close to neutral, ranging between 6.33 and 6.84. Conductivity values, which provide an indication of the concentration of total dissolved solids within groundwater, ranged between 0.231 milliSiemen per centimeter (mS/cm) and 0.448 mS/cm, which are indicative of freshwater conditions. Further details regarding groundwater geochemistry and its applicability to contaminant fate and transport are discussed in **Section 7.1.7**.

4.2.2 Inorganic Constituents

Five total inorganic constituents and four dissolved inorganic constituents were detected at concentrations exceeding either the adjusted Tapwater RSL or federal MCL (**Figure 4-4**). Since the surficial aquifer underlying the AOC 6 TNT Subareas is the Columbia aquifer, and CAX background concentrations for groundwater are not available for this aquifer, groundwater concentrations in the site-specific upgradient monitoring wells CAA06-MW01 and CAA06-MW06 were used for comparison purposes.

- Total and dissolved arsenic exceeded the MCL and adjusted Tapwater RSL in five groundwater samples; however, all of the concentrations in monitoring wells within the study area boundary were below those detected in reference monitoring well CAA06-MW06, which is upgradient of the AOC 6 TNT Subareas. The arsenic concentrations were also higher compared to monitoring well CAA06-MW03, which is also upgradient of the former TNT Graining House, Sump, and Catch Box Ruins since Penniman Lake was found to be recharging the surficial aquifer during the RI. Arsenic concentrations in groundwater at the AOC 6 TNT Subareas appear to be representative of naturally occurring conditions, as arsenic concentrations are typically elevated in the shallow coastal plain of southeast Virginia due to the aquifer composition and geochemical conditions. Arsenic is commonly adsorbed to, or co-precipitated with, iron and manganese oxides, adsorbed to clay mineral surfaces, and associated with sulfide minerals. Natural dissolving or desorbing of arsenic from these source materials releases arsenic to groundwater. In addition, the U.S. Geological Survey (USGS) has collected and analyzed arsenic in potable (drinkable) water from 18,850 wells in 595 counties across the United States during the past two decades, and naturally occurring arsenic concentrations in southeast Virginia are typically detected above the MCL (USGS, 2000).
- Total cyanide was detected at a concentration exceeding the adjusted Tapwater RSL in only one sample (CAA06-GW05-1013); however, this concentration likely represents elevated suspended solids within the sample since this inorganic constituent was not detected within the corresponding dissolved sample.
- Total and dissolved cobalt concentrations exceeded the adjusted Tapwater RSL (0.6 microgram per liter [μg/L]) in the five of the six groundwater samples. However, the maximum total and dissolved concentrations of 8.7 μg/L were detected in reference groundwater sample CAA06-GW01P-1013, upgradient of the AOC 6 TNT Subareas. These concentrations are likely attributable to naturally occurring background conditions.
- Total iron and manganese concentrations exceeded their respective adjusted Tapwater RSLs in each of the six groundwater samples. The maximum concentrations of total and dissolved iron detected in sample CAA06-GW02-1013 exceeded the respective concentrations detected in groundwater from reference wells CAA06-MW01 and CAA06-MW06, but were not significantly higher than the concentrations in reference well CAA06-MW06 and upgradient monitoring well CAA06-MW03. The concentrations of iron in groundwater are likely attributable to naturally occurring background conditions. With respect to total and dissolved manganese in groundwater samples, detected concentrations did not exceed those detected in groundwater in reference well CAA06-MW01. Similar to iron, manganese concentrations in groundwater are also likely attributable to naturally occurring, background conditions.

  Iron and manganese concentrations are typically elevated in groundwater of the shallow coastal plain of southeast Virginia due to the aquifer composition and geochemical conditions. Iron oxides can be variable within soil as a result of chemical weathering. The ORP and DO values listed in Table 2-3 suggest a more reducing environment at the AOC 6 subareas. Under these conditions, iron hydroxides and manganese oxides present in the soil matrix can reductively dissolve into soluble forms as evidenced by elevated iron and manganese concentrations within groundwater.

SECTION 5

5 Human Health Risk Assessment

5.1 Human Health Risk Assessment Overview

This section summarizes the AOC 6 TNT Subareas baseline HHRA, for which the primary objective was to assess the potential current and future risks to human health from exposure to COPCs associated with surface soil, surface and subsurface soil, and groundwater at the AOC 6 TNT Subareas. All of the data used in the risk assessment were fully validated, are considered useable for the HHRA, and are assumed to represent current conditions. **Table H-1** in **Appendix H** lists the samples that were evaluated in the HHRA. Soil samples collected in October 2008, November 2008, and September 2013 and groundwater samples collected in October 2013 were included in the risk assessment. The analytical data are included in **Appendix G**. The baseline HHRA text and tables are presented in **Appendixes H** and **I**, respectively.

The HHRA evaluated the carcinogenic risks and noncarcinogenic hazards to a reasonably maximally exposed individual, which is consistent with the methodologies in risk assessment guidance for Superfund sites (USEPA 1989, 1993, 2001, 2004). The reasonable maximum exposure (RME) is the highest exposure that is reasonably expected to occur at a site (USEPA, 1989). When the RME risk exceeded target risk levels, the central tendency exposure (CTE) risk was evaluated. The CTE risk is the risk to individuals who have average or typical exposure to the environmental media.

The maximum detected concentration of each constituent for each medium was compared to the criteria discussed as follows to select COPCs for quantitative evaluation in the HHRA. If the maximum concentration exceeded any criterion, the constituent was identified as a COPC for further evaluation with respect to risk. Constituents not detected in any sample or detected at concentrations less than the criteria were not identified as COPCs. The USEPA RSLs (USEPA, 2014) were used for evaluation of media samples as follows:

- Soil – USEPA RSLs for Residential Soil (May 2014 RSL Table)
- Groundwater – USEPA RSLs for Tapwater (May 2014 RSL Table)

A CSM was developed specifically for human exposures at AOC 6 (**Figure H-1** in **Appendix H**) to present an overview of site conditions, potential sources of contamination, potential contaminant-migration pathways, and potential exposure pathways to potential receptors.

5.2 Potential Receptors and Exposure Scenarios

Chemicals and inorganic constituents that pose a potential risk to human health may be present in site soil and groundwater. Potential current receptors exposed to these media are base workers and adult and child recreational users who may come in contact with surface soil. There is no planned future site use that is different from the current use at this time; however, future site use is unknown. Therefore, risks associated with exposure to soil and groundwater were evaluated to assess unrestricted land use, which assumes residential use as the most conservative case. In addition to evaluating hypothetical residential use (which is unlikely), potential future industrial use of the site was evaluated, which includes base workers, construction workers, and recreational users as potential future receptors.

For the future exposure scenarios, it was assumed that soil-moving activities associated with construction for future site development would result in subsurface soil being mixed with the current surface soil, resulting in subsurface soil being placed on the ground surface. Therefore, future exposure to soil was assumed to include exposure to the combined current surface and subsurface soil, so the surface and subsurface soil analytical data sets were combined together to evaluate this potential exposure. It was also conservatively assumed that groundwater from the surficial aquifer might be used as a future potable water supply; however, this is highly unlikely based on the viability of the surficial aquifer for that purpose. It is also unlikely that shallow groundwater will be used as a potable water supply for CAX because the base municipal water is supplied by the City of Newport News Waterworks.

Since historical site use is not associated with significant VOC contamination, and volatile constituents were not found to be potential constituents of concern (COCs) during previous investigations, VOCs were not included in RI groundwater sampling analyses. Therefore, the groundwater to air pathway is not considered a complete exposure pathway.

In summary, current receptors and exposure pathways quantitatively evaluated in the HHRA are:

- **Base worker:** Incidental ingestion of and dermal contact with surface soil. Inhalation of VOCs or particulate emissions from soil were not quantitatively evaluated because no COPCs were identified for this pathway.
- **Recreational Users (adult and child):** Incidental ingestion of and dermal contact with surface soil. Inhalation of VOCs or particulate emissions from soil were not quantitatively evaluated because no COPCs were identified for this pathway.

Future receptors and exposure pathways quantitatively evaluated in the HHRA include the following:

- **Base worker:** Incidental ingestion of and dermal contact with surface and subsurface soil; ingestion of shallow groundwater. Inhalation of VOCs or particulate emissions from soil were not quantitatively evaluated because no COPCs were identified for this pathway.
- **Recreational Users (adult and child):** Incidental ingestion of and dermal contact with surface and subsurface soil. Inhalation of VOCs or particulate emissions from soil were not quantitatively evaluated because no COPCs were identified for this pathway.
- **Construction worker:** Incidental ingestion of and dermal contact with surface and subsurface soil; dermal contact with shallow groundwater in an open excavation. Inhalation of VOCs or particulate emissions from soil were not quantitatively evaluated because no COPCs were identified for this pathway.
- **Resident (adult and child):** Incidental ingestion of and dermal contact with surface and subsurface soil; ingestion of shallow groundwater, and dermal contact with shallow groundwater while bathing/showering. Inhalation of VOCs or particulate emissions from soil were not quantitatively evaluated because no COPCs were identified for this pathway.

The COPCs identified for soil and groundwater at the AOC 6 TNT Subareas, and used to calculate the RME and CTE (when calculated) noncarcinogenic hazards and carcinogenic risks, are identified in **Table H-2** in **Appendix H**. The RME noncarcinogenic hazards and carcinogenic risks are presented by receptor in **Table H-3**, and the CTE results are summarized in **Table H-4**, in **Appendix H**. The risk calculations are presented in **Tables 7.1.RME** through **7.10.RME** and **7.1.CTE** through **7.9.CTE** in **Appendix I**. The CTE risks were calculated only when the RME hazards exceeded the noncarcinogenic target hazard index (HI) of 1, or the RME carcinogenic risks exceeded the target risk range of 1×10^{-6} to 1×10^{-4} (USEPA, 1994). **Tables 9.1.RME** through **9.10.RME** and **9.1.CTE** through **9.9.CTE** in **Appendix I** summarize the hazards and risks to each receptor.

5.3 Human Health Risk Assessment Findings

Human health COCs are identified for the scenarios with potentially unacceptable risks. The COCs are those COPCs that contribute an HI greater than 0.1 to a cumulative target organ HI that exceeds 1 or a carcinogenic risk greater than 1×10^{-6} to a cumulative carcinogenic risk that exceeds 1×10^{-4}. The results of the risks for each receptor are summarized as follows:

- Current or Future Base Worker: Potential unacceptable noncarcinogenic hazards associated with exposure to surface soil and combined surface and subsurface soil, and potential unacceptable carcinogenic risks associated with exposure to groundwater.
  - COC for surface soil is TNT
  - COC for surface and subsurface soil is TNT
  - COC for groundwater is arsenic
- Current or Future Recreational User (adult and child): Potential unacceptable noncarcinongenic hazards associated with exposure to surface soil and combined surface and subsurface soil.
  - COC for surface soil is TNT
  - COC for surface and subsurface soil is TNT
  - Lead is not a COC when evaluating exposure to lead in soil across the full site;~~,~~ however, if only exposed to soil within the ~~c~~Catch ~~b~~Box ~~r~~Ruins, lead is a COC for C~~c~~atch B~~b~~ox R~~r~~uins surface soil and combined surface and subsurface soil.
- Future Construction Worker: Potential unacceptable noncarcinogenic hazard associated with exposure to surface and subsurface soil. Carcinogenic risk associated with surface and subsurface soil, and noncarcinogenic hazard and carcinogenic risk associated with groundwater were within acceptable levels.
  - COC for surface and subsurface soil is TNT
- Future Resident (adult and child): Potential unacceptable carcinogenic risks and noncarcinongenic hazards associated with exposure to surface and subsurface soil and groundwater.
  - COCs for surface and subsurface soil are TNT, 2-nitrotoluene, arsenic, and hexavalent chromium.
  - COCs for groundwater are arsenic and iron
  - ~~.~~Lead is not a COC when evaluating exposure to lead in soil across the full site;~~,~~ however, if only exposed to soil within the ~~c~~Catch ~~b~~Box ~~r~~Ruins, lead is a COC for C~~c~~atch B~~b~~ox R~~r~~uins surface soil and combined surface and subsurface soil.
  -

To summarize, the COCs for AOC 6 media are as follows:

- Under Current Site Use:
  - Surface soil: TNT, plus lead within the Catch Box Ruins only~~ and lead (catch box ruins only)~~
- Under Future Recreational Use:
  - Soil: TNT, plus lead within the Catch Box Ruins only~~ and lead (catch box ruins only)~~
- Under Future Industrial Site Use
  - Soil: TNT
  - Groundwater: arsenic
- Under Future Residential Site Use:
  - Soil: TNT, 2-nitrotoluene, arsenic, and hexavalent chromium, plus lead within the Catch Box Ruins only~~and lead (catch box ruins only)~~
  - Groundwater: arsenic and iron

The soil COC 2-nitrotoluene was only detected in one of the thirty-nine soil samples, and the detection limits for all the other soil samples were below the human health risk-based screening level. As there was only one detected concentration, this concentration was used as the exposure point concentration to estimate the hazards and risks associated with exposure to 2-nitrotoluene. Therefore, the risks associated with exposure to 2-nitrotoluene across the site are likely over-estimated.

A comparison of site concentrations to background concentrations was not used to select the COPCs. Therefore, it is possible that any of the metals identified as COPCs and COCs may be associated with background conditions. Arsenic was identified as a COC in surface and subsurface soil. Arsenic concentrations in surface and subsurface soil ranged from 1.1 mg/kg to 20.9 mg/kg. More than half of these detections were below the 95 percent UTL from the CAX/Yorktown background values of 6.36 mg/kg and 5.54 mg/kg for surface and subsurface soil, respectively. Therefore, it is possible some of the risk associated with exposure to arsenic in soil is from background conditions.

The concentration of hexavalent chromium in subsurface soil exceeded the Residential soil RSL based on a carcinogenic risk of 10^{-6}. However, this concentration would not exceed the Residential soil RSL adjusted to a carcinogenic risk of 10^{-5} (3 mg/kg), indicating that the risk to a residential receptor would fall within the acceptable risk range of 10^{-4} to 10^{-6}. Therefore, it is unlikely there would be any adverse human health effects associated with exposure to hexavalent chromium alone in soil.

While arsenic and iron were identified as COCs in groundwater based on the quantitative HHRA, site concentrations of these constituents may be attributable to naturally occurring background conditions. Arsenic and iron concentrations are commonly found at naturally occurring concentrations that exceed human health screening criteria in shallow groundwater of the Atlantic Coastal Plain. In addition, iron is a required human nutrient. Therefore, it is unlikely there would be any adverse human health effects associated with exposure to the iron in groundwater.

The future residential land use scenario evaluated in this assessment is conservative, because it is unlikely that land use for AOC 6 will change to residential development in the future. Additionally, even if the site is used for residential development, it is unlikely shallow groundwater will be used as a potable water supply.

6 Ecological Risk Assessment

This section summarizes the results of the ERA conducted for the AOC 6 TNT Subareas. The complete ERA is contained in **Appendix J**.

6.1 Introduction

This ERA was conducted in accordance with the *Navy Policy for Conducting Ecological Risk Assessments* (CNO, 1999) and the Navy guidance for implementing this ERA policy (NAVFAC, 2003 and 2012). It considers data collected as part of previous evaluations of the AOC 6 TNT Subareas and data collected specifically for the RI. This ERA is completed through Step 3A of the 8-step ERA process (USEPA, 1997).

The previous ERA for the AOC 6 TNT Subareas was conducted as part of the recent SI report (CH2M HILL, 2012) and consisted of an ecological risk screening, constituting a Screening-level ERA (SERA) and an abbreviated version of Baseline ERA Step 3A. The results of the 2012 SI were used to develop the SAP for the RI (CH2M HILL, 2013). Additional surface soil, subsurface soil, and groundwater data were collected in 2013 to support the RI. The 2008 surface and subsurface soil data used in the SI were also included in this ERA. However, the 2008 groundwater data evaluated as part of the SI were not included in this ERA, since they were collected using DPT (the 2013 groundwater samples were collected from permanent monitoring wells).

6.2 Environmental Setting

The AOC 6 TNT Subareas, approximately 0.5 acre in size, are located near the southwestern bank of Penniman Lake (a large freshwater lake) and just north of King Creek (a tidal, estuarine water body) (**Figure 1-3**). They are composed of the remnants of the former TNT Graining House, its associated sump, and the ruins of the former TNT Catch Box. The Catch Box Ruins currently consist of an earthen, brick-lined depression located immediately east of the former TNT Graining House. The TNT Catch Box was used to separate TNT particles from wastewater associated with TNT Graining House processes. Only the concrete footprint of the former TNT Graining House currently exists on the site, as does a concrete-lined, open top pit believed to be the sump pit for the TNT Graining House. On September 19, 2013, the former TNT Graining House sump, located within the footprint of the TNT Graining House, was inspected. The concrete sump compartment measured 8 feet long, 2.5 feet wide, and 3.6 feet in depth, and contained about 2 feet of water above the bottom of the sump. Leaves, roots, and less than two inches of organic detritus, but not any residual material from former operations, were found on the bottom of the sump. Historical leaks and/or discharges from the former TNT Graining House sump and/or TNT Catch Box are the primary known/suspected sources of contamination at the AOC 6 TNT Subareas.

The AOC 6 TNT Subareas are currently wooded. Soils are somewhat acidic, with an average pH of 5.2 in surface soil and 5.4 in shallow subsurface soil. The results for TOC average just over 3 percent in surface soil, but less than 1 percent in shallow subsurface soil. Surface soil is comprised mainly of fine and medium sand, with about 10 to 20 percent silt/clay.

While the site does not contain any wetlands or water bodies, Penniman Lake is located approximately 50 feet east of the Catch Box Ruins, and King Creek is located about 100 feet south (across Garrison Road) of the remnants of the TNT Graining House (**Figure 1-3**). An earthern berm is present just north of the former TNT Graining House, rising about 15 feet above the surrounding grade. The topography on the remainder of the site is relatively flat but drops somewhat abruptly at the shoreline of Penniman Lake, and less abruptly south of Garrison Road toward King Creek (**Figure 3-1**). Surface runoff from the location of the former TNT Graining House and TNT Catch Box Ruins flows primarily east toward Penniman Lake. Due to the presence of Garrison Road, surface runoff from the locations of the former site structures is unlikely to reach King Creek. Groundwater (Columbia aquifer) was first encountered during RI sampling at a depth of about 5 to 8 feet bgs and flows primarily south toward King Creek (**Figure 3-5**) due to Penniman Lake surface water recharging groundwater during the RI. However, during low Penniman Lake water conditions (such as in times of drought), it is possible that the groundwater flow direction could reverse such that groundwater would potentially discharge into Penniman Lake.

Navy and DoD personnel have access to the AOC 6 TNT Subareas while pursuing recreational activities such as jogging, hunting, and fishing. Future land use at the AOC 6 TNT Subareas is not expected to change and will likely continue as recreational into the foreseeable future.

