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FINAL NO ACTION CONSENSUS LETTER FOR GROUNDWATER AT AREA OF CONCERN 2
NWS YORKTOWN VA
8/22/2013
CH2M HILL

Final No Action Consensus Letter for Groundwater at AOC 2, Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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DATE: August 22, 2013

This consensus letter summarizes groundwater data, human health risks, and ecological risks, and provides the rationale for no action for groundwater at the Naval Weapons Station (WPNSTA) Yorktown Cheatham Annex (CAX), Area of Concern (AOC 2), Dextrose Dump. A baseline human health risk assessment (HHRA) and screening-level ecological risk assessment (SERA) that provide support for the rationale for groundwater risk management considerations to support no action at AOC 2 are presented in this consensus letter. Soil at AOC 2 is being addressed separately, and will not be included as part of this consensus letter.

Background

AOC 2 is a small (less than 1 acre) wooded site located to the north of Garrison Road, along the southern perimeter of CAX, as depicted on **Figure 1**. AOC 2 was identified during site visits by the Navy, U.S. Environmental Protection Agency (USEPA), Virginia Department of Environmental Quality (VDEQ), and Baker Environmental, Inc. (Baker) in late 1997 and early 1998. AOC 2 consists of several rows of concrete foundation piers that at one time supported a shipping house associated with the former Penniman Shell Loading Plant (PSLP), which operated on the property now housing CAX during World War I (**Figure 2**). The majority of structures associated with the PSLP were demolished between 1918 and 1925. Grass-covered lanes leading to the site area are likely locations of former rail lines that have been removed. Several partially buried glass bottles (many of which are labeled "dextrose") and unlabeled drums were discovered in the area. Several mounds present in the area were suspected to contain buried debris (Baker, 2001). Historical information indicates the site is an unlined, non-permitted disposal area with unknown date(s) of debris disposal. Debris identified at AOC 2 includes respirator cartridge canisters, empty drums, dextrose bottles, and military clothing.

Previous Investigations

In May 1998, a routine housekeeping operation was performed at AOC 2 and a total of 470 glass bottles were removed from the ground surface. Approximately 5 percent of the bottles (24 bottles) were selected randomly and the contents analyzed, and results showed that each bottle had greater than 2,000 parts per million (ppm) of glucose, indicating that the bottles did contain dextrose, as suspected. Following the routine housekeeping operation, a field investigation was conducted in October 1998 to gain a better understanding of the nature and extent of possible contamination. Groundwater samples were collected from the Cornwallis Cave aquifer (the shallowest aquifer underlying the site) via temporary monitoring wells installed within direct push technology (DPT) soil borings. Samples were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), nitramines/nitroaromatics (explosives), inorganic constituents (total and dissolved), and cyanide. The report concluded that no VOCs, pesticides, PCBs, or explosives were detected in groundwater (Baker, 1999); however, one SVOC, diethyl phthalate, was detected and attributed to be a laboratory artifact.

During the 1998 field investigation, 12 partially buried and empty 55-gallon drums were observed at the ground surface. A subsequent investigation was conducted in November 1999 to investigate the drums and debris onsite. Six test pits were excavated. From each test pit, two soil samples were collected, one from within the debris zone and one from the native soil underneath the debris. A total of 43 drums were unearthed or collected from the ground surface. All of the drums were empty and eventually scrapped offsite. A few drums were coated with a small amount of tar or contained a small amount of tar residue on the bottom. At the request of the USEPA, a sample of the tar residue was collected and submitted for analysis for chemical warfare materials and degradation products; none were detected. Additional test pits were excavated in early 2000 to explore the extent of the buried debris materials, and four additional soil samples were collected. The report concluded that there has been very little, if any, impact to the soil or groundwater at the site and recommended delineating the extent of the debris (Baker, 2001).

Additional test trenches were excavated in 2001 to delineate the horizontal and vertical extent of the buried debris. Three separate waste areas were designated at AOC 2 depending on the type of debris present, and the waste volume for each area was calculated (**Figure 3**) (Baker, 2002).

A Site Inspection (SI) Report was completed in May 2012 with the objective to determine whether a release of hazardous constituents had occurred from past Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-related activities and, if so, determine whether a suspected release warranted further action. The SI Report concluded that no action for groundwater at AOC 2 was warranted and recommended the preparation of a consensus letter, including a risk assessment of the existing data, for CAX Partnering Team review to capture the no action recommendation (CH2M HILL, 2012).

Conceptual Site Model

The Conceptual Site Model (CSM) for groundwater at AOC 2 is based on the historical data summarized below and interprets the physical setting, distribution of contamination, potential migration pathways, and potential exposure receptor pathways. The CSM for AOC 2 is depicted on **Figure 4**.

Physical Setting

The topography of AOC 2 is predominantly flat. No wetlands or other surface water bodies are located at AOC 2, and there are no nearby water bodies downgradient of the site. Surface runoff at the site is anticipated to pond and infiltrate into the subsurface or evaporate.

The shallow aquifer underlying AOC 2 is the Cornwallis Cave Aquifer. Groundwater depths during the 1998 Field Investigation ranged from 22 to 33 feet below ground surface (bgs). Based on groundwater elevation data collected in 1998, groundwater flow is to the southeast, toward King Creek (Baker, 1999).

AOC 2 is located in a wooded area with no specified designated use (CH2M HILL, 2012). AOC 2 is not surrounded by a gate or fencing, but it is within the confines of CAX and access is restricted to the general public. Navy and Department of Defense (DoD) personnel do have access to the area, and several nearby tree stands are used for hunting. Future land use at AOC 2 is not expected to change and will likely continue as wooded/ green space for the foreseeable future.

Distribution of Groundwater Contamination

Groundwater samples were collected from four temporary monitoring wells during the 1998 Field Investigation and analyzed for VOCs, SVOCs, pesticides, PCBs, explosives, inorganic constituents (total and dissolved), and cyanide. These results were risk screened in the SI Report (CH2M HILL, 2012) and are summarized in **Table 1**; the full analytic report is provided in **Appendix A**. **Figure 5** shows the sample locations and exceedances of screening criteria for the groundwater samples.

The results were screened against base background groundwater values (95% upper tolerance limits [UTLs]) for inorganic constituents (CH2M HILL, 2011) and conservative screening values during the SI as follows:

- Federal Safe Drinking Water Act (Title 40 of the Code of Federal Regulations [CFR], Part 141) Maximum Contaminant Levels (MCLs) (groundwater)
- USEPA Regional Screening Levels (RSLs) for Tap Water (groundwater), adjusted as appropriate (for non-carcinogenic effects) (May 2012)

VOCs, SVOCs, Pesticides, PCBs, and Explosives

No VOCs, SVOCs, pesticides, PCBs, or explosives were detected at concentrations above screening criteria in the groundwater samples (**Appendix A**).

Inorganic Constituents

Fifteen total inorganic constituents (aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, thallium, vanadium, and zinc) and two dissolved inorganic constituents (arsenic and manganese) exceeded background concentrations and at least one screening criterion (adjusted Tap Water RSL and/or federal MCL) in groundwater (**Figure 5**).

Dissolved inorganic constituents data are likely more representative of inorganic constituent concentrations migrating in groundwater since the temporary well via DPT sampling method generally results in higher total inorganic constituent concentrations as a result of elevated turbidity during sampling. Maximum concentrations of dissolved arsenic and manganese detected in groundwater were 5.5J micrograms per liter (μg/L) and 317 μg/L, respectively, which exceeded screening criteria. Of these inorganic constituents that exceeded the screening criteria, no inorganic constituents exceeded the federal MCL, and only arsenic and manganese exceeded the adjusted Tap Water RSL. 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 natural source materials releases arsenic to groundwater.

Potential Migration Pathways

The source of potential contamination at AOC 2 is the historical debris that has been found within Area 2 of the site (i.e., respirator cartridge canisters and empty drums) (**Figure 3**). For Areas 1a, 1b, and 3, the debris is inert (dextrose bottles, deer carcasses, and military uniforms) and not considered a CERCLA source. Some of the Area 2 debris was removed during the 1999 investigation, with a full removal of Area 2 planned in the near future[1].

Receptors

Actual or potential exposures of human and ecological receptors associated with a site are determined by identifying the most likely, and most important, mechanisms and pathways of contaminant release and transport. A complete exposure pathway has three components: (1) a source or sources of contamination that results in a release to the environment; (2) a pathway and mechanism of chemical transport through an environmental medium; and (3) an exposure or contact point for a receptor.

The potential receptors included in the risk assessment of groundwater at AOC 2 were future adult/child residents and construction workers. No ecological receptors were evaluated during the risk assessment because there are no complete and significant exposure pathways to AOC 2 groundwater for ecological receptors.

Risk Assessment

Data for the CERCLA-related constituents identified at AOC 2 were compared to the screening criteria described above and identified on the detection table (**Table 1)**. Those constituents that exceeded one or more criteria (and background concentrations for inorganic constituents, if available) are shown on **Figure 5**. A baseline HHRA and SERA were completed to determine if any potential unacceptable risks associated with groundwater are present at AOC 2.

[1] The CAX Partnering Team agreed during the May 2011 Partnering meeting that the dextrose bottles and military clothing are inert and not CERCLA-related, and therefore will not be removed.

Human Health Risk Assessment Summary

The primary objective of the baseline HHRA is to assess the potential human health risks from contamination associated with groundwater at AOC 2. Groundwater data were evaluated in the risk assessment to characterize potential current and future risks based on current site conditions.

The risk assessment evaluated the carcinogenic risks and noncarcinogenic hazards to a reasonably maximally-exposed individual, which is consistent with the National Contingency Plan and the Risk Assessment Guidance for Superfund (RAGS) HHRA guidance documents (USEPA 1989, 2001, 2004, and 2009) and Chief of Naval Operations guidance document (CNO, 2001). 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 USEPA 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 baseline HHRA is presented as **Appendix B** of this consensus letter.

Potential Human Receptors and Exposure Scenarios

The preliminary CSM for human exposures presents an overview of site conditions, potential sources of contamination, potential contaminant-migration pathways, and potential exposure pathways to potential receptors. **Figure 4** presents the overall CSM for AOC 2, and **Figure B-1** in **Appendix B** presents the preliminary CSM for human exposures developed for AOC 2.

There are no potential current receptors exposed to groundwater at AOC 2. No future use of groundwater is planned at this time; however, the risk assessment conservatively assumed that in the unlikely event future residential development of the site occurs, the residents could use the groundwater as a potable water supply. Therefore, risks associated with groundwater were evaluated assuming future residential potable use as the most conservative case. Additionally, it was assumed that construction workers could be exposed to groundwater during any excavation activities.

HHRA Results

In accordance with the USEPA Region 3 guidance, filtered groundwater samples were used to determine inorganic constituent exposure concentrations for the residential scenarios because a review of the groundwater data determined a significant difference (an order of magnitude or greater) between the filtered (dissolved) and total results within each sample. Unfiltered groundwater samples were used to determine inorganic constituent exposure concentrations for the construction worker scenario, as a construction worker would directly contact the groundwater in an excavation.

The only RME scenario with a potentially unacceptable hazard is contact with unfiltered groundwater by future construction workers, which exceeds USEPA’s target hazard index (HI) of 1 because of dermal contact with chromium. However, the CTE scenario does not exceed USEPA’s target HI of 1, and chromium was not detected in any of the four filtered samples.

Additionally, in the absence of chromium speciation information, the toxicity values for hexavalent chromium, the more toxic form of chromium, were used to calculate the risks for total chromium. The use of hexavalent chromium toxicity values for total chromium is extremely conservative since the presence of trivalent chromium is strongly favored in natural waters because the concentrations of constituents known to reduce hexavalent chromium to trivalent chromium generally far outweigh the concentrations of the few constituents known to oxidize trivalent chromium to hexavalent chromium. Furthermore, once reduced, trivalent chromium is very stable in aquatic environments and highly unlikely to oxidize to hexavalent chromium. Thus, chromium in groundwater is more likely to be in its trivalent form than in its hexavalent form (Fendorf and Zasoski, 1992; Milacic and Stupar, 1995; and Weaver and Hochella, 2003). The maximum detected concentration of total chromium in the groundwater was below the Tap Water RSL for trivalent chromium.

Ecological Risk Assessment Summary

A SERA, constituting Step 1 of the ERA process, was completed for AOC 2 groundwater in accordance with the *Navy Policy for Conducting Ecological Risk Assessments* (CNO, 1999) and the Navy guidance for implementing this ERA policy (Naval Facilities Engineering Command, 2003). The Navy ERA policy and guidance, which describe a process consisting of eight steps organized into three tiers, are conceptually similar to the eight-step ERA process outlined in USEPA ERA guidance for the Superfund program (USEPA, 1997). For both sets of guidance, Steps 1 and 2 involve conducting a SERA using very conservative assumptions. The complete SERA is presented as **Appendix C** of this consensus letter.

The screening (preliminary) problem formulation is the first step of an ERA and establishes the goals, scope, and focus of the SERA. Step 1 of the ERA process is intended to answer two main questions:

- Do complete exposure pathways exist?
- Are sufficient data available to conduct the SERA?

If no complete exposure pathways exist, the ERA process terminates at Step 1 with a conclusion of negligible (acceptable) risk because exposure, and thus potential risk, can only occur if complete exposure pathways exist.