6.3 Analytical Data Used in the ERA

Both existing surface and shallow subsurface soil (from the 2012 SI), and surface soil, shallow subsurface soil, and groundwater samples collected as part of the RI (in 2013) were quantitatively evaluated in this ERA. Since ecological exposures are generally confined to the top two feet of the soil column, the soil data used in this ERA were confined to this depth range, but were evaluated separately as surface samples (0 to 6 inches) and shallow subsurface samples (6 to 24 inches); terrestrial food web exposures only considered the surface soil samples. The results from the two surface water samples collected from Penniman Lake (in 2008) for the SI were used to represent drinking water exposures in terrestrial food web models.

Although ecological receptors do not have direct exposure to groundwater, groundwater data collected as part of the RI were also evaluated in this ERA. This was done to provide a conservative evaluation of the potential for significant contaminant transport via groundwater to potential downgradient receiving water bodies (Penniman Lake and King Creek) and the subsequent potential exposure of ecological receptors in these water bodies. Only the groundwater data collected from permanent monitoring wells in 2013 for the RI were quantitatively evaluated in this ERA. The historical groundwater data used in the SI were not included, because they were direct-push samples.

The surface water and sediment data collected adjacent to the site (in Penniman Lake) and screened in the 2012 SI were not quantitatively evaluated in this ERA (except for the inclusion of the surface water data in the terrestrial food web models). Since Penniman Lake has now received a site designation (AOC 9), any further evaluation of surface water and sediment offshore of the AOC 6 TNT Subareas has been deferred to the Penniman Lake SI.

Background soil UTLs from the Yorktown-CAX background study (CH2M HILL, 2011) were also considered in the ERA. Because the background study does not contain background UTL values for the Columbia aquifer, two of the wells (CAA06-MW01 and CAA06-MW06; **Figure 2-1**) located upgradient of the AOC 6 TNT Subareas source areas were used to represent site-specific background conditions for groundwater. The remaining four wells were generally considered site wells.

6.4 Conceptual Site Model

The CSM relates potentially exposed receptor populations with potential source areas based on physical site characteristics and complete exposure pathways. Important components of the CSM are the identification of potential source areas, transport pathways, exposure media, exposure pathways and routes, and receptors. **Appendix J, Figure J-1** illustrates a diagrammatic CSM for the AOC 6 TNT Subareas. Key components of this CSM are discussed in **Appendix J. Appendix J, Table J-3** shows the assessment endpoints, risk hypotheses, and measurement endpoints used in the ERA and the receptors associated with each of these endpoints.

6.5 Results

6.5.1 Terrestrial Habitats

Ten assessment endpoints were developed for terrestrial habitats on the site (**Appendix J, Table J-3**). Lines of evidence for terrestrial habitats included:

- Comparison of surface soil and shallow subsurface soil concentrations with ESVs

- Comparison of modeled dietary doses with ingestion toxicity reference values
- Comparison of site soil concentrations with background concentrations

In surface soil, two inorganic constituents (lead and selenium) and five explosives (TNT, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 2-nitrotoluene, and 3,5-dinitroaniline) were identified as Step 3A COPCs for further risk evaluation. Lead was also identified as a Step 3A COPC for further risk evaluation for terrestrial food web exposures. The explosive TNT is the primary risk driver based on the magnitude of the ESV exceedances, but the extent of the exceedances is spatially limited. The highest TNT concentrations in surface soil occur in the composite sample from the former TNT Catch Box Ruins (CAA06-SO26-000H-0913). The other exceedances occur directly adjacent to the former TNT Catch Box Ruins to the east and south (samples CAA06-SS01-1008, CAA06-SS13-1108, and CAA06-SS36-0913) and in the vicinity of the former sump (samples CAA06-SS38-0913 and CAA06-SS02-1008). There were no detections of the other four explosive COPCs (which lacked ESVs) in any sample that did not also have an exceedance of the TNT ESV. Similarly, the two highest concentrations of lead in surface soil occurred in the two samples with the highest TNT concentrations. Thus, spatially limited risks associated with lead may occur for lower trophic level receptors. Although the 95 percent upper confidence level (UCL) concentration of lead in surface soil resulted in hazard quotients (HQs) in excess of 1 based on the Maximum Acceptable Toxicant Concentration for the shrew and mourning dove, there were no exceedances based on the mean concentration. Thus, given the very limited spatial area with elevated lead concentrations, potential risks for upper trophic level receptors from food web exposures are likely to be low. Selenium exceeded ESVs and background UTLs in only two surface soil samples and did not follow the spatial pattern of lead and TNT. The 95 percent UCL HQ was just over 1 (1.05). Thus, potential risks associated with selenium are low and do not appear to be site-related.

In summary, the primary risk drivers in surface soil are TNT and lead, but the locations with high concentrations are limited to the known source areas and/or the immediately adjacent areas.

In shallow subsurface soil, three inorganic constituents (hexavalent chromium, lead, and selenium) and five explosives (TNT, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 4-nitrotoluene, and 3,5-dinitroaniline) were identified as COPCs for further risk evaluation. The explosive TNT is the primary risk driver, based on the magnitude of the ESV exceedances, but, as with surface soil, the extent of the exceedances is spatially limited. The highest TNT concentrations in shallow subsurface soil occur in the composite sample from the former TNT Catch Box Ruins (CAA06-SO26-0H02-0913). The other exceedances occur directly adjacent to the former TNT Catch Box Ruins to the east and south (samples CAA06-SB01-1008, CAA06-SB13-1108, and CAA06-SB36-0H02-0913) and in the vicinity of the former sump (CAA06-SB38-0H02-0913). There were no detections of the other four explosive COPCs (which lacked ESVs) in any sample that did not also have an exceedance of the TNT ESV except for CAA06-SB03-1008, which had a low detection (28 µg/kg) of 1,3-dinitrobenzene. Similarly, the highest concentration of lead in shallow subsurface soil (and the only ESV exceedance) occurred in the sample with the highest TNT concentration. Thus, spatially limited risks associated with lead may occur for lower trophic level receptors. Selenium exceeded background UTLs in only three shallow subsurface soil samples and did not follow the spatial pattern of lead and TNT. While the 95 percent UCL HQ was over 1 (1.62), the mean HQ did not exceed 1 (0.92). Thus, potential risks associated with selenium are low and do not appear to be site-related. Although hexavalent chromium exceeded its ESV in a single sample, there were no ESV exceedances for total chromium and total chromium concentrations were at or below background levels. Thus, potential risks associated with chromium are not significant.

In summary, the primary risk drivers in shallow subsurface soil are TNT and lead, but, as with surface soil, the locations with high concentrations are limited to the known source areas and/or the immediately adjacent areas.

6.5.2 Aquatic Habitats

Potential aquatic exposures in Penniman Lake adjacent to the AOC 6 TNT Subareas will be evaluated as part of the Penniman Lake investigation. This ERA looked at the potential for off-site transport via groundwater to downgradient water bodies (Penniman Lake and King Creek). No chemical detected in site groundwater, except dissolved barium and dissolved iron, exceeded both its ESV and its background concentration. Dissolved iron exceeded its freshwater ESV (there was no marine ESV) by a factor of 27 based on the mean concentration. Thus, the mean HQ would exceed 1 even assuming a dilution factor of 10. The mean concentration of dissolved barium exceeded its freshwater (but not marine) ESV by a factor of less than 4. Thus, the mean HQ would be below 1 assuming a dilution factor of 10. However, the concentrations of dissolved barium and dissolved iron were not highly elevated relative to background concentrations, exceeding background in only 1 of the 4 site wells at maximum ratios of 1.73 and 1.23, respectively. The one background exceedance for barium was in CAA06-MW04, located south of Garrison Road near King Creek. King Creek is an estuarine water body and dissolved barium did not exceed its marine ESV. Thus, these two inorganic constituents do not appear to be site-related (neither one was a COPC in site soil) nor do they appear to be present at concentrations that would present a potential risk to aquatic receptors above background levels.

Cyanide also exceeded both its freshwater and marine ESV in one sample (CAA06-GW05-1013). The ESVs for cyanide are based on free (bioavailable) cyanide, not total cyanide, while the measured groundwater concentrations are for total cyanide. Only a small fraction of the total cyanide will be present in bioavailable forms. The mean HQ (undiluted) was slightly greater than 1 (1.04) based on the freshwater ESV and exceeded 1 (5.40) based on the marine ESV. Assuming a dilution factor of 10, the mean HQ is below 1 even if it is assumed that all of the cyanide is present in bioavailable forms. Cyanide was not a soil COPC and does not appear to be site related.

Based on the results of this evaluation, groundwater is not a significant transport medium for site-related constituents to Penniman Lake or King Creek, and site-related constituents that might reach these water bodies via groundwater would not pose an unacceptable risk to aquatic biota.

6.6 ERA Summary and Conclusions

In summary, the primary ecological risk drivers in surface and shallow subsurface soil are TNT and lead (**Appendix J, Table J-31**), but the locations with high concentrations are limited to the known source areas and/or the immediately adjacent areas. Based on the results of this evaluation, groundwater is not a significant transport medium for site-related constituents to Penniman Lake or King Creek, and site-related constituents that might reach these water bodies via groundwater would not pose an unacceptable risk to aquatic biota.

SECTION 7

7 Chemical Fate and Transport

This section discusses the fate and transport of soil and groundwater COCs identified from the HHRA and ERA (**Sections 5** and **6**, respectively) for the AOC 6 TNT Subareas. Surface water and sediment media were not evaluated since they are being assessed as part of the Penniman Lake SI. Fate and transport consists of the identification of theoretical chemical phases and migration and degradation pathways. An understanding of the mobility and persistence of a constituent in the subsurface is part of the overall assessment of the potential for that constituent to cause an adverse human health or environmental effect. As shown in **Table 7-1**, the COCs for the AOC 6 TNT Subareas include explosives and inorganic constituents in soil and inorganic constituents in groundwater. However, the concentrations of the inorganic constituent COCs in groundwater within the AOC 6 TNT Subareas were found to be attributable to naturally occurring background conditions.

Fate and transport characteristics for each group of COCs are described as follows. Chemical properties are listed in **Table 7-2**.

This section also presents and summarizes the overall CSM for the AOC 6 TNT Subareas, which was developed using the compendium of information and data presented in this RI report, including the fate and transport discussion in this section.

7.1 Chemical Mobility and Persistence

The mobility and persistence of the potential contaminants at the site are determined by their physical, chemical, and biological interaction with the environment. Mobility is the potential for a chemical to migrate from a site, and persistence is a measure of how long a chemical will remain in the environment. Because environmental conditions are an important factor, predicting contaminant behavior and migration can sometimes be difficult. Some of the mechanisms controlling mobility and persistence are described as follows.

7.1.1 Volatilization

Volatilization occurs when a compound transfers from the aqueous phase to the gas phase. Measures of a chemical's tendency to volatilize from water and soil include its vapor pressure and K_h. Compounds with K_h values higher than 10^{-3} atmospheres per cubic meter per mole (atm-m^3/M) are expected to volatilize readily from water to air, whereas those with K_h values lower than 10^{-5} atm-m^3/M are relatively non-volatile. Compounds with K_h values in between these values are expected to be moderately volatile. At a given temperature, the higher the vapor pressure of a compound, the higher the volatility of that compound.

Volatilization tends to occur more readily from shallow soil than from deeper soil or groundwater. In groundwater, volatilization can occur only at the air/water interface between the saturated and unsaturated zones, and movement of aqueous-phase contaminants from bulk groundwater to the interface is largely diffusion-limited. In unsaturated shallow soil, the soil gas pressure generally approximates the ambient air pressure. With depth, the soil gas pressure tends to increase, and it becomes more difficult for the gas to escape and equalize with the ambient air pressure.

Values of vapor pressure and K_h for the site COCs are provided in **Table 7-2**. The K_h values indicate that 2-nitrotoluene has moderate volatility, while TNT has very limited volatility. Due to the complexity of inorganic constituents and their variable forms in the environment, no K_h values can be provided for inorganic constituents. However, these constituents are typically not volatile under normal temperature and pressure conditions. Emissions to ambient air are usually in the form of particulates mobilized by wind.

7.1.2 Sorption

Sorption occurs when a constituent adheres to and becomes associated with solid particles in the geologic formation. The subsurface materials likely to sorb chemicals are clays and organic matter. Silty clay is present in the Yorktown confining unit. In addition, some inorganic constituents, such as arsenic species, can sorb to iron and oxyhydroxide or oxide coatings on soil and sediment grains.

The conventional measure of sorption is the distribution coefficient (K_d). The K_d for organic chemicals is the product of the soil organic carbon partition coefficient (K_{oc}) of the chemical and the fraction of organic carbon (f_{oc}) in the soil. Based on site-specific TOC data (**Table 4-2**), the f_{oc} content in AOC 6 subsurface soil is estimated at 0.006. In general, chemicals with a K_{oc} greater than 10,000 milliliters per gram (ml/g) have high degrees of adsorption and consequentially low mobility, whereas chemicals with a K_{oc} lower than 1,000 ml/g have lower degrees of adsorption and consequentially higher mobility. The explosive TNT has a moderate K_{oc} value, whereas 2-nitrotoluene has a low K_{oc} value. Sorption of TNT can increase with higher pH conditions and temperature (United States National Library of Medicine, 2011). It may also be slow to desorb.

The K_d for inorganic constituents is a complex function of pH, organic content, oxide coatings, and other factors; therefore, K_d is not easily estimated by methods other than site-specific testing. Due to the number of factors that impact the K_d values for inorganic constituents, these values range from 0.2 mL/g to 100,000 mL/g (**Table 7-2**). Generally, inorganic constituent adsorption increases with pH. Inorganic constituents most often sorb to clay minerals, organic matter, and iron and manganese oxyhydroxides. Inorganic constituents may be sorbed on the surface of the soil or fixed to the interior of the soil, where they are unavailable for release to groundwater. After available sorption sites are filled, most inorganic constituents are incorporated into the structures of major mineral precipitates as co-precipitates.

7.1.3 Solubility

Solubility is a measure of the degree to which a constituent will dissolve in water. Highly soluble chemicals are more likely to be leached from soil by precipitation or runoff that infiltrates into the subsurface. The two explosives (TNT and 2-nitrotoluene) have moderate water solubilities (**Table 7-2)**.

The solubilities of inorganic constituents are dependent on several factors and are, therefore, not included in **Table 7-2**. In general, solubility is highly dependent on the oxidation state of the inorganic constituent, which is dependent on subsurface conditions. The solubility of cations decreases as pH increases. Some cations may form complexes with oxygen and hydroxide, forming insoluble oxyhydroxides, or with phosphate, sulfate, and carbonate, forming insoluble mineral precipitates. Inorganic sulfide complexes, which form in reducing environments, are extremely insoluble and tend to reduce the total inorganic constituent concentrations (USEPA, 1979).

7.1.4 Bioaccumulation

Bioaccumulation is the extent to which a chemical will partition from water into the lipophilic parts (such as fat) of an organism. Bioaccumulation commonly is estimated by the octanol-water partition coefficient (K_{ow}). Chemicals with high values of K_{ow} tend to avoid the aqueous phase and remain in soil longer or bioaccumulate in the lipid tissue of exposed organisms. Accumulation of a chemical in the tissue of the organism can be quantified by a bioconcentration factor (BCF), which is the ratio of the concentration of the chemical in the tissue to the concentration in the water. The BCFs are both contaminant-specific and species-specific.

Table 7-2 lists some bioaccumulation values for the COCs. The explosive 2-nitrotoluene had the highest value. Bioaccumulation values for the other explosives were an order of magnitude lower. It is assumed that for an inorganic constituent to be taken up by a plant or to exert an effect on plant growth, it must be present in solution. Therefore, factors that influence the speciation and solubility of inorganic constituents in soil also affect bioconcentration. The pH of soil can also affect the amount of plant uptake of certain elements.

7.1.5 Transformation

Transformation occurs when the valence state of inorganic constituents is increased (oxidation) or decreased (reduction). It can be caused by changes in oxidation potential and/or pH and by microbial or non-microbial (abiotic) processes. Transformation may have a significant effect on the mobility of an inorganic constituent, either increasing or decreasing it.

The solid form of iron (iron hydroxides) is usually present in the natural soil matrix. If sufficient amounts of oxygen and nitrate are not present in the subsurface, iron hydroxides will be used as electron acceptors by metabolic activity and reductively dissolve into soluble forms. Sulfides present in groundwater can also reductively dissolve iron hydroxides. Several inorganic constituents (such as, arsenic) have a tendency to sorb to iron hydroxides. If these compounds are reductively dissolved, then the inorganic constituents that are bound to these hydroxides and oxides will also be released.

In oxidizing environments, arsenic and chromium primarily exist as oxyanions (hard anions that contain oxygen) and are relatively mobile. They can be adsorbed by clays, iron hydroxides, aluminum hydroxides, manganese compounds, and organic material at acidic and neutral pHs. Arsenic and chromium can be reduced from higher to lower valance states by organic matter, divalent inorganic constituents, and dissolved sulfide. Under reducing conditions, insoluble arsenic sulfides are precipitated in the presence of sulfides. Chromium will form insoluble chromium hydroxide or be sorbed by manganese oxides.

Lead forms insoluble inorganic sulfides in anaerobic environments. It tends to sorb and will be transported in water primarily with suspended colloidal particles (Eastern Research Group, 2003). Lead is relatively immobile in all matrices due to its strong tendency to be sorbed by iron and manganese oxides and the insolubility of many lead minerals.

7.1.6 Degradation

Degradation is the deterioration or destruction of a chemical either biologically (biodegradation) or abiotically through such processes as hydrolysis and photolysis. Biodegradation of chemicals by microbial organisms occurs through metabolic or enzymatic processes. Hydrolysis is the reaction of a chemical with water and photolysis is the result of exposing the chemical to light. The rate of degradation is dependent on the existing chemical, biological, and physical conditions of the medium in which the contaminant is located.

Two explosives have been identified as COCs at the AOC 6 TNT Subareas (TNT and 2-nitrotoluene). The explosive TNT can be aerobically biodegraded or anaerobically reduced by hydrogen, and it can also be co-metabolized. Nevertheless, degradation processes in soil can be slow and very high concentrations may be toxic to microorganisms. Anaerobic reduction would be expected to have the fastest degradation rate and result in several degradation products, including 2-amino and 4-amino DNT and azoxydimers. Another consideration is TNT is also subject to abiotic photolysis, where trinitrobenzene and trinitrobenzaldehyde are possible photolytic degradation products. 2-Nitrotoluene can be biodegraded via aerobic and anaerobic processes. The biodegradation of 2-nitrotoluene is very slow in unacclimated soil environments. 2-Nitrotoluene can potentially degrade via abiotic photolysis; however, it is not likely to undergo hydrolysis in the natural environment (United States National Library of Medicine, 2011).