As part of problem formulation, the ecological setting of AOC 2 was characterized in terms of the habitats and biota known or likely to be present. The types and concentrations of chemicals that are present in ecologically relevant media were also described based upon available analytical data for complete exposure pathways.

Potential Ecological Receptors and Exposure Scenarios

A transport pathway describes the mechanisms whereby site-related chemicals, once released, may be transported from a source to ecologically relevant media where exposures may occur. Groundwater is generally considered only as a transport medium since there are no ecological exposures to groundwater until it discharges to a water body or surfaces as a seep. The primary potential release mechanisms and transport pathways at AOC 2 related to groundwater include:

- Infiltration, percolation, and leaching of contaminants to groundwater and subsequent discharge to the surface water and sediment of downgradient water bodies

Given the small size of the site, the relatively small amount of documented debris, and the nature of the debris (as described in **Section C.2.1** of **Appendix C**), as well as the distance from AOC 2 to the nearest water body (King Creek; about 2,000 feet southeast of AOC 2), the potential for substantive transport of site-related constituents to King Creek via groundwater is not considered significant. Thus, this transport pathway is not considered to be complete and significant for ecological receptors.

ERA Results

Groundwater is not a significant transport medium for site-related constituents to King Creek because this pathway is not considered to be complete and significant for ecological receptors. There are no complete and significant exposure pathways to AOC 2 groundwater for ecological receptors. Thus, based upon ERA guidance (CNO, 1999; Naval Facilities Engineering Command, 2003; and USEPA, 1997) (see **Section C.1.1** of **Appendix C**), the ERA process terminates with a conclusion of no unacceptable risk.

Summary

The SI affirmed that groundwater at AOC 2 has been sufficiently characterized as well as the horizontal extent of the debris during the previous field investigations and trenching activities, and the available groundwater data are acceptable to recommend no action. In groundwater, 15 total inorganic constituents (aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, thallium, vanadium, and zinc) and two dissolved inorganic constituents (arsenic and manganese) exceeded background concentrations and at least one screening criterion. Results from the groundwater sampling indicate potential human health risks associated with exposure to aluminum, arsenic, beryllium, cadmium, chromium, cobalt, iron, lead, manganese, thallium, and vanadium. Of these 11 total inorganic constituents that pose potential human health risks, only arsenic and manganese were detected in the dissolved phase.

In accordance with USEPA Region 3 guidance, filtered groundwater samples (dissolved phase samples) were used to determine inorganic constituent exposure concentrations for the residential scenarios because a review of the groundwater data showed a significant difference (an order of magnitude or greater) between the filtered and total (unfiltered) results within each sample. Unfiltered groundwater samples were used to determine inorganic constituent exposure concentrations for the construction worker scenario because a construction worker would directly contact the groundwater in an excavation.

No potential unacceptable risk for groundwater at AOC 2 was identified for the future adult/child resident scenario. Potential unacceptable risk for groundwater at AOC 2 was identified for the construction worker scenario, due to potential exposure resulting in dermal contact with chromium. However, this potential risk was identified assuming that the chromium in groundwater at AOC 2 is hexavalent chromium, which is the most conservative scenario, whereas the chromium in groundwater is more likely present in the form of trivalent chromium. In addition, the maximum detected concentration of total chromium in the groundwater was below the Tap Water RSL for trivalent chromium. Also, the exposure frequency used during this evaluation of 125 days for the construction worker scenario is very conservative, and it is likely that any groundwater present in an excavation would be pumped out while performing construction activities.

Potential risk identified during the 2012 SI for AOC 2 warrants no action based on the following:

- Of the 15 total inorganic constituents that exceeded at least one screening criterion, only arsenic and manganese were detected in the dissolved phase in groundwater, which is more representative of inorganic concentrations potentially migrating in groundwater. In addition, none of the inorganic constituents detected in the dissolved phase in groundwater exceeded the federal MCLs. No potential unacceptable risk associated with groundwater at AOC 2 was identified for the future adult/child resident scenario.
- Although potential unacceptable human health risk was identified for the construction worker scenario based on an RME HI greater than 1 associated with concentrations of total chromium in groundwater, the CTE scenario does not exceed USEPA's target HI of 1, and chromium was not detected in any of the four filtered samples. In addition, the evaluated construction worker scenario is very conservative, and chromium in groundwater at AOC 2 is more likely to be trivalent chromium and not hexavalent chromium, for which the potential unacceptable risk was identified.
- Groundwater is not a significant transport medium for site-related constituents to King Creek because this pathway is not considered to be complete and significant for ecological receptors; therefore, there is no unacceptable ecological risk associated with groundwater at AOC 2.
- Future land use at AOC 2 is not expected to change and will likely continue as wooded/green space for the foreseeable future.
- Groundwater is not a source of potable water at AOC 2 or CAX, and there is no future or potential planned use for groundwater as a source of potable water in the vicinity.

No Action Groundwater Risk Management Consensus

The Navy, in partnership with the USEPA and VDEQ, has determined that AOC 2 groundwater poses no potential unacceptable risk to human health and the environment and that no action is required for groundwater.

Mr. Scott Park;
NAVFAC Mid-Atlantic — Scott R. Park — Date 9-18-13

Mr. Gerald Hoover;
USEPA Region 3 — Gerald P. Hoover — Date 9-18-13

Mr. Wade Smith;
VDEQ — [signature] — Date 09/18/2013

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Table

TABLE 1

AOC 2 Groundwater Detection and Exceedance Results

AOC 2 NFA Consensus Letter for Groundwater

Cheatham Annex

Williamsburg, Virginia

Station ID	CLEAN CAX BKG GW CC AQUIFER	CLEAN MCL-Groundwater (Dec. 2010)	CLEAN RSLs Tapwater Adjusted (May 2012)	CAA02-A2DPW01	CAA02-A2DPW02	CAA02-A2DPW03		CAA02-A2DPW04
Sample ID				CAA02-A2DPW01-1098	CAA02-A2DPW02-1098	CAA02-A2DPW03-1098	CAA02-A2DPW03P-1098	CAA02-A2DPW04-1098
Sample Date				10/22/98	10/22/98	10/22/98	10/22/98	10/22/98
Chemical Name								
Volatile Organic Compounds (UG/L)								
No Detections								
Semivolatile Organic Compounds (UG/L)								
Diethylphthalate	--	--	1,100	**1 J**	10 U	10 U	10 U	10 U
Pesticide/Polychlorinated Biphenyls (UG/L)								
No Detections								
Explosives (UG/L)								
No Detections								
Total Metals (UG/L)								
Aluminum	2,230	--	1,600	**189,000**	**59,300**	**2,110**	**2,210**	**96,700**
Antimony	18.8	6	0.6	**13.8**	**7.7**	2.4 U	2.4 U	**11.3**
Arsenic	2.28	10	0.045	**181**	**89.9**	**3.7 J**	**5.1 J**	**430**
Barium	118	2,000	290	**510**	**195 J**	**36.5 J**	**38.3 J**	**275**
Beryllium	2.45	4	1.6	**9.6**	**3.3 J**	0.2 U	0.2 U	**5.7**
Cadmium	0.605	5	0.69	**8.7**	**5.9**	4.3 U	4.3 U	**6.5**
Calcium	158,000	--	--	**2,520,000**	**722,000**	**153,000**	**160,000**	**1,230,000**
Chromium	15.1	100	0.031	**595**	**229**	**9.6 J**	**10**	**364**
Cobalt	20.6	--	0.47	**73.7**	**32.2 J**	6.3 U	6.3 U	**45.6 J**
Copper	12.2	1,300	62	**99.5**	**37**	4.1 U	4.1 U	**45.9**
Iron	3,590	--	1,100	**380,000**	**133,000**	**5,550**	**5,630**	**262,000**
Lead	21.3	15	15	**94.6**	**36.1**	1 U	1.2 B	**53.7**
Magnesium	3,600	--	--	**51,900**	**17,900**	**2,270**	**2,340**	**31,800**
Manganese	57.9	--	32	**1,360**	**394**	**36.7**	**37.5**	**684**
Nickel	11.4	--	30	**170**	**70.7**	9.6 U	9.6 U	**109**
Potassium	3,490	--	--	**55,400**	**18,800**	**1,780 J**	**1,710 J**	**36,500**
Selenium	--	50	7.8	2.2 U	**4.6 K**	2.2 U	**2.9 K**	2.2 U
Sodium	9,920	--	--	**18,900**	**12,600**	**7,190**	**7,290**	**13,100**
Thallium	--	2	0.016	**1.2 L**	**2 J**	1.2 U	1.2 U	1.2 U
Vanadium	26.2	--	7.8	**417**	**205**	**6.1 J**	**4.8 J**	**309**
Zinc	4.52	--	470	**667**	**264**	**13.5 J**	**13.3 J**	**424**
Dissolved Metals (UG/L)								
Aluminum, Dissolved	100	--	1,600	**210**	**172 J**	**167 J**	**193 J**	**159 J**
Arsenic, Dissolved	1.37	10	0.045	**2.4 J**	**3.6 J**	1.8 U	1.8 U	**5.5 J**
Barium, Dissolved	127	2,000	290	**35.2 J**	**36.4 J**	**27.3 J**	**27 J**	**23.2 J**
Calcium, Dissolved	148,000	--	--	**158,000**	**143,000**	**132,000**	**132,000**	**133,000**
Copper, Dissolved	3	1,300	62	4.1 U	**4.2 J**	4.1 U	**4.5 J**	**6.5 J**
Iron, Dissolved	631	--	1,100	**56.6 J**	**53.2 J**	**92.7 J**	**86.2 J**	**208**
Magnesium, Dissolved	3,880	--	--	**2,240**	**3,730**	**1,600**	**1,620**	**1,710**
Manganese, Dissolved	49.5	--	32	**164**	**317**	**24.1**	**23.8**	**25**
Potassium, Dissolved	1,710	--	--	**1,000 J**	**2,060 J**	**869 J**	**861 J**	**1,060 J**
Selenium, Dissolved	9.1	50	7.8	2.2 U	**7.5 K**	2.2 U	2.2 U	2.2 U
Sodium, Dissolved	10,000	--	--	**6,980**	**9,840**	**7,040**	**6,910**	**6,080**
Zinc, Dissolved	--	--	470	**7.1 J**	**8 J**	6.8 U	**11.8 J**	**7.5 J**

Notes:

Exceeds Background (BKG)

Exceeds BKG & Tapwater RSL

Exceeds BKG & MCL

Exceeds BKG, Tapwater RSL & MCL

Bold indicates detection

-- - No value available

B - Analyte not detected above the level reported in blanks

J - Analyte present, value may or may not be accurate or precise

K - Analyte present, value may be biased high, actual value may be lower

L - Analyte present, value may be biased low, actual value may be higher

U - Analyte not detected

UG/L - Micrograms per liter

Figures

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVFACENGCOM405450\CHEATHAMANNEX\MAPFILES\388429_AOC2_NFACONSENSUS\FIGURE 1 - LOCATION OF CHEATHAM ANNEX.MXD BHATHAWAY 8/16/2012 1:34:31 PM

Legend
- Study Area Boundary
- Activity Boundaries
- City/County Boundaries

N W E S

0 0.6 1.2 Miles

Figure 1
Base and AOC 2 Location Map
AOC 2 NFA Consensus Letter for Groundwater
Cheatham Annex
Williamsburg, Virginia

CH2MHILL

Legend

- Concrete Piers
- Study Area Boundary
- CAX Boundary / Fenceline
- Berm
- Topographic Surface Contour (feet above mean sea level)