7.1.7 Natural Attenuation Evaluation

Geochemical and general water quality parameters were measured during the RI to help evaluate natural attenuation processes in groundwater. The COCs identified in groundwater at the AOC 6 TNT Subareas include two inorganic constituents: arsenic and iron. However, the concentrations of these constituents were found to be attributable to naturally occurring background conditions.

Natural attenuation includes a variety of physical, chemical, or biological processes that under favorable conditions act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These processes consist of biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants.

Geochemical data are provided in **Tables 2-3** and **4-3** and can be used to assess the potential speciation of inorganic constituents. Physical attenuation processes can also be important. Sorption was discussed in **Section 7.1.2** while volatilization was discussed **in Section 7.1.1**.

In the Columbia aquifer, groundwater is under slightly anaerobic and more reducing conditions. The DO concentrations were typically measured below 0.5 mg/L. In the lateral cross/upgradient well (CAA06-MW01), the ORP value was measured at -53 mV. The ORP values were measured below -100 mV in the remainder of site monitoring wells, including monitoring wells CAA06-MW02 and CAA06–MW06, which are also located cross gradient of the former TNT Graining House and Catch Box Ruins, meaning they are not located downgradient of the source areas. In fact, groundwater from CAA06–MW06 had the most negative ORP value of all the monitoring wells present at the site. Monitoring well CAA06-MW04, which is located in the downgradient portion of the site, had the second lowest measured ORP value. Consistent with these low ORP values, groundwater from monitoring wells CAA06-MW04 and CAA06–MW06 also had the strongest geochemical indicators for biological reactions that proceed under more reduced conditions, thus, higher ferrous iron concentrations (iron reduction) and methane concentrations (methanogenesis). Sulfate concentrations in groundwater were also observed to be lower in downgradient monitoring wells, which may be indicative of sulfate reduction. The pH values were relatively neutral (greater than 6) across the aquifer.

The more reducing conditions observed in the Columbia aquifer at the AOC 6 TNT Subareas can impact inorganic constituent concentrations. Under these conditions, the solid forms of iron (iron hydroxides) and manganese (manganese oxides), which are usually present in the natural soil matrix, can reductively dissolve into soluble forms. Any inorganic constituents (such as, arsenic) that may be naturally bound to these hydroxides will also be released to groundwater. At the AOC 6 TNT Subareas, total and dissolved arsenic and iron concentrations were higher in monitoring wells with ORP values less than -100 mV in comparison to CAA06-MW01 (-53 mV).

7.2 Contaminant Migration

The following subsections present a generalized description of theoretical contaminant flow pathways at the AOC 6 TNT Subareas that may have resulted in the distribution of contaminants. Potential exposure and receptor pathways were discussed in Sections 5 and 6.

7.2.1 Unsaturated Zone Migration

Contaminants released to surface soil may have migrated vertically into subsurface soil through gravitational force or leaching from infiltration. Additionally, the former TNT Graining House sump was located bgs in a concrete pit. If there were cracks within the pit, a release may have been made directly to subsurface soil. The concrete foundation of the former TNT Graining House still exists at the site and should prevent infiltration where it is competent. Otherwise, the AOC 6 TNT Subareas are wooded and moderately vegetated with shrubs, providing limited to no restriction for infiltration. However, the vegetation should limit wind erosion and volatilization, which could release contaminants in surface soil to the atmosphere. The vegetation may also limit surface soil transport via surface runoff during storm events. Once in the unsaturated zone, contaminants may have sorbed to soil or organic matter, become trapped in residual pore spaces, or continued to leach and be transported to the saturated zone.

Only two explosives (TNT and 2-nitrotoluene) were identified as COCs in surface and subsurface soil at the site. The explosive TNT has a low mobility in soil based on its moderate sorption potential, slow desorption, and low volatility, while 2-nitrotoluene is considered to be more mobile in soil with its low sorption potential and moderate solubility. Because 2-nitrotoluene has moderate volatility, it may volatilize into the atmosphere and soil gas. The explosives are subject to aerobic and anaerobic biodegradation; however, anaerobic biodegradation may be faster. Therefore, biodegradation of these constituents may be slow in surface soil, which is considered to be aerobic due to its proximity to the atmosphere. If exposed to direct sunlight, contaminants in surface soil would be subject to abiotic photolysis.

Only three inorganic constituents were identified as either human health or ecological COCs in soil at the site. This includes lead (ecological COC) in surface soil and arsenic and hexavalent chromium (human health COCs) in combined surface/subsurface soil. The mobility of inorganic constituents in the unsaturated zone is highly dependent on the subsurface conditions. Assuming that the soil at the AOC 6 TNT Subareas exists under more oxidizing conditions, arsenic and chromium are typically present in forms that are more mobile. However, these inorganic constituents, along with lead, will potentially sorb or complex with clays, organic material, iron hydroxides, or manganese oxides, limiting their mobility. Only a small fraction of lead in soil will be in a water-soluble form.

7.2.2 Saturated Zone Migration

Iron and arsenic are the only COCs identified in groundwater at the AOC 6 TNT Subareas. Contaminants can enter groundwater by leaching through unsaturated zone soil. However, elevated concentrations of these inorganic constituents are likely the result of reductive dissolution of the naturally occurring mineralogy in the subsurface. Dissolved contaminants can be transported in groundwater through advection and dispersion. Advection is the primary transport mechanism and includes the transport of dissolved contaminants by the bulk motion of flowing groundwater. Dispersion is the spreading of dissolved contaminants from the path they would be expected to follow during advection due to the spatial variation in aquifer permeability, fluid mixing, and molecular diffusion.

At the AOC 6 TNT Subareas, groundwater in the Columbia aquifer has an overall flow direction of south-southwest towards King Creek. The estimated horizontal groundwater velocity of 0.022 ft/day at the site is relatively slow. Although no vertical hydraulic gradient data are available, the Penniman Lake surface water elevation measured during the August 2014 gauging event was over 1.5 feet higher than groundwater elevations measured at the site. This indicates that Penniman Lake is recharging the surficial aquifer at the AOC 6 TNT Subareas. It is possible that there may be times when groundwater discharges into the surface water body (such as, in times of drought).

Contaminants typically will not move as rapidly as groundwater because of retardation or the adsorption of the contaminant to the solid media. The advective migration rates of different dissolved contaminants vary depending on the K_d and the rate of groundwater flow. For each contaminant detected at the site, it is theoretically possible to calculate a retardation coefficient, which is an estimate of the degree to which the contaminant is slowed by adsorption in relation to the groundwater flow velocity. The retardation coefficient is calculated according to the following equation:

$$R = 1 + p_b \text{ x } K_d/n_e$$

Where :

R = Retardation coefficient (dimensionless)
p_b = Bulk density (grams per cubic centimeter [g/cm^3])
K_d = Distribution coefficient (ml/g)
n_e = effective porosity (dimensionless)

Assuming a bulk density of 1.5 g/cm^3 and an effective porosity of 0.3, the estimated retardation coefficients are listed in **Table 7-2**. Retardation coefficients for inorganic constituents are variable depending on the form of the chemical in the subsurface and may range from 8 to 100,000 for arsenic and iron. The effect of retardation is estimated by dividing the groundwater flow velocity by R, which provides a value of migration that is either equal to (in the case of no retardation) or less than (in the presence of retardation) the groundwater flow velocity (**Table 7-2**).

Transport and partitioning of inorganic constituents in water is dependent on the oxidation state of the constituent and on interactions with other materials present. Under the more reducing conditions generally observed in the Columbia aquifer at the site, iron will be transformed into its more soluble form. Any inorganic constituent (such as, arsenic) that may be naturally bound to iron hydroxides and manganese oxides can also become more mobile. If sulfides are present in groundwater, arsenic may co-precipitate.

7.3 Conceptual Site Model Summary

This subsection summarizes the CSM for the AOC 6 TNT Subareas, which qualitatively combines and interprets site-specific physical characteristics (such as, hydrogeology), contaminant sources, nature and extent of contamination, potential migration of the contaminants, and the potential exposure and receptor pathways. **Figure 7-1** provides a graphical depiction of the CSM and supports the discussion in this section. The CSM is a living document used to support potential risk management decisions and aid in defining the effectiveness of potential remedial alternatives, if needed.

7.3.1 Physical Characteristics

The AOC 6 TNT Subareas are a 0.5-acre section of CAX, which includes the former TNT Graining House Sump and TNT Catch Box Ruins. The concrete foundation of the former TNT Graining House still exists and also includes three separate pits, or vaults, below the level of the foundation. This area is surrounded by an earthen berm. The depression for the former TNT Catch Box Ruins is located to the east of the concrete foundation; however, bricks, which supposedly lined the depression, were not observed during the most recent site visits. Penniman Lake is located to the north and east of the site and Garrison Road and King Creek are located to the south of the site. Garrison Road is a topographic high point (**Figure 1-3**) and the ground topography slopes away from the road on both sides with a steeply decreasing grade towards the shoreline of Penniman Lake. Therefore, overland flow during storm events is likely directed towards the lake. Other than the concrete foundation, the AOC 6 TNT Subareas are wooded and moderately vegetated with shrubs, providing limited restriction for infiltration to the subsurface. Garrison Road is gravel-covered.

At the AOC 6 TNT Subareas, the subsurface lithology consists primarily of silty sand, which is underlain by a fat clay. A silty, sandy clay layer is observed within the silty sand. The TOC content is considered to be moderate, with an average f_{oc} of 0.006 in subsurface soil, and could facilitate sorption of some constituents.

The groundwater aquifer of interest is the shallow, unconfined Columbia aquifer, which is underlain by the Yorktown confining unit. The depth to groundwater ranges between 5 and 8 feet bgs. Groundwater in the Columbia aquifer generally flows to the south-southwest towards King Creek at an estimated groundwater velocity of 0.022 ft/day (8 feet per year). During the August 2014 groundwater gauging event, the surface water elevation of Penniman Lake was higher than groundwater elevations beneath the AOC 6 TNT Subareas. This suggests that the lake is recharging the shallow aquifer in this area of CAX, resulting in a groundwater flow direction away from the lake. However, during low Penniman Lake surface water conditions (such as, in times of drought), it is possible that the groundwater flow direction could reverse such that groundwater would potentially discharge into the lake.

7.3.2 Potential Sources of Contamination and Migration Pathways

The sources of contamination at the AOC 6 TNT Subareas are considered to be potential historical leakage or discharge from the former TNT Graining House Sump and/or TNT Catch Box Ruins. The former TNT Catch Box Ruins were used to separate TNT particles from wastewater. The primary potential migration pathways of COCs in the site media are:

- Leaching of contaminants from impacted surface soil into subsurface soil
- Dissolved contaminant migration in the Columbia aquifer with groundwater flow (via advection and dispersion)

Less prominent fate and transport mechanisms which may be active at the AOC 6 TNT Subareas include volatilization of surface soil contaminants into the atmosphere, stormwater runoff of surface soil contaminants towards Penniman Lake, and leaching of contaminants from subsurface soil into groundwater.

7.3.3 Distribution and Transport of COCs

Two explosives (TNT and 2-nitrotoluene) were identified as COCs in surface and subsurface soil at the site. In surface soil and subsurface soil, the highest concentrations of TNT were observed in samples collected within the former TNT Catch Box Ruins. Elevated concentrations were also detected in soil to the north/northeast of the former TNT Catch Box Ruins and to the southeast of the former TNT Graining House. Concentrations of explosives were observed to decrease sharply over a horizontal distance. For example, there were no detections of explosives in surface soil sample CAA06-S229-0913, even though it is only 20 feet from surface soil samples CAA06-SS13-1108 (TNT: 51,000 μg/kg) and CAA06-SS01-1008 (TNT: 4,500,000 μg/kg). In general, concentrations of TNT were lower in subsurface soil in comparison to co-located surface soil. The only exception to this was observed at sample location CAA06-SO13, located outside the northern edge of the former TNT Catch Box Ruins; subsurface soil concentrations were an order of magnitude higher than surface soil concentrations. The highest concentrations of 2-nitrotolune were detected at the southeast corner of the former TNT Graining House. However, 2-nitrotolune was not detected in subsurface soil. The TNT constituent is considered to have low mobility in soil, while 2-nitrotoluene is considered to be more mobile. However, no explosives have been detected in groundwater. Therefore, these contaminants are not leaching to groundwater.

Inorganic constituents were identified as COCs in soil and groundwater. The mobility of inorganic constituents is highly dependent on the subsurface conditions, which influences the oxidation state of the inorganic constituent and interactions with other materials present. At the AOC 6 TNT Subareas, pH values in soil are slightly acidic (surface soil is pH is typically below 5.5 and subsurface soil pH is typically below 6.0). The ORP levels and DO concentrations in groundwater suggest a more reducing environment.

- Lead was identified as a COC in surface soil. The highest surface soil concentrations were observed at the former TNT Catch Box Ruins. Concentrations in sample CAA06-SO26-000H-0913 (1,100 mg/kg) were two orders of magnitude higher than the background concentration of 17.4 mg/kg. Elevated concentrations of lead were also observed to the southeast of the former TNT Graining House and just north of the former TNT Catch Box Ruins. Lead is relatively immobile in soil due to its strong tendency to be sorbed by iron and manganese oxides and the insolubility of many lead minerals. As a result, subsurface soil concentrations were an order of magnitude lower than the co-located surface soil samples.
- Hexavalent chromium was identified as a COC in combined surface/subsurface soil. However, there was only one surface soil sample (CAA06-SS03-1008) with a total chromium concentration (34.7 mg/kg) greater than the background value of 18.2 mg/kg. In subsurface soil, two samples were analyzed for hexavalent chromium (CAA06-SS26-0913 and CAA06-SS27-0913). Although the total chromium concentration in each of these subsurface soil samples was below the background value of 33.7 mg/kg, the hexavalent chromium concentration in sample CAA06-SS27-0913 was reported above its residential RSL and ESV. Total chromium subsurface soil concentrations were similar to, or slightly higher than, the co-located surface soil concentrations. While chromium may be more mobile under oxidizing conditions, it readily complexes with clays, organic material, iron hydroxides, or manganese oxides, limiting its mobility.
- Arsenic was identified as a COC in combined surface/subsurface soil. Arsenic was detected at its highest concentrations in surface soil located just south of the former TNT Graining House Sump and in subsurface soil located at the former TNT Catch Box Ruins. Arsenic concentrations in surface soil were generally similar to, or slightly lower than, subsurface soil concentrations. As with chromium, arsenic may be more mobile under oxidizing conditions; however, it readily complexes with clays, organic material, iron hydroxides, or manganese oxides, limiting its mobility.
- Arsenic and iron were identified as a COCs in groundwater. However, elevated arsenic and iron concentrations are attributed to naturally occurring background conditions reflective of the natural reductive dissolution process rather than the result of a CERCLA release. Arsenic, which is typically bound to iron hydroxides and manganese oxides, can be released into groundwater under reducing conditions as iron and manganese are transformed into forms that are more mobile. Monitoring wells CAA06-MW01, -MW02, -MW06 are located upgradient or sidegradient of the suspected release areas

(former TNT Graining House and TNT Catch Box Ruins) and in areas with soil concentrations below the background UTLs. Therefore, groundwater from these wells is considered to be representative of the range of background concentrations present in this area of CAX. Both arsenic and iron concentrations in monitoring wells located adjacent to or downgradient of the suspected release areas were all below the ranges of representative background values.

7.3.4 Risk Receptors

Future land use at the AOC 6 TNT Subareas is not expected to change and will likely continue as wooded/recreational in the foreseeable future. Groundwater at CAX is not a current or anticipated source of potable drinking water. However, groundwater at CAX is considered to be of potential beneficial use under Commonwealth of Virginia regulations.

The only current human receptors at the site are base workers and adult and child recreational users. There are unacceptable human health risks to all current receptors and future receptors (current receptors, construction workers, and residents) from potential exposure to contaminants in soil and groundwater. There are unacceptable risks to ecological receptors from exposure to surface soil and subsurface soil.

SECTION 8

8 Conclusions and Recommendations

This section summarizes the major conclusions of the RI for the AOC 6 TNT Subareas, which are based on the findings and results presented and evaluated in earlier sections of this report. It also presents a recommended path forward to address potentially unacceptable risks to human health or the environment from site-related COCs at the AOC 6 TNT Subareas.

The objectives of the RI have been achieved – data gaps have been filled, the nature and extent of contamination have been sufficiently defined, the CSM has been updated to reflect the compilation of data from all investigation activities to date, and human health and ecological risks have been assessed.

8.1 Conclusions

The HHRA and ERA presented herein identified the following COCs:

Risk Component	Medium		
	Surface Soil	Subsurface Soil	Groundwater
Human Health	TNT, 2-nitrotoluene, arsenic, ~~and~~ hexavalent chromium, and lead*	TNT, 2-nitrotoluene, arsenic, and hexavalent chromium	Arsenic and iron
Ecological	TNT and lead	TNT and lead	No unacceptable risks to aquatic biota identified

*Unlike the other listed COCs lead is not a COC when evaluating exposure to lead in soil across the full site; however, if only exposed to soil within the Catch Box Ruins, lead is a COC for Catch Box Ruins surface soil and combined surface and subsurface soil.

Although arsenic and iron were identified as groundwater COCs based on their conservative inclusion in the HHRA for evaluation, the concentrations of arsenic and iron found in groundwater during the RI at the AOC 6 TNT Subareas were attributable to naturally occurring background conditions and not the result of site-related contamination.

8.1.1 Soil

The human health COC 2-nitrotoluene was only detected in one of the thirty-nine soil samples; therefore, this concentration was used as the exposure point concentration, and the risks associated with exposure to 2-nitrotoluene across the site are likely over-estimated.

For the remaining COCs in soil, the concentrations of TNT, hexavalent chromium, arsenic, and lead exceeding screening criteria are shown on **Figure 8-1**.

No explosives were detected in groundwater during the SI; therefore, these contaminants are not leaching from the soil to groundwater.

8.1.2 Groundwater

Arsenic and iron were identified as COCs in groundwater in the HHRA. However, elevated arsenic and iron concentrations are attributed to naturally occurring background conditions reflective of the natural reductive dissolution process rather than the result of a CERCLA release. Monitoring wells located upgradient or sidegradient of the suspected release areas and in areas with soil concentrations below the background UTLs had arsenic and iron concentrations higher than monitoring wells downgradient of the release areas. Therefore, groundwater from these reference wells is considered to be representative of the range of background concentrations present in this area of CAX. Both arsenic and iron concentrations in monitoring wells located adjacent to or downgradient of the suspected release areas were all below the ranges of representative background values.

With regard to ecological risk, groundwater would not pose an unacceptable risk to aquatic biota.

8.2 Recommendations

The following recommendations are proposed for the AOC 6 TNT Subareas:

1. Prepare an FFS to develop and evaluate remedial alternatives to address potentially unacceptable human health or ecological risks associated with TNT and lead in soil at the AOC 6 TNT Subareas. Since the size of the AOC 6 TNT Subareas is relatively small (approximately 0.5 acre) and the approximate boundaries of the TNT and lead contamination in soil are defined, an FFS would allow for a more efficient evaluation of several potential remedial alternatives.