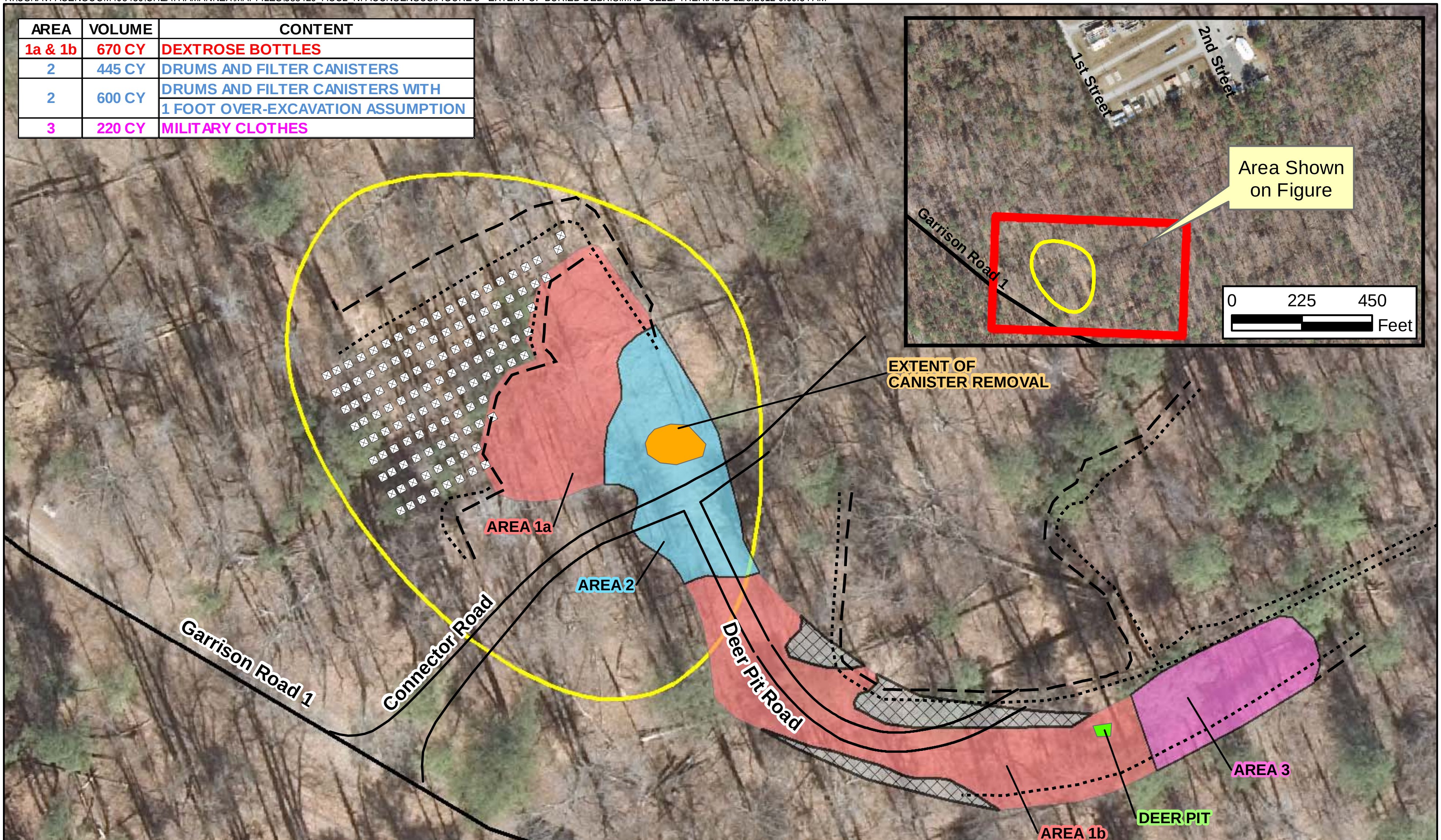
N W E S

0 25 50 Feet

Figure 2
AOC 2 - Dextrose Dump
AOC 2 NFA Consensus Letter for Groundwater
Cheatham Annex
Williamsburg, Virginia

CH2MHILL.

AREA	VOLUME	CONTENT
1a & 1b	670 CY	DEXTROSE BOTTLES
2	445 CY	DRUMS AND FILTER CANISTERS
2	600 CY	DRUMS AND FILTER CANISTERS WITH 1 FOOT OVER-EXCAVATION ASSUMPTION
3	220 CY	MILITARY CLOTHES



Legend

- Study Area Boundary
- CAX Boundary / Fenceline
- Concrete Piers
- Top of Bank
- Toe of Slope

N W E S

0 30 60 Feet

Figure 3
Extent of Buried Debris
AOC 2 NFA Consensus Letter for Groundwater
Cheatham Annex
Williamsburg, Virginia

CH2MHILL

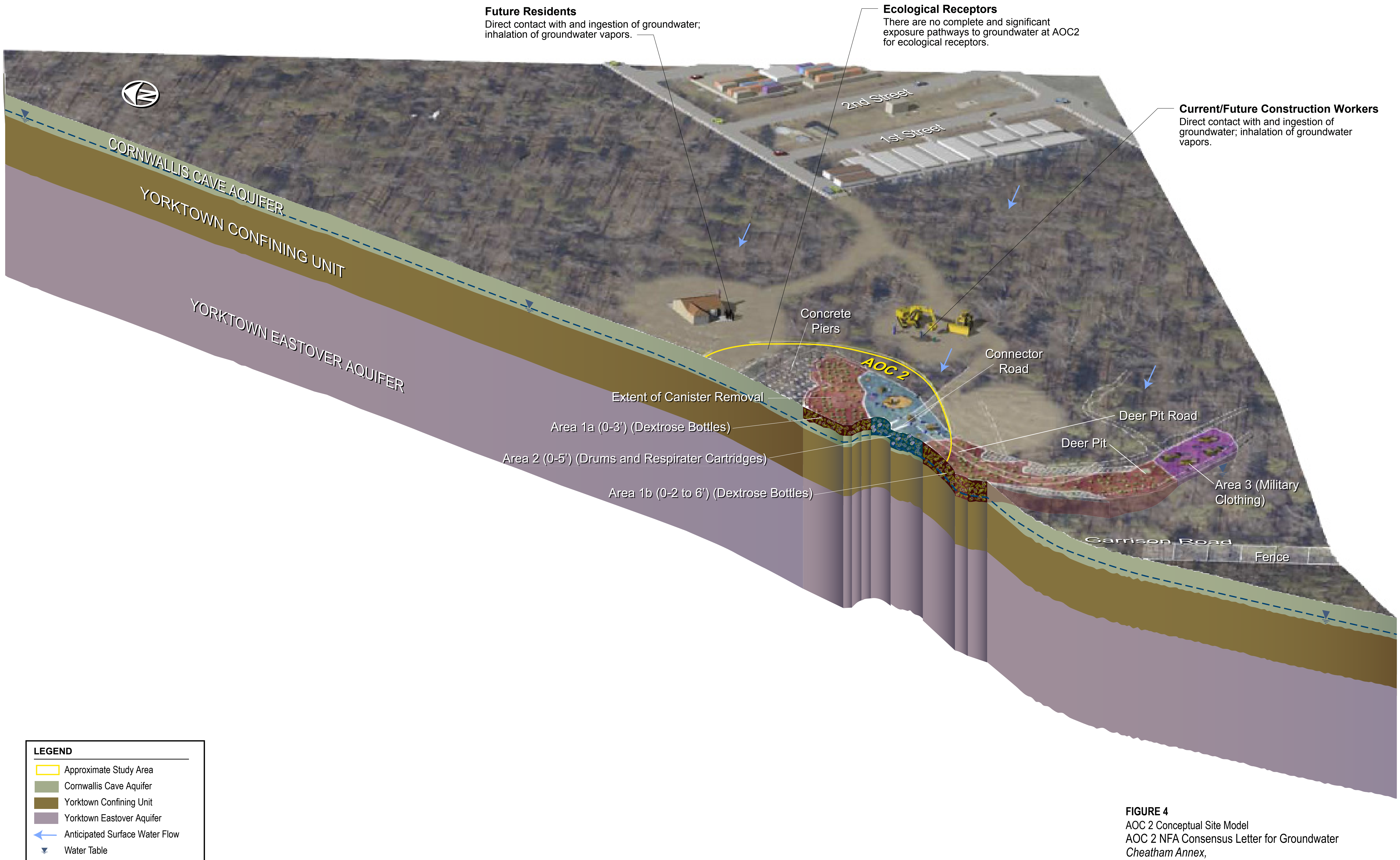


FIGURE 4
AOC 2 Conceptual Site Model
AOC 2 NFA Consensus Letter for Groundwater
Cheatham Annex,
Williamsburg, Virginia