   No further action is recommended for arsenic and hexavalent chromium. The arsenic concentrations are within the range of soil background 95% UTLs (CH2M HILL, 2011), as shown on **Figure 8-1**. Hexavalent chromium was not detected in surface soil, and in subsurface soil, the risk to a residential receptor would fall within the acceptable risk range for this constituent, as discussed in Section 5.3.

2. Since there was only one detection of the human health COC 2-nitrotoluene, the risks associated with exposure to it across the site are likely over-estimated, and since this one detection is within the approximate distribution of TNT contamination south of the former TNT Graining House Sump, it would be addressed as part of the FFS remedial alternatives associated with TNT in this area, such that no further action with respect to 2-nitrotoluene is warranted.

3. No further action is recommended for groundwater since the groundwater data evaluated during this RI indicate that the concentrations of arsenic and iron in groundwater are likely attributable to naturally occurring background conditions and not from historical leakage or discharge from the former TNT Graining House Sump and/or TNT Catch Box Ruins.

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Appendix A
Soil Boring and Monitoring Well Construction Logs

Appendix B
Survey Reports

Appendix C
IDW Analytical Data

Appendix D
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APPENDIX H

Baseline Human Health Risk Assessment

H.1 Introduction

Appendix H presents the baseline human health risk assessment (HHRA) for CAX Area of Concern (AOC) 6 TNT Subareas. The HHRA was conducted to assess the nature, magnitude, and probability of potential harm to public health posed by exposure to site-related constituents in soil and groundwater at AOC 6. The data evaluated in the HHRA are discussed in Section 5 of the Remedial Investigation (RI) report. The HHRA incorporates the general methodology described in the following U.S. Environmental Protection Agency (USEPA) documents:

- Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part A (USEPA, 1989)
- Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part D (USEPA, 2001)
- Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) (USEPA, 2004)
- USEPA Region III Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening (USEPA, 1993)

The HHRA consists of the following components:

- Human Health Conceptual Site Model
- Identification of chemicals of potential concern (COPCs)
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Uncertainty Assessment

These components are described in the following sections. Risk calculation spreadsheets for AOC 6 were prepared in accordance with *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part D* (USEPA, 2001) to screen for COPCs and to calculate risks estimates associated with the COPCs. These spreadsheets are presented in Appendix I.

H.2 Human Health Conceptual Site Model

The human health conceptual site model (CSM) showing potential human health exposure scenarios for current and potential future site use is provided in Table 1 of Appendix I and graphically on Figure H-1. The CSM provides a current understanding of the source(s) of contamination, release and transport mechanisms, current and potential future land use, and identifies potentially complete human exposure pathways for AOC 6.

The history of the AOC 6 TNT subareas is unknown. The subareas were originally identified as potential waste sources through a review of historical aerial photographs, engineering drawings, and site reconnaissance visits (Weston, 1999). Potential historical leakage or discharge from the former TNT Graining House sump and/or TNT Catch Boxes are the primary known and suspected sources of contamination at the AOC 6 TNT subareas.

The primary release mechanisms transporting the COPCs from the source, through environmental media, and to potential receptors are:

- Direct release of waste constituents to downgradient surface soil
- Leaching of chemicals or metals from surface soil to subsurface soil and subsequently to groundwater via infiltrating precipitation
- Surface runoff from source areas to downgradient surface soil, surface water, and sediment (surface water and sediment are not evaluated in this HHRA, but as part of the Penniman Lake RI)

- Future household use of groundwater from wells

The AOC 6 TNT subareas are wooded and moderately vegetated with shrubs. The subareas are located within the confines of CAX and access is restricted to the general public. Navy and DoD personnel have access to the AOC 6 TNT subareas and they are currently used by Navy and DoD personnel for recreational activities such as jogging, hunting, and fishing. Therefore, there is the potential for base workers and adult/child recreational users (Navy and DoD personnel and their families) to access the site. The current receptors could be exposed to surface soil through incidental ingestion, dermal contact, and inhalation of volatile and/or particulate emissions.

Although there are no plans for future site development, future site use is unknown. Therefore, potential future human receptors include the current receptors, and if the investigation area is developed for future use, future residents or construction workers. Future receptors could be exposed to surface and subsurface soil if future development activities occur at the investigation area, such as construction of future residential housing or industrial buildings, or piping and utility work, and the soil is re-worked, bringing subsurface soil to the surface. Exposure routes for the future exposure to soil are the same as those for current exposure to surface soil.

Although groundwater beneath the site is not currently used as a potable water supply, it was conservatively assumed that groundwater could be used as a future residential or industrial potable water supply. Additionally, due to the relatively shallow range of depths to groundwater (from about 6 feet below ground surface and deeper), it was assumed that construction workers could be exposed to groundwater during future excavation activities.

Since historic site use is not associated with significant volatile organic compound (VOC) contamination, and volatile constituents were not found to be potential constituents of concern during previous investigations, VOCs were not included in groundwater analysis. Therefore, the groundwater to air pathway is not considered a complete exposure pathway.

H.3 Identification of COPCs

The identification of COPCs includes data collection, evaluation, and screening to identify those chemicals which contribute the most to the total risk estimates associated with the site. The data collection and evaluation involve gathering and reviewing the available site data and identifying a set of data for the risk assessment that meets project-specific data quality objectives. Once compiled, the data set is screened against concentrations that are protective of human health to focus the risk assessment efforts on the constituents and media of potential concern for human receptors.

H.3.1 Data Summary

All data used in the risk assessment were fully validated and are assumed to represent current conditions. Table H-1, presented at the end of this HHRA, lists the samples evaluated by the HHRA and the analytes for each sample. Soil samples collected in October 2008, November 2008, and September 2013 and groundwater samples collected in October 2013 were included in the risk assessment. Groundwater samples were analyzed for both total and dissolved metals. The total and dissolved concentrations of aluminum, iron, and manganese were compared for each monitoring well to note if there were significant differences (over an order of magnitude) between the two in any of the wells, following USEPA guidance (USEPA, 1992). Because no significant differences were noted between total and dissolved concentrations of these indicator metals in any of the wells, the total metals data were used to evaluate risks associated with potable use of groundwater. The total metals data were also used for the construction worker exposure to groundwater because the construction worker would be exposed to the groundwater directly in the ground (in an excavation). Groundwater samples collected using direct push sampling techniques (DPT) in November 2008 were not evaluated in the risk assessment. Groundwater samples collected using DPT sampling methodology are not typically used for HHRA due to the higher suspended solids and particulates in groundwater samples collected using DPT.

The data collected during site investigations were evaluated to assess their reliability for use in the quantitative risk assessments. The following criteria were used to assess data usability based on past discussions with USEPA and the Navy:

- Estimated values flagged with a J, K, or L were treated as unqualified detected concentrations.
- Data qualified with an R (rejected) were not used in the risk assessment.
- Data qualified with a B (blank contamination) were used in the risk assessment as if the results were non-detects, with the blank-related concentrations of each constituent used as the sample detection limit.
- For duplicate samples, the maximum concentration between the two samples was used as the sample concentration.
- Non-detected values were included in the risk assessment and exposure point concentration (EPC) calculations at the detection limit using ProUCL (USEPA, 2013a).

Detailed results for sampling that was performed at AOC 6 are presented in Section 2 of the RI report.

H.3.2 Selection of COPCs

The selection of COPCs was based on the criteria presented in the USEPA Region III technical guidance manual (USEPA, 1993) and *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part D* (USEPA, 2001). The maximum detected concentration of each constituent for each medium was compared to the criteria discussed below to select the COPCs. If the maximum concentration exceeded the criteria, the constituent was selected as a COPC. Constituents that were not detected in any of the samples or were detected at concentrations less than the criteria were not identified as COPCs. The following screening criteria were used in the HHRA, as presented in Tables 2.1 through 2.5 in Appendix I:

- **Comparison with Health-based Criteria for Soil:** Soil data were compared to the USEPA residential soil regional screening levels (RSLs) (USEPA, 2014a). RSLs based on noncarcinogenic effects were based on a hazard quotient of 0.1 to account for exposure to multiple constituents with the same target organ or target effect. RSLs based on carcinogenic effects were based on a $1x10^{-6}$ carcinogenic risk as presented in the RSL table. Lead concentrations were compared to the USEPA residential child soil screening value of 400 milligrams per kilogram (mg/kg) (USEPA, 1994a). Soil data were also compared to generic USEPA risk-based soil screening levels (SSLs) for protection of groundwater (noncarcinogenic effects based on a hazard quotient of 0.1, as was done for RSLs). SSLs were not used to identify COPCs but are discussed in Section H.6 as an indication of potential leaching from soil to groundwater at levels of potential concern.
- **Comparison with Health-based Criteria for Soil–to-air Pathway:** The maximum detected concentrations in soil were used to model the maximum ambient air concentrations. Volatile and fugitive emissions from soil were estimated using the volatilization factor (VF) and particulate emission factor (PEF) approach presented in USEPA's soil screening guidance (USEPA, 1996). The modeled air concentrations were compared to USEPA RSLs for ambient air (USEPA, 2014a). RSLs based on noncarcinogenic effects were based on a hazard quotient of 0.1 to account for exposure to multiple constituents. RSLs based on carcinogenic effects were based on a carcinogenic risk of $1x10^{-6}$ as presented in the RSL table.
- **Comparison with Health-based Criteria for Groundwater:** Groundwater data were compared to the USEPA RSLs for tap water (USEPA, 2014a). RSLs that are based on noncarcinogenic effects were based on a hazard quotient of 0.1 to account for exposure to multiple constituents. RSLs based on carcinogenic effects were based on a carcinogenic risk of $1x10^{-6}$ as presented in the RSL table. Lead concentrations in groundwater were compared to the federal action level of 15 micrograms per liter (μg/L) (USEPA, 2009a).
- **Essential Human Nutrients:** Constituents that are considered essential nutrients and are toxic only at very high doses were eliminated from the quantitative risk analysis. These constituents are calcium, magnesium, potassium, and sodium. Although iron and manganese are also considered essential nutrients and are only toxic at very high doses, they were included in the HHRA because toxicity values are available for these two nutrients.
- **Comparison to Background Concentrations**: Background concentrations were not used to identify/eliminate any of the COPCs. However, background concentrations are included in the screening tables, if available, and

are discussed in the risk characterization, if applicable (i.e., constituents resulting in risks above target risk levels may be associated with background conditions). Background concentrations for surface soil are the 95 percent upper tolerance level (95% UTL) from the CAX/Yorktown background surface soil samples and background concentrations for the combined surface and subsurface soil are the lower of the 95% UTL from the CAX/Yorktown background surface soil samples and subsurface soil samples (CH2M HILL, 2012). Background values for the groundwater are the groundwater concentrations in the two site-specific upgradient monitoring wells, CAA06-MW01 and CAA06-MW06.

Four of the soil samples (two surface soil and two subsurface soil) collected in September 2013 included analysis for both total and hexavalent chomium. Because hexavalent chromium data were available, the hexavalent chromium concentrations in soil were screened using hexavalent chromium RSLs and the total chromium concentrations in soil were screened using trivalent chromium RSLs. The uncertainties associated with this screening approach are discussed in Section H.7. Groundwater samples were not collected for hexavalent chromium analysis; however, none of the six groundwater samples had detections of chromium.

H.3.3 COPCs

Table H-2, presented at the end of this HHRA, lists the constituents identified as COPCs for each medium, as summarized below.

Surface Soil:

- One semivolatile organic compound (SVOC) (2,4-dinitrotoluene)
- Five explosives (1,3-dinitrobenzene, 2,4,6-trinitrotoluene, 2-amino-4,6-dinitrotoluene, 2-nitrotoluene, and 4-amino-2,6-dinitrotoluene)
- Seven metals (aluminum, arsenic, cobalt, iron, lead, thallium, and vanadium)
- No COPCs were identified for particulate or volatile emissions from surface soil to air

Surface and Subsurface Soil:

- One SVOC (2,4-dinitrotoluene)
- Five explosives (1,3-dinitrobenzene, 2,4,6-trinitrotoluene, 2-amino-4,6-dinitrotoluene, 2-nitrotoluene, and 4-amino-2,6-dinitrotoluene)
- Eight metals (aluminum, arsenic, hexavalent chromium, cobalt, iron, lead, thallium, and vanadium)
- No COPCs were identified for particulate or volatile emissions from surface and subsurface soil to air

Groundwater:

- Five total metals (arsenic, cobalt, cyanide, iron, and manganese)

H.4 Exposure Assessment

Exposure refers to the potential contact of an individual with a constituent. The exposure assessment identifies pathways and routes by which an individual may be exposed to the COPCs, and estimates the magnitude, frequency, and duration of potential exposure. Constituent intakes and associated health risks are only quantified for complete exposure pathways.

The components of exposure assessment include the following:

- Development of the CSM for human health
- Calculation of EPCs
- Development of exposure assumptions for potentially complete exposure pathways
- Calculation of intake for COPCs using calculated EPCs and exposure assumptions

H.4.1 Conceptual Site Model for Human Health

The CSM for human health is presented in Section H.2 and Figure H-1.

The potentially exposed populations evaluated in the risk assessment are shown in Figure H-1 and Appendix I, Table 1. Potential current receptors include base workers, and Navy and DoD personnel and their families who may use the site for recreational activities such as jogging, hunting, and fishing. These receptors may be exposed to the surface soil.

Future site use and future receptors will most likely remain the same as the current site use and receptors. However, although there are no plans for future site development, future site use is unknown. Therefore, potential future human health receptors include the current receptors, and if the investigation area is developed for future use, future residents or construction workers. Future receptors could be exposed to surface and subsurface soil if future development activities occur at the investigation area, such as future residential housing or industrial buildings are constructed, or piping and utility work performed, and the soil is re-worked, bringing subsurface soil to the surface.

Although groundwater beneath the site is not currently used as a potable water supply, it was conservatively assumed that groundwater could be used as a future residential or industrial potable water supply. Additionally, due to the relatively shallow range of depths to groundwater (from about 6 feet below ground surface and deeper), it was assumed that construction workers could be exposed to groundwater during future excavation activities.

Since historic site use is not associated with significant VOC contamination, and volatile constituents were not found to be potential constituents of concern during previous investigations, VOCs were not included in groundwater analysis. Therefore, the groundwater to air pathway is not considered a complete exposure pathway.

In summary, current receptors and potentially complete exposure routes for quantitative evaluation are:

- **Base Worker**: Incidental ingestion and dermal contact with surface soil.
- **Recreational User (adult and child):** Incidental ingestion and dermal contact with surface soil.

Future receptors and potentially completely exposure routes include the following:

- **Base Worker**: Incidental ingestion and dermal contact with surface and subsurface soil; ingestion of shallow groundwater.
- **Recreational User (adult and child):** Incidental ingestion and dermal contact with surface and subsurface soil.
- **Resident (adult and child):** Incidental ingestion and dermal contact with surface and subsurface soil; ingestion of shallow groundwater, and dermal contact with shallow groundwater while bathing/showering.
- **Construction worker:** Incidental ingestion and dermal contact with surface and subsurface soil; dermal contact with shallow groundwater in an open excavation.

H.4.2 Calculation of Exposure Point Concentrations

Exposure is quantified by estimating the EPCs for COPCs in environmental media and constituent intake (ingestion, dermal absorption) by the receptor. EPCs are the estimated constituent concentrations that a receptor may contact and are specific to each exposure medium. The EPCs for AOC 6 are provided in Tables 3.1.RME through 3.3.RME of Appendix I.

EPCs may be directly monitored or estimated using environmental models. Constituent concentrations in surface soil, surface and subsurface soil, and groundwater were measured for this assessment. Fate and transport modeling was used to estimate constituent concentrations in volatile and particulate emissions from soil for the COPC screening only, as COPCs were not identified for this pathway.

Concentrations in volatile and particulate emissions from soil were estimated using the VF and PEF approach presented in *Supplemental Guidance for Developing Soil Levels for Superfund Sites* (USEPA, 2002). For volatile constituents, PEFs and VFs were used to estimate potential ambient air concentrations. For non-volatile constituents, PEFs were used to estimate potential ambient air concentrations. VFs were calculated using site-specific input parameters and default values and are provided in Appendix I, Table 2.2A. The calculated air concentrations are shown in Appendix I, Tables 2.2 and 2.4.

ProUCL software Version 5.0 (USEPA, 2013a) was used to calculate the EPCs. The recommendations outlined in the ProUCL software documentation (USEPA, 2013a) were followed to select the appropriate 95 percent upper confidence levels (95 percent UCLs) used as the EPCs. The maximum detected concentration was used as the EPC where the estimated 95 percent UCL was greater than the maximum detected concentration or where only one detected concentration was available for a data grouping, or where less than eight samples were available for a soil data grouping. Following USEPA groundwater guidance (USEPA, 2014b), a minimum of 3 wells in the core of the plume should generally be used to calculate the groundwater EPC. Therefore, as six groundwater samples were collected, a 95% UCL was calculated for all groundwater COPCs. The arithmetic mean concentration of detected values was used as the EPC for lead. The ProUCL output is included in Appendix I.

The EPCs for groundwater were calculated using all of the site-related groundwater samples because there is no groundwater plume at the site and no groundwater hot spots were identified.

H.4.3 Estimation of Chemical Intakes for Individual Pathways

Chemical intake is the amount of the chemical constituent entering the receptor's body. The quantification of exposure is based on an estimate of the chronic daily intake (CDI), the average amount of the COPC entering the receptor's body per day. Chemical intake estimates for the ingestion and dermal exposure pathways are generally expressed as follows:

$$\mathrm{CDI} = \frac{\mathrm{C} \times \mathrm{CR} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{BW} \times \mathrm{AT}}$$

Where

CDI	=	chronic daily intake (mg/kg-day)
C	=	chemical concentration (mg/L, mg/kg)
CR	=	contact rate (L/day, mg/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

For the dermal pathway, the contact rate incorporates the skin surface area in contact with the exposure medium (soil or groundwater) and an absorption (soil) or permeability (groundwater) factor.

For soil, the contact rate is calculated as follows:

CR = SA x SSAF x DABS

Where

SA	=	Skin surface area in contact with soil (cm^2)
SSAF	=	soil to skin adherence factor (mg/cm^2-day)
DABS	=	dermal absorption factor, chemical specific (unitless)

Chemical-specific skin absorption fractions for soil were obtained from USEPA's Dermal Exposure Assessment Guidance (USEPA, 2004) and the USEPA RSL table (2014a), which recommend 10.2 percent for 2,4-dinitrotoluene, 3.2 percent for 2,4,6-trinitrotoluene, 0.6 percent for 2-Amino-4,6-dinitrotoluene, 0.9 percent for 4-Amino-2,6-dinitrotoluene, 10 percent for all other explosives, 3 percent for arsenic, and 1 percent for all other inorganics.