ES033011003122VBO CSMCAXAOC_Fig3_CSM_Site_AOC2_rev1.ai 09/14/12 LED/ct

CH2MHILL

DVR \\MNUSTRICTGFS01\PROJECTS\USNAVFACENGCOM405450\CHEATHAMANNEX\MAPFILES\388429_AOC2_NFACONSENSUS\FIGURE 5 - GROUNDWATER SAMPLE LOCATIONS.MXD CELEFTHERIADIS 12/5/2012 9:03:16 AM

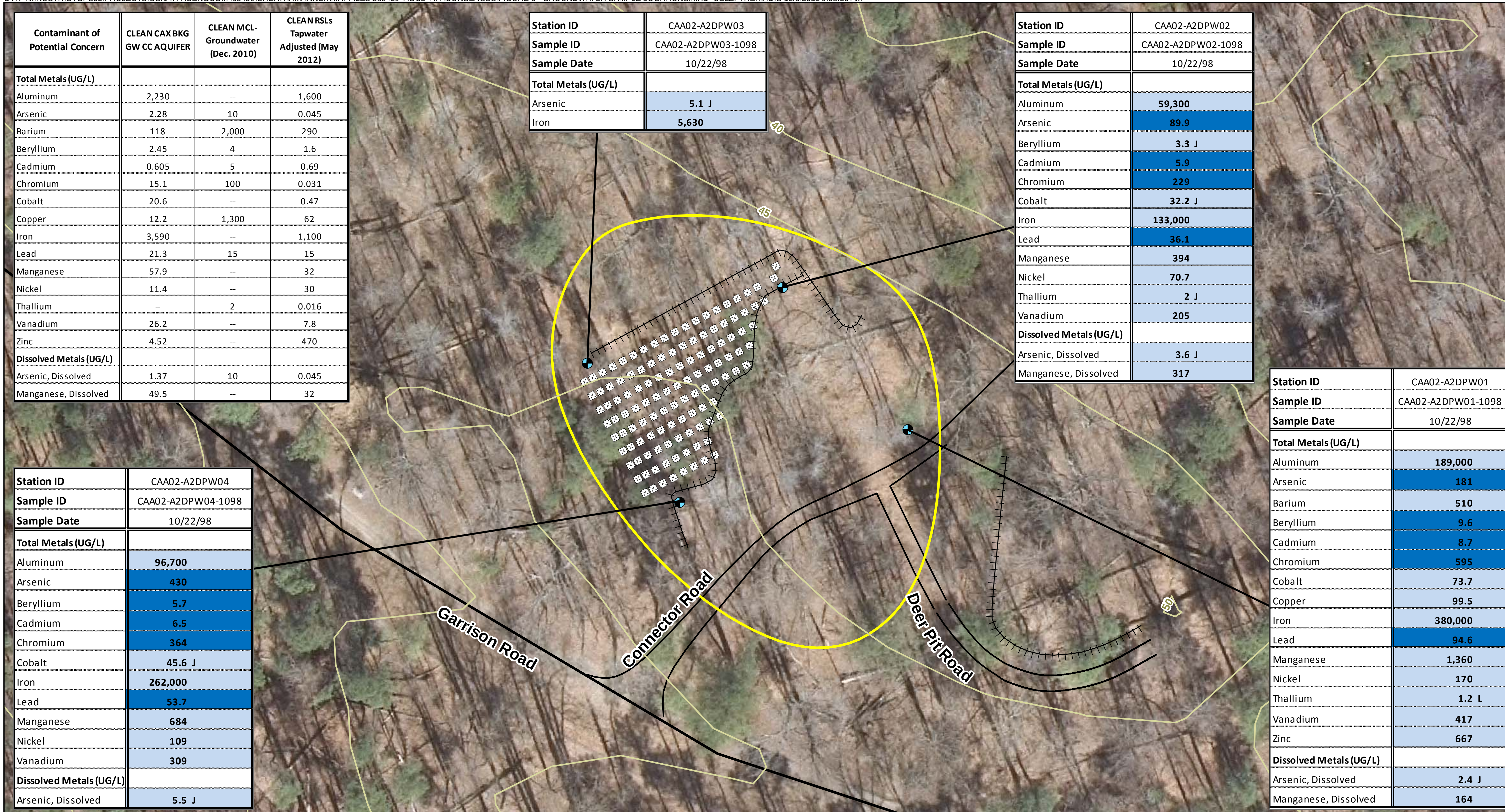
Contaminant of Potential Concern	CLEAN CAX BKG GW CC AQUIFER	CLEAN MCL-Groundwater (Dec. 2010)	CLEAN RSLs Tapwater Adjusted (May 2012)
Total Metals (UG/L)			
Aluminum	2,230	--	1,600
Arsenic	2.28	10	0.045
Barium	118	2,000	290
Beryllium	2.45	4	1.6
Cadmium	0.605	5	0.69
Chromium	15.1	100	0.031
Cobalt	20.6	--	0.47
Copper	12.2	1,300	62
Iron	3,590	--	1,100
Lead	21.3	15	15
Manganese	57.9	--	32
Nickel	11.4	--	30
Thallium	--	2	0.016
Vanadium	26.2	--	7.8
Zinc	4.52	--	470
Dissolved Metals (UG/L)			
Arsenic, Dissolved	1.37	10	0.045
Manganese, Dissolved	49.5	--	32

Station ID	CAA02-A2DPW03
Sample ID	CAA02-A2DPW03-1098
Sample Date	10/22/98
Total Metals (UG/L)	
Arsenic	5.1 J
Iron	5,630

Station ID	CAA02-A2DPW02
Sample ID	CAA02-A2DPW02-1098
Sample Date	10/22/98
Total Metals (UG/L)	
Aluminum	59,300
Arsenic	89.9
Beryllium	3.3 J
Cadmium	5.9
Chromium	229
Cobalt	32.2 J
Iron	133,000
Lead	36.1
Manganese	394
Nickel	70.7
Thallium	2 J
Vanadium	205
Dissolved Metals (UG/L)	
Arsenic, Dissolved	3.6 J
Manganese, Dissolved	317