For groundwater, the contact rate is calculated as follows:

CR = DAevent x SA

Where

DAevent = dermally absorbed dose per event (mg/cm^2-event)
SA = Skin surface area in contact with water (cm^2)

The dermally absorbed dose per event is calculated using chemical-specific permeability constants and additional chemical specific parameters which are shown in supplemental tables to the Table 7 series in Appendix I.

The intake and exposure equations require exposure parameters that are specific to each exposure pathway. Many of the exposure parameters have default values, which were used for this assessment. These assumptions, based on estimates of body weights, media intake levels, and exposure frequencies and duration, are provided in USEPA guidance (USEPA, 1989; 1991; 1993; 2004; 2011; 2014c), and Virginia Department of Environmental Quality (VDEQ) guidance (2003). Other assumptions (for example, for the recreational user and construction worker scenarios) require consideration of location-specific information and were made using professional judgment. Tables 4.1.RME through 4.3.RME and Tables 4.1.CTE though 4.3.CTE of Appendix I present the exposure parameters that were used for the exposure scenarios evaluated in the risk assessment. RME scenario exposure parameters were compiled for all scenarios; CTE parameters were compiled only for scenarios where the RME noncarcinogenic hazard or carcinogenic risk for an environmental medium was greater than the noncarcinogenic hazard or carcinogenic risk target levels (cumulative noncarcinogenic hazard index (HI) >1, and carcinogenic risk $>1 \times 10^{-4}$).

H.5 Toxicity Assessment

Toxicity assessment defines the relationship between the magnitude of exposure and possible severity of adverse effects, and weighs the quality of available toxicological evidence. Toxicity assessment generally consists of two steps: hazard identification and dose-response assessment. Hazard identification is the process of characterizing the potential adverse effects from exposure to the chemical and the type of health effect involved. Dose-response assessment is the process of quantitatively evaluating the toxicity information and characterizing the relationship between the dose of the constituent administered or received and the incidence of adverse health effects in the exposed population. Toxicity criteria (e.g., reference doses [RfDs] and cancer slope factors [CSFs]) are derived from the dose-response relationship.

USEPA recommends that a tiered approach be used to obtain the toxicity values (RfDs and CSFs) that are used to estimate noncarcinogenic hazards and carcinogenic risks (USEPA, 2003a). The hierarchy of toxicity value sources is the following:

1. Integrated Risk Information System (IRIS) (USEPA, 2014d)
2. Provisional Peer-Reviewed Toxicity Values (PPRTV)
3. Other peer-reviewed USEPA and non-USEPA sources (USEPA, 2013b), including the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997), California Environmental Protection Agency Toxicity Criteria Database (2014), New Jersey Department of Environmental Protection chromium work group (NJDEP, 2009), and Agency for Toxic Substances and Disease Registry (2014)

The use of toxicity values from sources other than IRIS increases the uncertainty of the quantitative risk estimates. Some of the COPCs elicit both systemic (noncarcinogenic) toxic effects and cancer (carcinogenic) effects. Because of this, these constituents are evaluated as both noncarcinogens and carcinogens. The health risks for carcinogenic and noncarcinogenic effects were estimated separately based on different toxicity values.

Hexavalent chromium was analyzed in a subset of the soil samples, but was not analyzed in any of the groundwater samples. Hexavalent chromium was detected and identified as a COPC for combined surface and subsurface soil but was not detected in the surface soil. As hexavelant chromium was not detected in the surface soil, the total chromium data were compared to the screening values for trivalent chromium to determine that total chromium was not a COPC for surface soil. Chromium was not detected in groundwater.

The non-carcinogenic toxicity values are provided in Table 5.1 of Appendix I, and the carcinogenic toxicity values are provided in Table 6.1 of Appendix I.

H.5.1 Toxicity Information for Noncarcinogenic Effects

Noncarcinogenic health effects include a variety of toxic effects on body systems, ranging from toxicity to the kidneys to central nervous system disorders. The toxicity of a chemical is assessed through a review of toxic effects noted in short-term (acute) animal studies, long-term (chronic) animal studies, and epidemiological investigations.

USEPA (1989) defines the chronic RfD as a dose that is likely to be without appreciable risk of deleterious effects during a lifetime of exposure. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound (for example, 7 years to a lifetime), and consider uncertainty in the toxicological database and sensitive receptors. Subchronic RfDs (applicable for exposures less than 7 years), which are all provisional values (that is, not verified by USEPA), were used for the construction worker scenario, if available. Chronic RfDs were used to evaluate noncarcinogenic risks to all other receptors included in the HHRA. In the development of RfDs, all available studies examining the toxicity of a chemical following exposure are considered on the basis of scientific merit. The lowest dose level at which an observed toxic effect occurs is identified as the lowest observed adverse effect level, and the dose at which no effect is observed is identified as the no observed adverse effect level. Several uncertainty factors (UFs) may be applied to account for uncertainties such as limited data, extrapolation of data from animal studies to human exposures, or the use of subchronic studies to develop chronic criteria. These UFs range from 10 to 10,000, and are based on professional judgment. Consequently, there are varying degrees of uncertainty in the toxicity criteria, which range from 1 to 3,000 for the COPCs identified for this site.

In accordance with USEPA guidance, oral RfDs were adjusted from administered dose (oral) to absorbed dose (dermal) to evaluate dermal toxicity. When appropriate, the RfDs were adjusted using oral absorption factors (USEPA, 2004). This adjustment is shown in Table 5.1 in Appendix I.

H.5.2 Toxicity Information for Carcinogenic Effects

Potential carcinogenic effects are quantified as CSFs that convert estimated exposures directly to incremental lifetime carcinogenic risks.

CSFs may be derived from the results of chronic animal bioassays, human epidemiological studies, or both. Animal bioassays are usually conducted at dose levels that are much higher than are likely to be encountered in the environment. This design detects possible adverse effects in the relatively small test populations used in the studies. The actual risks from exposure to a potential carcinogen are not likely to exceed the estimated risks and are probably much lower or even zero.

As was done for oral RfDs, oral CSFs were adjusted from administered dose (oral) to absorbed dose (dermal) to evaluate dermal toxicity. When appropriate, the CSFs were adjusted using oral absorption factors (USEPA, 2004). This adjustment is shown in Table 6.1 in Appendix I.

H.5.3 Approach for Potential Mutagenic Effects

Consistent with the cancer guidelines and supplemental guidance (USEPA, 2005a and 2005b), cancer risks were estimated using age-dependent adjustment factors (ADAFs) for COPCs which act via a mutagenic mode of action (MMOA). Hexavalent chromium was the only COPC that is categorized as a chemical with a MMOA.

The calculation of cancer risk using ADAFs is presented in the Table 7 series in Appendix I. Because chemical-specific data are not available for hexavalent chromium, default ADAFs, as included in *Derivation of RBCs for Carcinogens that Act Via a Mutagenic Mode of Action and Incorporate Default ADAFs* (USEPA, 2006), were used for the MMOA evaluation. The default ADAFs used to adjust the CSF are 10 for 0 to 2-year-olds, 3 for 2- to 6-year-olds, 3 for 6- to 12-year-olds, and 1 for 16- to 26-year-olds. The CSF was multiplied by the appropriate ADAF to derive the age-specific CSF for a receptor to calculate the total carcinogenic risk. Additionally, the exposure factors for children 0 to 2 years old and 2 to 6 years old were assumed to be the same as the parameters for a child 0 to 6 years old, except for the exposure duration, which was 2 years and 4 years, respectively. The exposure factors for the adult residential receptor were used for residents 6 to 16 years old and 16 to 26 years old, with the exception of the exposure durations, which were 10 years for each age-range.

H.5.4 Constituents for Which USEPA Toxicity Values Are Not Available

Quantitative oral toxicity criteria are not available for lead. As a screening tool, lead is screened against 400 mg/kg in soil and 15 μg/L in groundwater, based on residential exposure. The potential risks associated with residential exposures to lead are addressed using the Integrated Exposure Uptake Biokinetic (IEUBK) Lead Model and the Adult Lead Model (ALM), as described in Section H.6.1.

H.6 Risk Characterization

Risk characterization combines the results of the previous elements of the risk assessment to evaluate the potential health risks associated with exposure to the COPCs. The risk characterization is then used as an integral component in remedial decision making and selection of potential remedies or actions, as necessary.

H.6.1 Methods for Estimating Risks

Potential human health risks are discussed independently for carcinogenic and noncarcinogenic constituents because of the different toxicological endpoints, relevant exposure duration, and methods used to characterize risk. Exposure to some constituents may result in both noncarcinogenic and carcinogenic effects (i.e., arsenic), and therefore, these constituents were evaluated in both groups. The methodology used to estimate noncarcinogenic hazards and carcinogenic risks are described below.

H.6.1.1. Noncarcinogenic Hazard Estimation

Noncarcinogenic health risks are estimated by comparing the calculated exposures to RfDs. The calculated intake divided by the RfD is equal to the hazard quotient (HQ):

$$HQ = Intake / RfD$$

The intake and RfD represent the same exposure route (i.e., oral intakes are divided by oral RfDs). An HQ that exceeds 1 (i.e., intake exceeds the RfD) indicates that there is a potential for adverse health effects associated with exposure to that constituent.

To assess the potential for noncarcinogenic health effects posed by exposure to multiple constituents, an HI approach is used (USEPA, 1986). This approach assumes that noncarcinogenic hazards associated with exposure to more than one constituent are additive (HI = sum of the HQs). Synergistic or antagonistic interactions between constituents are not considered. The HI may exceed 1 even if all of the individual HQs are less than 1. HIs may be added across exposure routes and media to estimate the total noncarcinogenic health effects to a receptor posed by exposure through multiple routes and media. If the HI is greater than 1, separate HIs are estimated for each target organ to assess whether the HI for a specific target organ is greater than 1. A target organ-specific HI greater than 1 indicates there is some potential for adverse noncarcinogenic health effects associated with exposure to the COPCs. If the HI for each target organ does not exceed 1, noncarcinogenic hazards are not expected.

H.6.1.2. Carcinogenic Risk Estimation

The potential for carcinogenic effects due to exposure to site-related constituents is evaluated by estimating the excess lifetime carcinogenic risk (ELCR). ELCR is the incremental increase in the probability of developing cancer during one's lifetime in addition the probability to developing cancer associated with exposure to all non-site related sources of carcinogens.

Carcinogenic risk is calculated by multiplying the intake by the CSF.

$$ELCR = Intake \times CSF$$

The combined risk from exposure to multiple constituents was evaluated by adding the risks from individual constituents. Risks were also added across the exposure routes and media if an individual would be exposed through multiple routes and to multiple media.

As required under the *National Oil and Hazardous Substances Contingency Plan* (USEPA, 1994b) "[f]or known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} to 10^{-6} using information on the relationship between dose and response." When a cumulative carcinogenic risk to a receptor under the assumed RME exposure conditions exceeds 1 in 10 thousand (10^{-4} ELCR), CERCLA generally requires remedial action to reduce risks at the site.

H.6.1.3. Approach for Lead

Lead concentrations less than 0.015 mg/L in groundwater (the Safe Drinking Water Act action level for lead in potable water) and less than 400 mg/kg in soil (USEPA, 1994a) are considered adequately protective of human health under residential land-use conditions. Lead was retained as a COPC when exceeding these values. Lead was identified as a COPC for surface soil and combined surface and subsurface soil. Lead does not have available published toxicity factors, and therefore potential risks associated with lead are evaluated differently than the other COPCs. The toxicity of lead is evaluated by USEPA based on blood-lead uptake using a physiologically based pharmacokinetic model called the IEUBK model.

The potential risks associated with residential/recreational exposure to lead by children were addressed using the IEUBK lead model for Windows, Version 1.1, Build 11 (USEPA, 2010). The IEUBK model provides predictions of the probability of elevated blood lead levels for children from ages 0 to 7 years with potential exposure to lead in various media. The IEUBK model was used to evaluate potential risks associated with current and future recreational and future residential child exposures to lead in soil. The arithmetic mean of the lead concentrations in surface soil (current exposure scenarios) and combined surface and subsurface soil (future exposure scenarios) was used with the default input parameters to represent site-specific exposures to lead. The IEUBK model results are expressed as the predicted geometric mean blood lead level for children and the percent of the population potentially experiencing concentrations above USEPA's recommended level of 10 micrograms per deciliter (µg/dL), below which adverse manifestations are not expected. USEPA's target level for lead is less than 5 percent of the population exceeding the10 µg /dL blood lead level (USEPA, 1994a).

An interim approach to assessing risks associated with adult exposures to lead was developed by USEPA's Technical Review Workgroup for Lead (USEPA, 2003b) and updated in 2005 and 2009 (USEPA, 2009b). This methodology is a variation of the IEUBK model. The ALM is used to evaluate risks associated with nonresidential adult exposures to lead in soil. The model focuses on estimating fetal blood concentrations in women exposed to lead in soil (USEPA, 2003b). It was used in this risk evaluation to be protective of potentially sensitive receptors within the base worker, construction worker, and recreational populations that may be exposed to soil. Because the lead model is a probabilistic model, several of the USEPA default parameters are based on central tendency (i.e., average) values (USEPA, 2003b). Therefore, the arithmetic mean lead concentrations for surface soil, and surface and subsurface soil, served as input values for the soil concentrations.

The exposure parameters used in the ALM for ingestion and exposure frequency are the same as those used for the CTE scenarios to evaluate direct contact with soil. The soil ingestion rate of 20 mg/day was assumed for the adult recreational user; 50 mg/day was assumed for the base worker; and 100 mg/day was assumed for the construction worker. An exposure frequency of 26 days/year was assumed for the adult recreational user; 219 days/year was assumed for the base worker; and 125 days/year for the construction worker.

ALM spreadsheets provided by USEPA (2009b) were used to calculate blood lead concentrations for the various scenarios, as needed. The model results are expressed as the predicted geometric mean blood lead level for adults (that is, women of child-bearing age), the corresponding 95th percentile fetal blood lead concentrations, and the percent of the population potentially experiencing concentrations above 10 µg/dL, below which adverse manifestations are not expected.

The only area of the site where lead concentrations in soil exceeded the screening level was in the ~~c~~Catch ~~b~~Box R~~r~~uins area. Therefore, in addition to evaluating exposure to the average concentration of lead across the site, exposure to lead within the ~~c~~Catch ~~b~~Box ~~r~~Ruins area was evaluated. The average concentration of lead in the samples collected from the catch box ruins area (CAA06-SO01 and -SO26) was used for this evaluation. The same exposure scenarios evaluated for lead exposure across the site were also evaluated for exposure to lead within the ~~c~~Catch ~~b~~Box ~~r~~Ruins.

H.6.1.4. Comparison to SSLs

Soil data were compared to generic SSLs from the RSL table to identify if potential leaching from soil to groundwater could result in concentrations in groundwater at levels of potential concern to human health. Tables 2.1 and 2.3 in Appendix I present SSLs, with noncarcinogenic effects based on a hazard quotient of 0.1 and carcinogenic effects based on a $1x10^{-6}$ carcinogenic risk, as presented in the RSL table. All constituents in soil, except chrysene, fluoranthene, pyrene, beryllium, chromium, and silver, had maximum detected concentrations exceed their applicable SSLs. Therefore, these constituents may be leaching to groundwater at concentrations of potential concern to human health if the groundwater is used as a potable water supply. The SSLs from the RSL table are extremely conservative, do not account for dilution or attenuation (are calculated using a dilution and attenuation factor of 1), and are only an estimate for the migration to groundwater pathway. Since groundwater data is available at AOC 6, the actual groundwater concentrations were used to evaluate risk from exposure to groundwater.

H.6.2 Risk Assessment Results

The results of risk estimates for AOC 6 are summarized below by receptor. A summary of the RME results is presented in Table H-3, and the CTE results are summarized in Table H-4, presented at the end of this HHRA. The risk calculations are presented in Tables 7.1.RME through 7.10.RME, and 7.1.CTE through 7.9.CTE in Appendix I. CTE risks were calculated only when the RME hazards exceeded the noncarcinogenic target HI of 1, or the RME carcinogenic risks exceeded the acceptable risk range of 1×10^{-6} to 1×10^{-4}. Tables 9.1.RME through 9.10.RME and 9.1.CTE through 9.9.CTE in Appendix I summarize the hazards and risks to each receptor. The constituents of concern (COCs) are identified below for each receptor. The COCs are those COPCs that contribute an HI greater than 0.1 to a cumulative target organ HI that exceeds 1, or a carcinogenic risk greater than 1×10^{-6} to a cumulative carcinogenic risk that exceeds 1×10^{-4}.

H.6.2.1. Current Base Worker (Tables 9.1.RME and 9.1.CTE, Appendix I)

The risk assessment assumed that a current base worker could be exposed to surface soil through incidental ingestion and dermal contact.

- Cumulative HI (RME) = 12, exceeds target HI, associated with 2,4,6-trinitrotoluene.
- Cumulative HI (CTE) = 5, exceeds target HI, associated with 2,4,6-trinitrotoluene.
- Cumulative ELCR (RME) = 7x10-5, within target risk range.
- ALM model (surface soil across site - Tables 11.1a and 11.1b, catch box ruins surface soil - Tables 11.1c and 11.d, Appendix I) demonstrated no adverse effects above acceptable levels associated with exposure to lead either in surface soil across the site or surface soil in catch box ruins area.
- COC for surface soil: 2,4,6-trinitrotoluene

H.6.2.2. Current Adult Recreational User (Tables 9.2.RME and 9.2.CTE, Appendix I)

The risk assessment assumed that a current adult recreational user could be exposed to surface soil through incidental ingestion and dermal contact.

- Cumulative HI (RME) = 3, exceeds target HI, associated with 2,4,6-trinitrotoluene.
- Cumulative HI (CTE) = 0.3, less than target HI.
- Cumulative ELCR (RME) = $1x10^{-5}$, within target risk range.
- ALM model (surface soil across site - Tables 11.2a and 11.2b, catch box ruins surface soil – Tables 11.2c and 11.2d, Appendix I) demonstrated no adverse effects above acceptable levels associated with exposure to lead.
- COC for surface soil: 2,4,6-trinitrotoluene

H.6.2.3. Current Child Recreational User (Tables 9.3.RME and 9.3.CTE, Appendix I)

The risk assessment assumed that a current child recreational user could be exposed to surface soil through incidental ingestion and dermal contact.