Station ID	CAA02-A2DPW04
Sample ID	CAA02-A2DPW04-1098
Sample Date	10/22/98
Total Metals (UG/L)	
Aluminum	96,700
Arsenic	430
Beryllium	5.7
Cadmium	6.5
Chromium	364
Cobalt	45.6 J
Iron	262,000
Lead	53.7
Manganese	684
Nickel	109
Vanadium	309
Dissolved Metals (UG/L)	
Arsenic, Dissolved	5.5 J

Station ID	CAA02-A2DPW01
Sample ID	CAA02-A2DPW01-1098
Sample Date	10/22/98
Total Metals (UG/L)	
Aluminum	189,000
Arsenic	181
Barium	510
Beryllium	9.6
Cadmium	8.7
Chromium	595
Cobalt	73.7
Copper	99.5
Iron	380,000
Lead	94.6
Manganese	1,360
Nickel	170
Thallium	1.2 L
Vanadium	417
Zinc	667
Dissolved Metals (UG/L)	
Arsenic, Dissolved	2.4 J
Manganese, Dissolved	164



Legend
- Groundwater Sample Locations
- Concrete Piers
- Study Area Boundary
- CAX Boundary / Fenceline
- Berm
- Topographic Surface Contour (feet above mean sea level)

Notes:
- **Exceeds BKG and Tapwater RSL**
- **Exceeds BKG and MCL**
- **Exceeds BKG, Tapwater RSL, and MCL**

-- - No value available
B - Analyte not detected above the level reported in blanks
J - Analyte present, value may or may not be accurate or precise
K - Analyte present, value may be biased high, actual value may be lower
L - Analyte present, value may be biased low, actual value may be higher
U - Analyte not detected
UG/L - Micrograms per liter

Figure 5
Groundwater Sample Locations and Exceedances
AOC 2 NFA Consensus Letter for Groundwater
Cheatham Annex
Williamsburg, Virginia

CH2MHILL.

Appendix A
Laboratory Analytical Data

Station ID	CAA02-A2DPW01	CAA02-A2DPW02	CAA02-A2DPW03		CAA02-A2DPW04
Sample ID	CAA02-A2DPW01-1098	CAA02-A2DPW02-1098	CAA02-A2DPW03-1098	CAA02-A2DPW03P-1098	CAA02-A2DPW04-1098
Sample Date	10/22/98	10/22/98	10/22/98	10/22/98	10/22/98
Chemical Name					
Volatile Organic Compounds (UG/L)					
1,1,1-Trichloroethane	10 U	10 UL	10 UL	10 UL	10 UL
1,1,2,2-Tetrachloroethane	10 U	10 UL	10 UL	10 UL	10 UL
1,1,2-Trichloroethane	10 U	10 UL	10 UL	10 UL	10 UL
1,1-Dichloroethane	10 U	10 UL	10 UL	10 UL	10 UL
1,1-Dichloroethene	10 U	10 UL	10 UL	10 UL	10 UL
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,2-Dichloroethane	10 U	10 UL	10 UL	10 UL	10 UL
1,2-Dichloroethene (total)	10 U	10 UL	10 UL	10 UL	10 UL
1,2-Dichloropropane	10 U	10 UL	10 UL	10 UL	10 UL
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U
2-Butanone	10 U	10 UL	10 UL	10 UL	10 UL
2-Hexanone	10 U	10 UL	10 UL	10 UL	10 UL
4-Methyl-2-pentanone	10 U	10 UL	10 UL	10 UL	10 UL
Acetone	10 U	10 UL	10 UL	10 UL	10 UL
Benzene	10 U	10 UL	10 UL	10 UL	10 UL
Bromodichloromethane	10 U	10 UL	10 UL	10 UL	10 UL
Bromoform	10 U	10 UL	10 UL	10 UL	10 UL
Bromomethane	10 U	10 UL	10 UL	10 UL	10 UL
Carbon disulfide	10 U	10 UL	10 UL	10 UL	10 UL
Carbon tetrachloride	10 U	10 UL	10 UL	10 UL	10 UL
Chlorobenzene	10 U	10 UL	10 UL	10 UL	10 UL
Chloroethane	10 U	10 UL	10 UL	10 UL	10 UL
Chloroform	10 U	10 UL	10 UL	10 UL	10 UL
Chloromethane	10 U	10 UL	10 UL	10 UL	10 UL
cis-1,3-Dichloropropene	10 U	10 UL	10 UL	10 UL	10 UL
Dibromochloromethane	10 U	10 UL	10 UL	10 UL	10 UL
Ethylbenzene	10 U	10 UL	10 UL	10 UL	10 UL
Methylene chloride	10 U	10 UL	10 UL	10 UL	10 UL
Styrene	10 U	10 UL	10 UL	10 UL	10 UL
Tetrachloroethene	10 U	10 UL	10 UL	10 UL	10 UL
Toluene	10 U	10 UL	10 UL	10 UL	10 UL
trans-1,3-Dichloropropene	10 U	10 UL	10 UL	10 UL	10 UL
Trichloroethene	10 U	10 UL	10 UL	10 UL	10 UL
Vinyl chloride	10 U	10 UL	10 UL	10 UL	10 UL
Xylene, total	10 U	10 UL	10 UL	10 UL	10 UL
Semivolatile Organic Compounds (UG/L)					
2,4,5-Trichlorophenol	25 U	25 U	25 U	25 U	25 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U
2,4-Dinitrophenol	25 U	25 U	25 U	25 U	25 U
2,4-Dinitrotoluene	1 U	1 U	1 U	1 U	1 U
2,6-Dinitrotoluene	1 U	1 U	1 U	1 U	1 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U
2-Nitroaniline	25 U	25 U	25 U	25 U	25 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	10 U	10 U	10 U	10 U	10 U
3-Nitroaniline	25 U	25 U	25 U	25 U	25 U
4,6-Dinitro-2-methylphenol	25 U	25 U	25 U	25 U	25 U
4-Bromophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
4-Chloro-3-methylphenol	10 U	10 U	10 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U
4-Chlorophenyl-phenylether	10 U	10 U	10 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U
4-Nitroaniline	25 U	25 U	25 U	25 U	25 U
4-Nitrophenol	25 U	25 U	25 U	25 U	25 U
Acenaphthene	10 U	10 U	10 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U
Anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(a)anthracene	10 U	10 U	10 U	10 U	10 U
Benzo(a)pyrene	10 U	10 U	10 U	10 U	10 U
Benzo(b)fluoranthene	10 U	10 U	10 U	10 U	10 U
Benzo(g,h,i)perylene	10 U	10 U	10 U	10 U	10 U
Benzo(k)fluoranthene	10 U	10 U	10 U	10 U	10 U
bis(2-Chloroethoxy)methane	10 U	10 U	10 U	10 U	10 U