- Cumulative HI (RME) = 27, exceeds target HI, associated with 2,4,6-trinitrotoluene.
- Cumulative HI (CTE) = 3, exceeds target HI, associated with 2,4,6-trinitrotoluene.
- Cumulative ELCR (RME) = 4×10^{-5}, within target risk range.
- IEUBK model (Tables 11.3a and 11.3b, Figure 11-1, Appendix I)~~, conservatively used to evaluate recreational exposure to soil,~~ demonstrated no adverse effects above acceptable levels associated with exposure to lead in soil across the site for a residential or recreational child. However, the IEUBK model (Tables 11.3c and 11.3d, Figure 11-2, Appendix I) demonstrated adverse effects above acceptable levels associated with exposure to lead in ~~c~~Catch ~~b~~Box ~~r~~Ruins surface soil.
- COCs for surface soil: 2,4,6-trinitrotoluene, lead (~~c~~Catch ~~b~~Box ~~r~~Ruins area only)

H.6.2.4. Future Base Worker (Tables 9.4.RME and 9.4.CTE, Appendix I)

The risk assessment assumed that a future base worker could be exposed to surface and subsurface soil through incidental ingestion and dermal contact, and groundwater used as a potable water supply through ingestion.

- Cumulative HI (RME) = 7, exceeds target HI, associated with 2,4,6-trinitrotoluene in soil.
  - Cumulative HI (RME) for soil = 5, exceeds target HI, associated with 2,4,6-trinitrotoluene.
  - Cumulative HI (RME) for groundwater = 2, exceeds target HI, however, no target organ HIs exceed target level.
- Cumulative HI (CTE) = 3, exceeds target HI.
  - Cumulative HI (RME) for soil = 2, exceeds target HI, associated with 2,4,6-trinitrotoluene.
  - Cumulative HI (RME) for groundwater = 0.8, less than target level.
- Cumulative ELCR (RME) = 2×10^{-4}, exceeds target risk range, associated with arsenic in groundwater.
  - Cumulative ELCR (RME) for soil = 3×10^{-5}, within target risk range.
  - Cumulative ELCR (RME) for groundwater = 2×10^{-4}, exceeds target risk range, associated with arsenic.
- Cumulative ELCR (CTE) = 3×10^{-5}, within target risk range.
- ALM model (soil across site - Tables 11.4a and 11.4b, ~~c~~Catch ~~b~~Box ~~r~~Ruins soil – Tables 11.4c and 11.4d, Appendix I) demonstrated no adverse effects above acceptable levels associated with exposure to lead.
- COC for soil: 2,4,6-trinitrotoluene
- COC for groundwater: arsenic

H.6.2.5. Future Adult Recreational User (Table 9.5.RME, Appendix I)

The risk assessment assumed that a future adult recreational user could be exposed to surface and subsurface soil through incidental ingestion and dermal contact.

- Cumulative HI (RME) = 1, does not exceed target HI.
- Cumulative ELCR (RME) = 6×10^{-6}, within target risk range.
- ALM model (soil across site - Tables 11.5a and 11.5b, ~~c~~Catch ~~b~~Box ~~r~~Ruins soil – Tables 11.5c and 11.5d, Appendix I) demonstrated no adverse effects above acceptable levels associated with exposure to lead.

H.6.2.6. Future Child Recreational User (Tables 9.6.RME and 9.5.CTE, Appendix I)

The risk assessment assumed that a future child recreational user could be exposed to surface and subsurface soil through incidental ingestion and dermal contact.

- Cumulative HI (RME) = 11, exceeds target HI, associated with 2,4,6-trinitrotoluene.
- Cumulative HI (CTE) = 1, does not exceed target HI.
- Cumulative ELCR (RME) = $2x10^{-5}$, within target risk range.
- IEUBK model (Tables 11.6a and 11.6b, Figure 11-~~2~~3, Appendix I), conservatively run to assess recreational exposure to soil, demonstrated no adverse effects above acceptable levels associated with exposure to lead in soil across the site. However, the IEUBK model (Tables 11.6c and 11.6d, Figure 11-4, Appendix I) demonstrated adverse effects above acceptable levels associated with exposure to lead in ~~c~~Catch ~~b~~Box ~~r~~Ruins surface soil.
- COC for soil: 2,4,6-trinitrotoluene, lead (~~c~~Catch ~~b~~Box ~~r~~Ruins area only)

H.6.2.7. Future Construction Worker (Tables 9.7.RME and 9.6.CTE, Appendix I)

The risk assessment assumed that a future construction worker could be exposed to surface and subsurface soil through incidental ingestion and dermal contact, and to groundwater in an excavation through dermal contact.

- Cumulative HI (RME) = 8, exceeds target HI, associated with 2,4,6-trinitrotoluene in soil.
  - Cumulative HI (RME) for soil = 8, exceeds target HI, associated with 2,4,6-trinitrotoluene.
  - Cumulative HI (RME) for groundwater = 0.1, below target HI.
- Cumulative HI (CTE) = 2, exceeds target HI, associated with 2,4,6-trinitrotoluene in soil.
  - Cumulative HI (RME) for soil = 2, exceeds target HI, associated with 2,4,6-trinitrotoluene.
- Cumulative ELCR (RME) = $2x10^{-6}$, within target risk range.
- ALM model (Tables 11.7a and 11.7b, Appendix I) demonstrated no adverse effects above acceptable levels associated with exposure to lead. ALM model results for lead in ~~c~~Catch ~~b~~Box ~~r~~Ruins surface and subsurface soil (Tables 11.7c and 11.7d, Appendix I) indicate upper end of range is slightly above acceptable level (probability that fetal blood lead level exceeds target level is 5.1 percent, compared to the acceptable goal of 5 percent).
- COC for soil: 2,4,6-trinitrotoluene

H.6.2.8. Future Adult Resident (Non-carcinogenic Hazard, Tables 9.8.RME and 9.7.CTE, Appendix I)

The risk assessment assumed that a future adult resident could be exposed to surface and subsurface soil through incidental ingestion and dermal contact, and to shallow groundwater through ingestion and dermal contact while showering. Carcinogenic risks were not calculated for an adult resident, but rather for a lifetime child/adult resident, following USEPA guidance.

- Cumulative HI (RME) = 14, exceeds target HI, associated with 2,4,6-trinitrotoluene in soil and arsenic in groundwater.
  - Cumulative HI (RME) for soil = 7, exceeds target HI, associated with 2,4,6-trinitrotoluene.
  - Cumulative HI (RME) for groundwater = 6, exceeds target HI, associated with arsenic and iron.
- Cumulative HI (CTE) = 4, exceeds target HI, however, no target organ HIs exceed the target HI.
- Lead evaluated for the more-conservative child resident using IEUBK model, see Section H.6.2.9.
- COC for soil: 2,4,6-trinitrotoluene
- COCs for groundwater: arsenic, iron

H.6.2.9. Future Child Resident (Non-carcinogenic Hazard, Tables 9.9.RME and 9.8.CTE, Appendix I)

The risk assessment assumed that a future child resident could be exposed to surface and subsurface soil through incidental ingestion and dermal contact, and to shallow groundwater through ingestion and dermal contact while bathing. Carcinogenic risks were not calculated for a child resident, but rather for a lifetime child/adult resident, in accordance with USEPA guidance.

- Cumulative HI (RME) = 84, exceeds target HI, associated with 2,4,6-trinitrotoluene in soil and arsenic and iron in groundwater.
  - Cumulative HI (RME) for soil = 73, exceeds target HI, associated with 2,4,6-trinitrotoluene.
  - Cumulative HI (RME) for groundwater = 11, exceeds target HI, associated with arsenic and iron.
- Cumulative HI (CTE) = 22, exceeds target HI, associated with 2,4,6-trinitrotoluene in soil and arsenic in groundwater.
  - Cumulative HI (RME) for soil = 17, exceeds target HI, associated with 2,4,6-trinitrotoluene.
  - Cumulative HI (RME) for groundwater = 5, exceeds target HI, associated with arsenic.
- IEUBK model (Tables 11.6a and 11.6b, Figure 11-~~2~~3, Appendix I) demonstrated no adverse effects above acceptable levels associated with exposure to lead in soil across the site. However, the IEUBK model (Tables 11.6c and 11.6d, Figure 11-4, Appendix I) demonstrated adverse effects above acceptable levels associated with exposure to lead in ~~c~~Catch ~~b~~Box ~~r~~Ruins surface soil.
- COC for soil: 2,4,6-trinitrotoluene, lead (~~c~~Catch ~~b~~Box ~~r~~Ruins only)
- COCs for groundwater: arsenic, iron

H.6.2.10. Future Lifetime Resident (Carcinogenic Risk, Tables 9.10.RME and 9.9.CTE, Appendix I)

The risk assessment assumed that a future lifetime child/adult resident could be exposed to surface and subsurface soil through incidental ingestion and dermal absorption, and to shallow groundwater through ingestion and dermal contact while showering.

- Cumulative ELCR (RME) = 8×10^{-4}, exceeds target risk range, associated with 2,4,6-trinitrotoluene, 2-nitrotoluene, arsenic, and hexavalent chromium in soil and arsenic in groundwater.
  - Cumulative ELCR (RME) for soil = 2×10^{-4}, exceeds target risk range, associated with 2,4,6-trinitrotoluene, 2-nitrotoluene, arsenic, and hexavalent chromium.
  - Cumulative ELCR (RME) for groundwater = 6×10^{-4}, exceeds target risk range, associated with arsenic.
- Cumulative ELCR (CTE) = 2×10^{-4}, exceeds target risk range, primarily associated with arsenic in groundwater.
  - Cumulative ELCR (RME) for soil = 3×10^{-5}, within target risk range.
  - Cumulative ELCR (RME) for groundwater = 2×10^{-4}, exceeds target risk range, associated with arsenic.
- COCs for soil: 2,4,6-trinitrotoluene, 2-nitrotoluene, arsenic, and hexavalent chromium
- COC for groundwater: arsenic

H.7 Uncertainty Associated with Human Health Assessment

The risk measures used in site risk assessments are not fully probabilistic estimates of risk, but are conditional estimates given that a set of assumptions about exposure and toxicity are realized. Thus, it is important to specify the assumptions and uncertainties inherent in the risk assessment to place the risk estimates in proper perspective.

H.7.1 Uncertainty in Data Evaluation and COPC Selection

The sampling of site media focused on areas that were most likely affected by past site activities. Therefore, the uncertainty associated with missing a contaminated location is expected to be minimal because the investigation was focused to find the most likely and potentially highest areas of contamination. The uncertainty associated with the data analysis is minimal; all of the data were validated before being used in the HHRA. A data quality evaluation was performed on all analytical data evaluated in the HHRA, as discussed in Section 5 of the RI.

The general assumptions used in the COPC selection process were conservative to ensure that true COPCs were not eliminated from the quantitative risk assessment and that the reasonable maximum risk was estimated. RSLs based on residential assumptions were used to select the COPCs for all exposure scenarios, including non-residential scenarios.

Four of the soil samples (two surface soil and two subsurface soil) included analysis for hexavalent chomium, while all soil samples (twenty-two surface soil and twenty-two subsurface soil) were analyzed for total chromium. Because hexavalent chromium data were available, the hexavalent chromium concentrations in soil were screened using hexavalent chromium RSLs and the total chromium concentrations in soil were screened using trivalent chromium RSLs. However, there is some uncertainty associated with the samples where only total chromium was analyzed. It is possible the risks were underestimated in the HHRA if hexavalent chromium was present in the soil at locations where it was not analyzed.

A comparison of site concentrations to background concentrations was not used to select the COPCs. Therefore, it is possible that any of the metals identified as COPCs and COCs may be associated with background conditions. Arsenic was identified as a COC in surface and subsurface soil. Arsenic concentrations in surface and subsurface soil ranged from 1.1 mg/kg to 20.9 mg/kg. More than half of these detections were below the 95 percent UTL from the CAX/Yorktown background value of 5.54 mg/kg for surface and subsurface soil. Therefore, it is possible some of the risk associated with exposure to arsenic in soil is from background conditions. Additionally, the detected concentrations of arsenic in the groundwater samples collected from the site-related monitoring wells were within the range of concentrations detected in the site-specific background monitoring wells. Therefore, the potential risks associated with exposure to arsenic in groundwater may be associated with background conditions.

Detection limits for constituents that were not detected within a media were compared to the screening levels to determine if there are any non-detected constituents with detection limits above the screening level. There were a few SVOCs, explosives, and metals detected with detection limits above the screening level, however, most were within an order of magnitude or two above the screening level, and would not result in unacceptable risks if they were present at concentrations below their detection limit. Based on this evaluation, there are not expected to be any non-detected analytes present at the site that would result in unacceptable risks, or changes to the results of the HHRA evaluation.

H.7.2 Uncertainty Associated with Exposure Assessment

Uncertainty in the exposure assessment was generally treated with conservative decision rules and assumptions, and therefore the uncertainty likely overestimates actual exposure to COPCs. Several exposure pathways evaluated by the HHRA, such as residential land use, are hypothetical and are not likely to occur in the future at AOC 6. It is also not likely that shallow groundwater would be used as a potable or industrial water supply because of the availability of better water supplies with respect to both water quality and quantity. Most of the exposure factors used for quantitation of exposure are generally conservative and reflect ~~worst-case, or~~ upper-bound~~,~~ assumptions for the exposure.

The percent of a constituent absorbed through the skin is another source of uncertainty and is likely to be affected by many parameters, including soil loading, moisture content, organic content, pH, and presence of other constituents. The availability of a constituent for absorption through the skin depends on site-specific fate and transport properties of the chemical species available for eventual absorption. Constituent concentrations, specific properties of the constituent, and the kinetics of constituents being released all affect the amount of a constituent that is absorbed. These factors contribute to the uncertainty associated with dermal absorption estimates, and make it difficult to quantify the amount of certain constituents absorbed through the skin from soil.

The future soil exposure scenario adds additional conservatism by assuming that the subsurface soil will become surface soil during any future construction activities, and that future receptors may come in contact with what is the current surface soil and current subsurface soil in the future. During many construction projects, clean fill material such as topsoil is placed over the soil that is disturbed during excavation projects. The topsoil material is generally needed to support growth of grass and other landscape plants. This would decrease the possibility of future exposure to both the current surface and subsurface soil after any construction activities.

H.7.3 Uncertainty Associated with Toxicity Assessment

Uncertainty associated with the noncarcinogenic toxicity factors is included in the toxicity tables for AOC 6 in Appendix I. Several UFs were applied to extrapolate dose points from animal studies to humans. These UFs range between 1 and 3,000. Therefore, there is a high degree of uncertainty in the noncarcinogenic toxicity criteria based on the available scientific data for each constituent. The noncarcinogenic toxicity factors are most likely an overestimate of actual toxicity.

The uncertainty associated with CSFs is mostly due to the low dose extrapolation where carcinogenicity at low doses is assumed to be a linear response. This is a conservative assumption, which introduces a high uncertainty into slope factors that are extrapolated from this area of the dose-response curve. The CSFs are based on the assumption that there is no threshold level for carcinogenicity; however, most of the experimental studies indicate the existence of a threshold level. Therefore, CSFs developed by USEPA represent upper-bound estimates. Carcinogenic risks generated in this assessment should be regarded as an upper-bound estimate on potential carcinogenic risks, rather than an accurate representation of carcinogenic risk. The true carcinogenic risk is likely to be less than the predicted value (USEPA, 1989). Uncertainty is also associated with the application of the MMOA ADAFs for chromium due to its mutagenic MOA; this may overestimate or underestimate risks. Additionally, generic ADAFs were used in the MMOA calculations because no chemical specific ADAFs are available for the COPCs.

Use of provisional toxicity factors (such as values from ATSDR, HEAST, California EPA, and New Jersey DEP) increases the uncertainty of the quantitative hazard and risk estimates. These provisional values were used to provide a quantitative estimate rather than a merely qualitative risk discussion; however, these values should be interpreted cautiously because USEPA has not approved these toxicity values.

CSFs developed by USEPA represent upper-bound estimates. Carcinogenic risks generated in this assessment should be regarded as an upper-bound estimate of the potential carcinogenic risks rather than an accurate representation of carcinogenic risk. The true carcinogenic risk is likely to be less than the predicted value (USEPA, 1989).

Additional uncertainty lies in the prediction of relative sensitivities of different species of animals and the applicability of animal data to humans.

A large degree of uncertainty is associated with the oral-to-dermal adjustment factors (based on constituent-specific gastrointestinal absorption factors) used to transform the oral RfDs based on administered doses to dermal RfDs based on absorbed doses. It is not known if the adjustment factor results in an underestimate or overestimate of the actual toxicity associated with dermal exposure.

H.7.4 Uncertainty in Risk Characterization

The ALM and IEUBK models demonstrated no adverse effects above acceptable levels associated with lead in all exposure scenarios. However, one surface soil sample (CAA06-SO26-000H-0913, the 3-point composite soil sample) had a lead concentration of 1,100 mg/kg, which was much higher than other lead concentrations, ranging from 4 to 580 mg/kg. This soil sample also had the highest detection of 2,4,6-trinitrotoluene. It is possible that this 3 point composite sample could be considered a hot spot. If that is the case, then the risk from lead could be underestimated for a receptor who is only exposed to soil at this location and not across the site. Therefore, the ALM and IEUBK models were also used to evaluate exposure to lead in the cCatch bBox rRuins area, the location of this elevated sample. The results of this hot spot lead evaluation are discuss in Section H.6.2.

The uncertainties identified in each component of risk assessment ultimately contribute to uncertainty in risk characterization. The addition of risks and HIs across pathways and constituents contributes to uncertainty based on chemical interactions such as additivity, synergism, potentiation, and susceptibility of exposed receptors.

H.8 Human Health Risk Summary

The HHRA was conducted to evaluate the current and future potential human health risks associated with exposure to surface soil, surface and subsurface soil, and groundwater at AOC 6.

Tables H-3 and H-4, presented at the end of this HHRA, and Tables 9.1.RME through 9.10.RME and 9.1.CTE through 9.9.CTE in Appendix I summarize the RME and CTE potential hazards and risks to each receptor. Tables 10.1.RME through 10.9.RME and 10.1.CTE through 10.6.CTE, Appendix I, show the receptor scenarios with cumulative HIs greater than 1, or total carcinogenic risks greater than 1×10^{-4}. The COPCs that contribute HIs greater than 0.1 or carcinogenic risks greater than 1×10^{-6} are included in the tables. COCs are identified for the scenarios with potentially unacceptable risks. The COCs are those COPCs that contribute an HI greater than 0.1 to a cumulative target organ HI that exceeds 1 or a carcinogenic risk greater than 1×10^{-6} to a cumulative carcinogenic risk that exceeds 1×10^{-4}. Risk estimates and COCs are summarized below.

Base Worker

- Exposure to surface soil under current scenario and exposure to surface and subsurface soil and groundwater under future scenarios
- Current scenario
  - Total HI (RME and CTE) for exposure to surface soil exceeds target HI.
  - Total ELCR (RME and CTE) for exposure to surface soil within target risk range
  - COC for surface soil is 2,4,6-trinitrotoluene
- Future scenario
  - Total HI (RME and CTE) for exposure to soil and groundwater exceeds target HI.
  - Total ELCR (RME) for exposure to soil and groundwater exceeds target risk range, total ELCR (CTE) within target risk range
  - COC for soil is 2,4,6-trinitrotoluene
  - COC for groundwater is arsenic

Recreational User (Adult and Child)

- Exposure to surface soil under current scenario and exposure to surface and subsurface soil under future scenarios
- Current Scenario
  - Total HI (RME and CTE) for child recreator exceeds target hazard level, total HI (RME) for adult recreator exceeds target hazard level.
  - Total ELCR (RME and CTE) within target risk range
  - COC for surface soil is 2,4,6-trinitrotoluene
  - Lead is a COC only for surface soil within ~~for~~ the ~~c~~Catch ~~b~~Box ~~r~~Ruins ~~surface soil~~
- Future Scenario
  - Total HI (RME) for child recreator exceeds target hazard level

- Total HI (RME and CTE) for adult recreator and total HI (CTE) for child recreator do not exceed target hazard level
- Total ELCR (RME and CTE) within target risk range
- COC for soil is 2,4,6-trinitrotoluene
- COC for soil is 2,4,6-trinitrotolueneLead is a COC only for soil within the cCatch bBox rRuins soil

Construction Worker

- Exposure to surface and subsurface soil and groundwater under future scenarios
- Future Scenario only
  - Total HI (RME and CTE) exceeds target hazard level
  - Total ELCR (RME and CTE) within target risk range
  - COC for soil is 2,4,6-trinitrotoluene

Resident (Adult and Child)

- Exposure to surface and subsurface soil and groundwater under future scenarios
- Future Scenario only
  - Total HI (RME and CTE) exceeds target hazard level
  - Total ELCR (RME and CTE) exceeds target risk level
  - COCs for soil are 2,4,6-trinitrotoluene, 2-nitrotoluene, arsenic, and hexavalent chromium
  - Lead is a COC only for soil within the cCatch bBox rRuins soil
  - COCs for groundwater are arsenic and iron

To summarize, under current site use, 2,4,6-trinitrotoluene is a human health COC for surface soil and lead is a COC only for surface soil within the cCatch bBox rRuins area. For future unrestricted site use, 2,4,6-trinitrotoluene, 2-nitrotoluene, arsenic, and hexavalent chromium are human health COCs for soil, lead is s COC only for cCatch bBox rRuins area soil, and arsenic and iron are human health COCs for groundwater.

The soil COC, 2-Nitrotoluene, a COC for soil, was only detected in one of the thirty-nine soil samples and the detection limits for all the other soil samples were below the human health risk-based screening level. As there was only one detected concentration, this concentration was used as the exposure point concentration to estimate the hazards and risks associated with exposure to 2-nitrotoluene. Therefore, the risks associated with exposure to 2-nitrotoluene across the site are likely over-estimated.

The concentration of hexavalent chromium in subsurface soil exceeded the Residential soil RSL based on a carcinogenic risk of 10^{-6}. However, this concentration would not exceed the Residential soil RSL adjusted to a carcinogenic risk of 10^{-5} (3 mg/kg), indicating that the risk to a residential receptor would fall within the acceptable risk range of 10^{-4} to 10^{-6}. Therefore, it is unlikely there would be any adverse human health effects associated with exposure to hexavalent chromium in soil.

Iron, which is a COC in groundwater, is a required human nutrient. Ingestion of iron in groundwater would not result in intake of iron levels above the recommended dietary allowances for either children or adults. Therefore, it is unlikely there would be any adverse human health effects associated with exposure to the iron in groundwater. The detected concentrations of arsenic, a COC for groundwater, in the groundwater samples collected from the site-related monitoring wells were within the range of concentrations detected in the site-specific background monitoring wells. Therefore, the potential risks associated with exposure to arsenic in groundwater may be associated with background conditions.

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Tables

Figure

TABLE 11.1a
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas - Surface Soil Across Site – Base Worker
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	122.6	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Table 11.1b
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in surface soil; See Table 3.1.RME
What was the point of exposure and location?	AOC 6 TNT Subareas surface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.1b
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix.	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 219 days/year was used for the base worker scenario.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	Yes
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface Soil	An input concentration value of 122.6 ppm in surface soil results in geometric mean blood lead levels ranging from 1.2 to 1.7 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 2.8 to 5.1 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.007% to 0.5%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.1c
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas – Catch Box Ruins Surface Soil – Base Worker
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	840	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Table 11.1d
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in Catch Box Ruins surface soil
What was the point of exposure and location?	AOC 6 TNT Catch Box Ruins surface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.1d
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix.	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 219 days/year was used for the base worker scenario.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	Yes
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface Soil	An input concentration value of 840 ppm in surface soil results in geometric mean blood lead levels ranging from 2.2 to 2.7 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 5.2 to 8.3 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.3% to 2.9%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.2a
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas - Surface Soil Across Site – Adult Recreational User
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	122.6	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Table 11.2b
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in surface soil; See Table 3.1.RME
What was the point of exposure and location?	AOC 6 TNT Subareas surface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.2b
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix.	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 26 days/year was used for the recreational scenario.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	No. A value of 20 mg/day was used for the recreational scenario.
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface Soil	An input concentration value of 122.6 ppm in surface soil results in geometric mean blood lead levels ranging from 1.0 to 1.5 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 2.4 to 4.6 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.002% to 0.4%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.2c
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas – Catch Box Ruins Surface Soil – Adult Recreational User
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	840	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Table 11.2d
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in Catch Box Ruins surface soil
What was the point of exposure and location?	AOC 6 TNT Catch Box Ruins surface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.2d
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix.	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 26 days/year was used for the recreational scenario.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	No. A value of 20 mg/day was used for the recreational scenario.
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface Soil	An input concentration value of 840 ppm in surface soil results in geometric mean blood lead levels ranging from 1.1 to 1.6 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 2.5 to 4.8 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.003% to 0.4%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.3a
RAGS D IEUBK LEAD WORKSHEET – AOC 6 TNT Subareas - Surface Soil Across Site, Child Recreational User
Child (Age 0 – 84 Months)
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration Used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	122.6	mg/kg	Average Detected Value in Surface Soil	400	mg/kg	Recommended Soil Screening Level
Water	4	µg/L	IEUBK Model Default Value	15	µg/L	Recommended Drinking Water Action Level

2. Lead Model Questions

Question	Response for Residential Lead Model
What lead model (version and date was used)?	Lead Model for Windows, Version 1.1 Build 11 (February, 2010)
Where are the input values located in the risk assessment report?	Located in IEUBKwin OUTPUT (Attached as Table 11.3b and Figure 11.1)
What range of media concentrations were used for the model?	9.9– 1,100 mg/kg (surface soil)
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in surface soil; See Table 3.1.RME
Was soil sample taken from top 2 cm? If not, why?	Yes
Was soil sample sieved? What size screen was used? If not sieved, provide rationale.	No – Samples were collected for multiple analyses.
What was the point of exposure/location?	AOC 6 TNT Subareas surface soil.
Where are the output values located in the risk assessment report?	IEUBKwin OUTPUT (Attached as Table 11.3b and Figure 11.1)
Was the model run using default values only?	No – Assumed site-specific arithmetic mean concentration of lead in surface soil.
Was the default soil bioavailability used?	Yes -- Default is 30%
Was the default soil ingestion rate used?	Yes -- Default values for 7 age groups are 85, 135, 135, 100, 090, and 85 mg/day
If non-default values were used, where is the rationale for the values located in the risk assessment report?	In the HHRA section of the report.

3. Final Result

Medium	Result	Comment/PRG [1]
Surface Soil	Input value of 122.6 mg/kg in surface soil results in <0.04% of children above a blood lead level of 10 µg/dL. Geometric mean blood lead = 2.0 µg/dL. This is below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children exceeding 10 µg/dL blood lead.	PRG not calculated.

1. For additional information, see www.epa.gov/superfund/health/contaminants/lead

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.3c
RAGS D IEUBK LEAD WORKSHEET – AOC 6 TNT Subareas – Catch Box Ruins Surface Soil, Child Recreational User
Child (Age 0 – 84 Months)
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration Used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	840	mg/kg	Average Detected Value in Catch Box Ruins Surface Soil	400	mg/kg	Recommended Soil Screening Level
Water	4	µg/L	IEUBK Model Default Value	15	µg/L	Recommended Drinking Water Action Level

2. Lead Model Questions

Question	Response for Residential Lead Model
What lead model (version and date was used)?	Lead Model for Windows, Version 1.1 Build 11 (February, 2010)
Where are the input values located in the risk assessment report?	Located in IEUBKwin OUTPUT (Attached as Table 11.3d and Figure 11.2)
What range of media concentrations were used for the model?	580– 1,100 mg/kg (surface soil)
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in catch box ruins surface soil
Was soil sample taken from top 2 cm? If not, why?	Yes
Was soil sample sieved? What size screen was used? If not sieved, provide rationale.	No – Samples were collected for multiple analyses.
What was the point of exposure/location?	AOC 6 TNT catch box ruins surface soil.
Where are the output values located in the risk assessment report?	IEUBKwin OUTPUT (Attached as Table 11.3d and Figure 11.2)
Was the model run using default values only?	No – Assumed site-specific arithmetic mean concentration of lead in surface soil.
Was the default soil bioavailability used?	Yes -- Default is 30%
Was the default soil ingestion rate used?	Yes -- Default values for 7 age groups are 85, 135, 135, 100, 090, and 85 mg/day
If non-default values were used, where is the rationale for the values located in the risk assessment report?	In the HHRA section of the report.

3. Final Result

Medium	Result	Comment/PRG [1]
Surface Soil	Input value of 840 mg/kg in surface soil results in 30% of children above a blood lead level of 10 µg/dL. Geometric mean blood lead = 7.8 µg/dL. This is above the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children exceeding 10 µg/dL blood lead.	PRG not calculated.

1. For additional information, see www.epa.gov/superfund/health/contaminants/lead

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.4a
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas - Surface and Subsurface Soil Across Site– Base Worker
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	80.44	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Table 11.4b
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in surface and subsurface soil; See Table 3.2.RME
What was the point of exposure and location?	AOC 6 TNT Subareas surface and subsurface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.4b
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix.	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 219 days/year was used for the base worker scenario.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	Yes
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface and Subsurface Soil	An input concentration value of 80.44 ppm in surface and subsurface soil results in geometric mean blood lead levels ranging from 1.1 to 1.6 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 2.6 to 4.9 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.005% to 0.5%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.4c
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas – Catch Box Ruins Surface and Subsurface Soil– Base Worker
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	543.75	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Table 11.4d
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in catch box ruins surface and subsurface soil
What was the point of exposure and location?	AOC 6 TNT catch box ruins surface and subsurface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.4d
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix.	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 219 days/year was used for the base worker scenario.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	Yes
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface and Subsurface Soil	An input concentration value of 543.75 ppm in surface and subsurface soil results in geometric mean blood lead levels ranging from 1.8 to 2.3 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 4.2 to 7.0 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.093% to 1.6%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.5a
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas - Surface and Subsurface Soil Across Site – Adult Recreational User
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	80.44	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Table 11.5b
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in surface and subsurface soil; See Table 3.2.RME
What was the point of exposure and location?	AOC 6 TNT Subareas surface and subsurface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.5b
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix.	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 26 days/year was used for the recreational scenario.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	No. A value of 20 mg/day was used for the recreational scenario.
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface and Subsurface Soil	An input concentration value of 80.44 ppm in surface and subsurface soil results in geometric mean blood lead levels ranging from 1.0 to 1.5 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 2.4 to 4.6 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.002% to 0.4%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.5c
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas – Catch Box Ruins Surface and Subsurface Soil – Adult Recreational User
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	543.75	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Table 11.5d
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in catch basin ruins surface and subsurface soil
What was the point of exposure and location?	AOC 6 TNT catch basin ruins surface and subsurface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.5d
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix.	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 26 days/year was used for the recreational scenario.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	No. A value of 20 mg/day was used for the recreational scenario.
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface and Subsurface Soil	An input concentration value of 543.75 ppm in surface and subsurface soil results in geometric mean blood lead levels ranging from 1.0 to 1.5 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 2.5 to 4.7 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.003% to 0.4%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.6a
RAGS D IEUBK LEAD WORKSHEET – AOC 6 TNT Subareas - Surface and Subsurface Soil Across Site, Child (Age 0 – 84 Months)
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration Used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	80.44	mg/kg	Average Detected Value in Surface Soil	400	mg/kg	Recommended Soil Screening Level
Water	4	µg/L	IEUBK Model Default Value	15	µg/L	Recommended Drinking Water Action Level

2. Lead Model Questions

Question	Response for Residential Lead Model
What lead model (version and date was used)?	Lead Model for Windows, Version 1.1 Build 11 (February, 2010)
Where are the input values located in the risk assessment report?	Located in IEUBKwin OUTPUT (Attached as Table 11.6b and Figure 11.3)
What range of media concentrations were used for the model?	4 – 1,100 mg/kg (surface and subsurface soil)
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in surface and subsurface soil; See Table 3.2.RME
Was soil sample taken from top 2 cm? If not, why?	Yes
Was soil sample sieved? What size screen was used? If not sieved, provide rationale.	No – Samples were collected for multiple analyses.
What was the point of exposure/location?	AOC 6 TNT Subareas surface and subsurface soil.
Where are the output values located in the risk assessment report?	IEUBKwin OUTPUT (Attached as Table 11.6b and Figure 11.3)
Was the model run using default values only?	No – Assumed site-specific arithmetic mean concentration of lead in surface and subsurface soil.
Was the default soil bioavailability used?	Yes -- Default is 30%
Was the default soil ingestion rate used?	Yes -- Default values for 7 age groups are 85, 135, 135, 100, 090, and 85 mg/day
If non-default values were used, where is the rationale for the values located in the risk assessment report?	In the HHRA section of the report.

3. Final Result

Medium	Result	Comment/PRG [1]
Surface and subsurface Soil	Input value of 80.44 mg/kg in soil results in <0.01% of children above a blood lead level of 10 µg/dL. Geometric mean blood lead = 1.6 µg/dL. This is below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children exceeding 10 µg/dL blood lead.	PRG not calculated.

1. For additional information, see www.epa.gov/superfund/health/contaminants/lead

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.6c
RAGS D IEUBK LEAD WORKSHEET – AOC 6 TNT – Catch Box Ruins Surface and Subsurface Soil, Child (Age 0 – 84 Months)
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration Used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	543.75	mg/kg	Average Detected Value in Surface Soil	400	mg/kg	Recommended Soil Screening Level
Water	4	µg/L	IEUBK Model Default Value	15	µg/L	Recommended Drinking Water Action Level

2. Lead Model Questions

Question	Response for Residential Lead Model
What lead model (version and date was used)?	Lead Model for Windows, Version 1.1 Build 11 (February, 2010)
Where are the input values located in the risk assessment report?	Located in IEUBKwin OUTPUT (Attached as Table 11.6d and Figure 11.4)
What range of media concentrations were used for the model?	4 – 1,100 mg/kg (surface and subsurface soil)
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure concentration was the arithmetic mean of lead concentrations in catch box ruins surface and subsurface soil
Was soil sample taken from top 2 cm? If not, why?	Yes
Was soil sample sieved? What size screen was used? If not sieved, provide rationale.	No – Samples were collected for multiple analyses.
What was the point of exposure/location?	AOC 6 TNT Subareas surface and subsurface soil.
Where are the output values located in the risk assessment report?	IEUBKwin OUTPUT (Attached as Table 11.6d and Figure 11.4)
Was the model run using default values only?	No – Assumed site-specific arithmetic mean concentration of lead in surface and subsurface soil.
Was the default soil bioavailability used?	Yes -- Default is 30%
Was the default soil ingestion rate used?	Yes -- Default values for 7 age groups are 85, 135, 135, 100, 090, and 85 mg/day
If non-default values were used, where is the rationale for the values located in the risk assessment report?	In the HHRA section of the report.

3. Final Result

Medium	Result	Comment/PRG [1]
Surface and subsurface Soil	Input value of 543.75 mg/kg in soil results in 11.1% of children above a blood lead level of 10 µg/dL. Geometric mean blood lead = 5.6 µg/dL. This is above the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children exceeding 10 µg/dL blood lead.	PRG not calculated.

1. For additional information, see www.epa.gov/superfund/health/contaminants/lead

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.7a
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas - Surface and Subsurface Soil Across Site – Construction Worker
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	80.44	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Attached as Table 11.7b
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure point concentration was based on the arithmetic mean of lead concentrations in surface and subsurface soil; See Table 3.2.RME
What was the point of exposure and location?	AOC 6 TNT Subareas surface and subsurface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.7b
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 125 days/year was used for the construction worker scenario, assuming duration of construction project is one-half of a year.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	No. An IR value of 100 mg/day was used, based on recommendation in the Adult Lead Model FAQs. http://www.epa.gov/superfund/lead/almfaq.htm#soil ingestion rate.
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface and Subsurface Soil	An input concentration value of 80.44 ppm in surface soil and subsurface soil results in geometric mean blood lead levels ranging from 1.3 to 1.8 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 3.0 to 5.4 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.011% to 0.7%. These values are below the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

TABLE 11.7c
RAGS D ADULT LEAD WORKSHEET
Calculations of Blood Lead Concentrations – AOC 6 TNT Subareas – Catch Box Ruins Surface and Subsurface Soil – Construction Worker
Remedial Investigation
Naval Weapons Station Yorktown, Yorktown, Virginia

1. Lead Screening Questions

Medium	Lead Concentration used in Model Run		Basis for Lead Concentration Used For Model Run	Lead Screening Concentration		Basis for Lead Screening Level
	Value	Units		Value	Units	
Soil	543.75	mg/kg	Average Detected Value	400	mg/kg	Recommended Soil Screening Level

2. Lead Model Questions

Question	Response
What lead model was used? Provide reference and version	USEPA Adult Lead Model, Version dated 6/21/2009
If the EPA Adult Lead Model (ALM) was not used provide rationale for model selected.	N/A
Where are the input values located in the risk assessment report?	Attached as Table 11.7d
What statistics were used to represent the exposure concentration terms and where are the data on concentrations in the risk assessment that support use of these statistics?	Exposure point concentration was based on the arithmetic mean of lead concentrations in catch box ruins surface and subsurface soil
What was the point of exposure and location?	AOC 6 TNT Subareas surface and subsurface soil
Where are the output values located in the risk assessment report?	Attached as Table 11.7d
What GSD value was used? If this is outside the recommended range of 1.8-2.1), provide rationale in Appendix	Default values were used (1.8 and 2.1).
What baseline blood lead concentration (PbB_0) value was used? If this is outside the default range of 1.7 to 2.2 provide rationale in Appendix.	Default values from ALM were used (1.0 and 1.5 ug/dL).
Was the default exposure frequency (EF; 219 days/year) used?	No. A value of 125 days/year was used for the construction worker scenario, assuming duration of construction project is one-half of a year.
Was the default BKSF used (0.4 ug/dL per ug/day) used?	Yes
Was the default absorption fraction (AF; 0.12) used?	Yes
Was the default soil ingestion rate (IR; 50 mg/day) used?	No. An IR value of 100 mg/day was used, based on recommendation in the Adult Lead Model FAQs. http://www.epa.gov/superfund/lead/almfaq.htm#soil ingestion rate.
If non-default values were used for any of the parameters listed above, where is the rationale for the values located in the risk assessment report?	Discussion of parameters in HHRA Section.

3. Final Result

Medium	Result	Comment/RBRG [1]
Surface and Subsurface Soil	An input concentration value of 543.75 ppm in surface soil and subsurface soil results in geometric mean blood lead levels ranging from 2.8 to 3.3 ug/dL for women of child-bearing age in homogeneous and heterogeneous populations. The 95th percentile fetal blood lead concentrations range from 6.6 to 10 ug/dL. The probabilities that the fetal blood lead levels exceed 10 ug/dL range from 0.94% to 5.1%. The upper range of these values are slightly above the blood lead goal as described in the 1994 OSWER Directive of no more than 5% of children (fetuses of exposed women) exceeding 10 ug/dL blood lead.	PRG not calculated.

1. Attach the ALM or IEUBK spreadsheet output file upon which the Risk Based Remediation Goal (RBRG) was based and description of rationale for parameters used. For additional information, see www.epa.gov/superfund/programs/lead

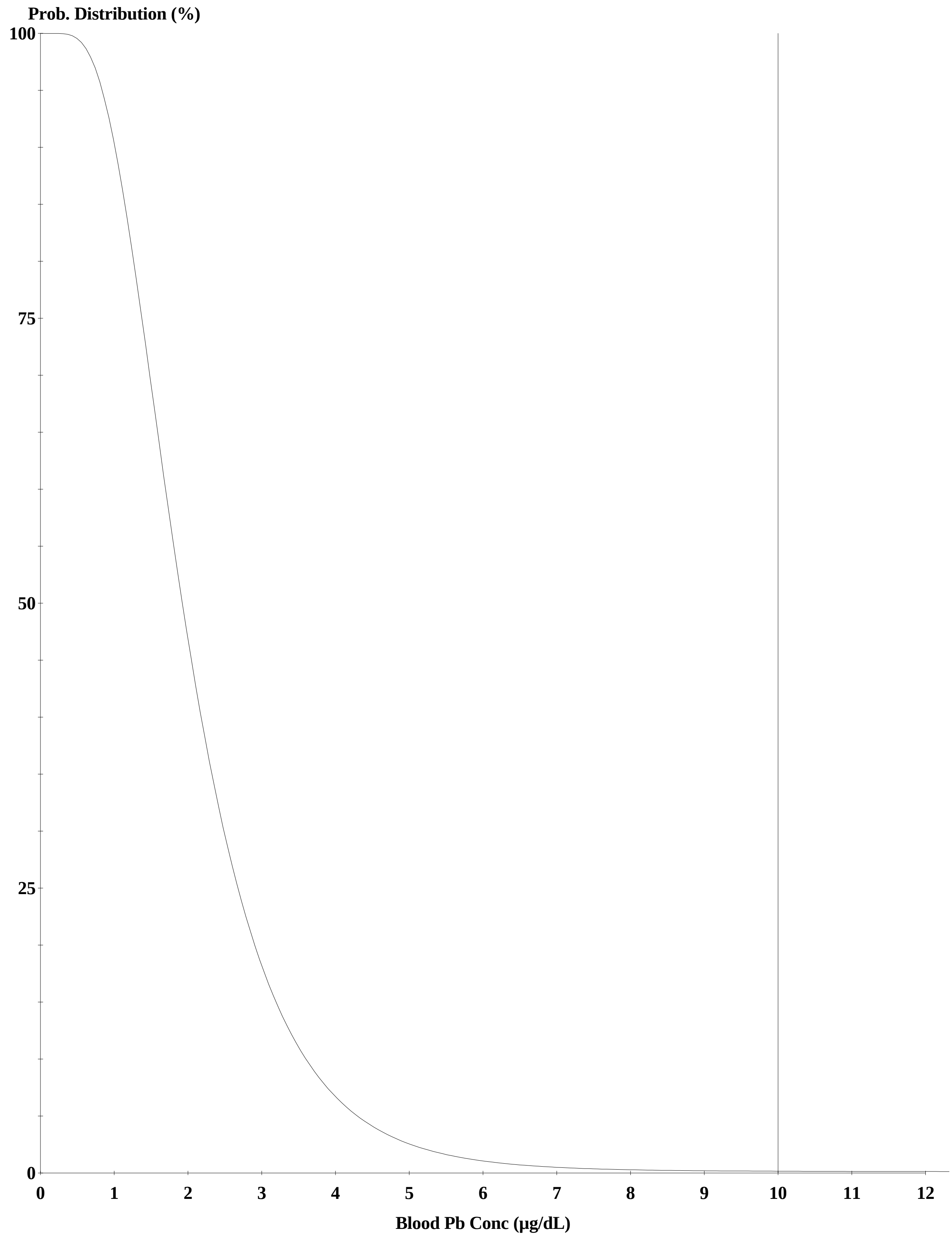
Table 11.7b
Calculations of Blood Lead Concentrations (PbBs) - AOC 6 TNT - Catch Box Ruins Surface and Subsurface Soil
Remedial Investigation
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Exposure Medium: Catch Box Ruins Surface and Subsurface Soil
Receptor: Construction Worker

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 1999-2004	GSDi and PbBo from Analysis of NHANES III (Phases 1&2)
PbS	Soil lead concentration	ug/g or ppm	543.75	543.75
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9	0.9
BKSF	Biokinetic Slope Factor	ug/dL per ug/day	0.4	0.4
GSD_i	Geometric standard deviation PbB	--	1.8	2.1
PbB_0	Baseline PbB	ug/dL	1.0	1.5
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.1	0.1
IR_{S+D}	Total ingestion rate of outdoor soil and indoor dust	g/day	--	--
W_S	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--	--
K_{SD}	Mass fraction of soil in dust	--	--	--
$AF_{S, D}$	Absorption fraction (same for soil and dust)	--	0.12	0.12
$EF_{S, D}$	Exposure frequency (same for soil and dust)	days/yr	125	125
$AT_{S, D}$	Averaging time (same for soil and dust)	days/yr	182	182
PbB_{adult}	**PbB of adult worker, geometric mean**	**ug/dL**	**2.8**	**3.3**
$PbB_{fetal, 0.95}$	95th percentile PbB among fetuses of adult workers	ug/dL	6.6	10.0
PbB_t	Target PbB level of concern (e.g., 10 ug/dL)	ug/dL	**10.0**	**10.0**
$P(PbB_{fetal} > PbB_t)$	**Probability that fetal PbB > PbB_t, assuming lognormal distribution**	**%**	**0.940%**	**5.1%**

U.S. EPA Technical Review Workgroup for Lead, Adult Lead Committee
Version date 6/21/09

Source: U.S. EPA (1996). Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil

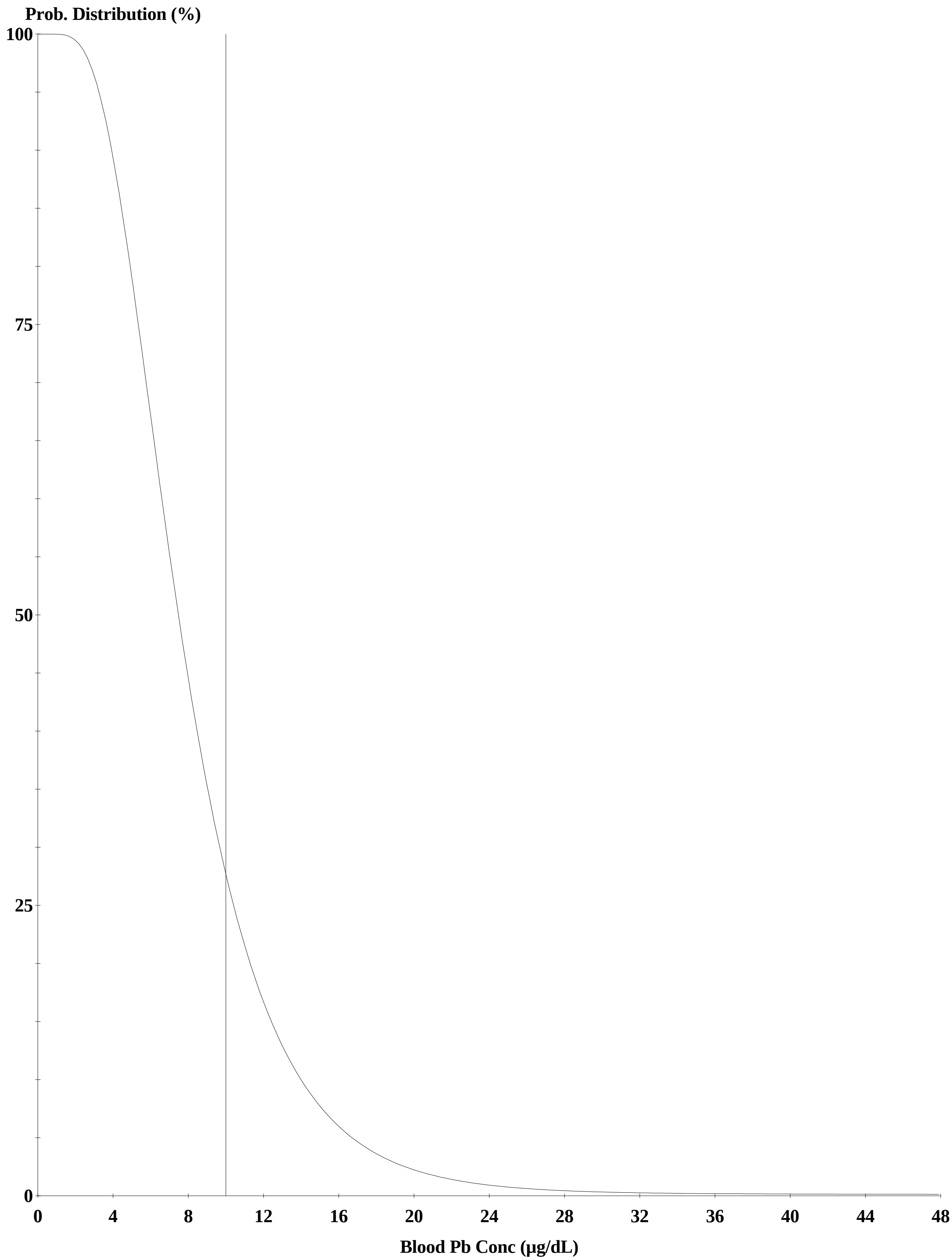


Cutoff = 10.000 µg/dl
Geo Mean = 2.016
GSD = 1.600
% Above = 0.033

Age Range = 0 to 84 months

Run Mode = Research

Figure 11-1
Surface soil across site, recreational child

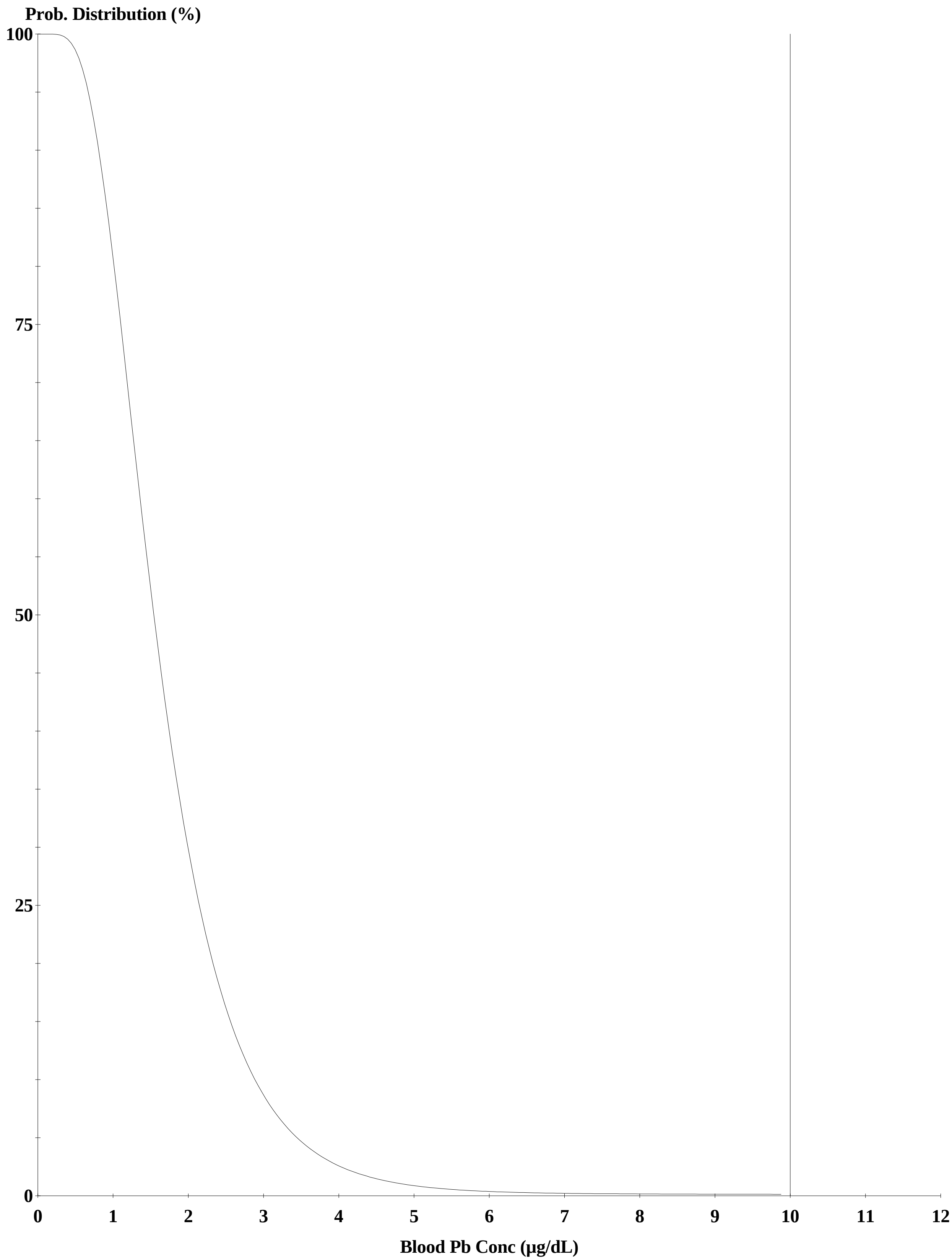


Cutoff = 10.000 µg/dl
Geo Mean = 7.834
GSD = 1.600
% Above = 30.179

Age Range = 0 to 84 months

Run Mode = Research

Figure 11-2
Catch Box Ruins Surface, recreational child

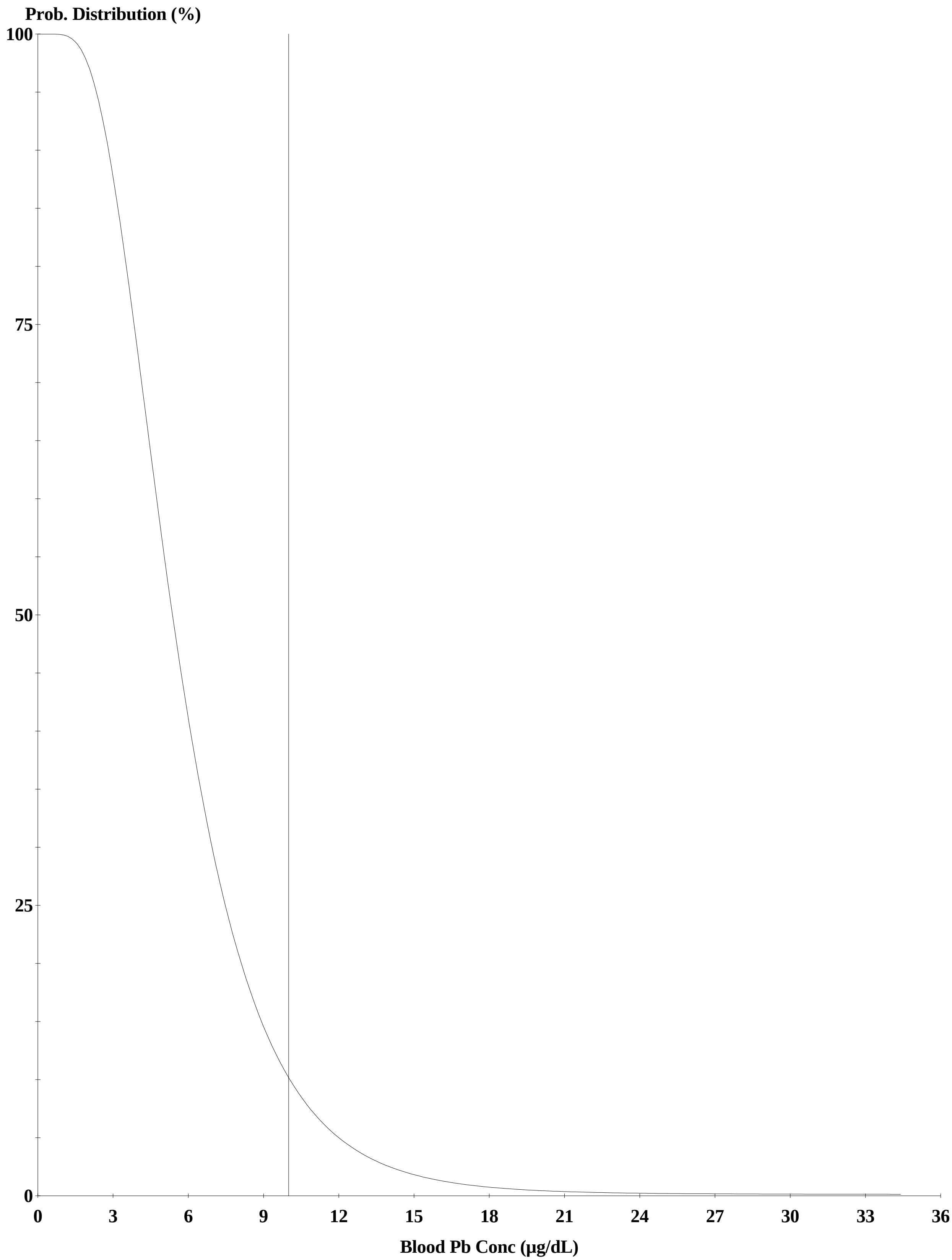


Cutoff = 10.000 µg/dl
Geo Mean = 1.616
GSD = 1.600
% Above = 0.005

Age Range = 0 to 84 months

Run Mode = Research

Figure 11-3
Recreational/Residential Child
Soil Across Site



Cutoff = 10.000 μg/dl
Geo Mean = 5.628
GSD = 1.600
% Above = 11.066

Age Range = 0 to 84 months

Run Mode = Research

Figure 11-4
Recreational/Residential Child
Catch Box Ruins Soil