Appendix A
AOC 2 Groundwater Analytical Results

Station ID	CAA02-A2DPW01	CAA02-A2DPW02	CAA02-A2DPW03		CAA02-A2DPW04
Sample ID	CAA02-A2DPW01-1098	CAA02-A2DPW02-1098	CAA02-A2DPW03-1098	CAA02-A2DPW03P-1098	CAA02-A2DPW04-1098
Sample Date	10/22/98	10/22/98	10/22/98	10/22/98	10/22/98
Chemical Name					
bis(2-Chloroethyl)ether	10 U	10 U	10 U	10 U	10 U
bis(2-Chloroisopropyl)ether	10 U	10 U	10 U	10 U	10 U
bis(2-Ethylhexyl)phthalate	3 B	2 B	1 B	2 B	2 B
Butylbenzylphthalate	10 U	10 U	10 U	10 U	10 U
Carbazole	10 U	10 U	10 U	10 U	10 U
Chrysene	10 U	10 U	10 U	10 U	10 U
Dibenz(a,h)anthracene	10 U	10 U	10 U	10 U	10 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U
Diethylphthalate	1 J	10 U	10 U	10 U	10 U
Dimethyl phthalate	10 U	10 U	10 U	10 U	10 U
Di-n-butylphthalate	10 U	10 U	10 U	10 U	10 U
Di-n-octylphthalate	10 U	10 U	10 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U
Fluorene	10 U	10 U	10 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U
Indeno(1,2,3-cd)pyrene	10 U	10 U	10 U	10 U	10 U
Isophorone	10 U	10 U	10 U	10 U	10 U
Naphthalene	10 U	10 U	10 U	10 U	10 U
n-Nitroso-di-n-propylamine	10 U	10 U	10 U	10 U	10 U
n-Nitrosodiphenylamine	10 U	10 U	10 U	10 U	10 U
Nitrobenzene	1 U	1 U	1 U	1 U	1 U
Pentachlorophenol	25 U	25 U	25 U	25 U	25 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U
Phenol	10 U	10 U	10 U	10 U	10 U
Pyrene	10 U	10 U	10 U	10 U	10 U
Pesticide/Polychlorinated Biphenyls (UG/L)					
4,4'-DDD	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
4,4'-DDE	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
4,4'-DDT	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
Aldrin	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
alpha-BHC	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
alpha-Chlordane	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
Aroclor-1016	1 UJ	1 UJ	1 UJ	1 R	1 R
Aroclor-1221	2 UJ	2 UJ	2 UJ	2 R	2 R
Aroclor-1232	1 UJ	1 UJ	1 UJ	1 R	1 R
Aroclor-1242	1 UJ	1 UJ	1 UJ	1 R	1 R
Aroclor-1248	1 UJ	1 UJ	1 UJ	1 R	1 R
Aroclor-1254	1 UJ	1 UJ	1 UJ	1 R	1 R
Aroclor-1260	1 UJ	1 UJ	1 UJ	1 R	1 R
beta-BHC	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
delta-BHC	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
Dieldrin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
Endosulfan I	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
Endosulfan II	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
Endosulfan sulfate	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
Endrin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
Endrin aldehyde	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
Endrin ketone	0.1 UJ	0.1 UJ	0.1 UJ	0.1 R	0.1 R
gamma-BHC (Lindane)	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
gamma-Chlordane	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
Heptachlor	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
Heptachlor epoxide	0.05 UJ	0.05 UJ	0.05 UJ	0.05 R	0.05 R
Methoxychlor	0.5 UJ	0.5 UJ	0.5 UJ	0.5 R	0.5 R
Toxaphene	5 UJ	5 UJ	5 UJ	5 R	5 R
Explosives (UG/L)					
1,3,5-Trinitrobenzene	1 U	1 U	1 U	1 U	1 U
1,3-Dinitrobenzene	1 U	1 U	1 U	1 U	1 U
2,4,6-Trinitrotoluene	1 U	1 U	1 U	1 U	1 U
2-Amino-4,6-dinitrotoluene	1 U	1 U	1 U	1 U	1 U
2-Nitrotoluene	1 U	1 U	1 U	1 U	1 U
3-Nitrotoluene	1 U	1 U	1 U	1 U	1 U
4-Amino-2,6-dinitrotoluene	1 U	1 U	1 U	1 U	1 U
4-Nitrotoluene	1 U	1 U	1 U	1 U	1 U
HMX	1 U	1 U	1 U	1 U	1 U
PETN	1 U	1 U	1 U	1 U	1 U
RDX	1 U	1 U	1 U	1 U	1 U
Tetryl	1 U	1 U	1 U	1 U	1 U

Station ID	CAA02-A2DPW01	CAA02-A2DPW02	CAA02-A2DPW03		CAA02-A2DPW04
Sample ID	CAA02-A2DPW01-1098	CAA02-A2DPW02-1098	CAA02-A2DPW03-1098	CAA02-A2DPW03P-1098	CAA02-A2DPW04-1098
Sample Date	10/22/98	10/22/98	10/22/98	10/22/98	10/22/98
Chemical Name					
Total Metals (UG/L)					
Aluminum	189,000	59,300	2,110	2,210	96,700
Antimony	13.8	7.7	2.4 U	2.4 U	11.3
Arsenic	181	89.9	3.7 J	5.1 J	430
Barium	510	195 J	36.5 J	38.3 J	275
Beryllium	9.6	3.3 J	0.2 U	0.2 U	5.7
Cadmium	8.7	5.9	4.3 U	4.3 U	6.5
Calcium	2,520,000	722,000	153,000	160,000	1,230,000
Chromium	595	229	9.6 J	10	364
Cobalt	73.7	32.2 J	6.3 U	6.3 U	45.6 J
Copper	99.5	37	4.1 U	4.1 U	45.9
Cyanide	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Iron	380,000	133,000	5,550	5,630	262,000
Lead	94.6	36.1	1 U	1.2 B	53.7
Magnesium	51,900	17,900	2,270	2,340	31,800
Manganese	1,360	394	36.7	37.5	684
Mercury	0.15 B	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	170	70.7	9.6 U	9.6 U	109
Potassium	55,400	18,800	1,780 J	1,710 J	36,500
Selenium	2.2 U	4.6 K	2.2 U	2.9 K	2.2 U
Silver	1 U	1 U	1 U	1 U	1 U
Sodium	18,900	12,600	7,190	7,290	13,100
Thallium	1.2 L	2 J	1.2 U	1.2 U	1.2 U
Vanadium	417	205	6.1 J	4.8 J	309
Zinc	667	264	13.5 J	13.3 J	424
Dissolved Metals (UG/L)					
Aluminum, Dissolved	210	172 J	167 J	193 J	159 J
Antimony, Dissolved	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U
Arsenic, Dissolved	2.4 J	3.6 J	1.8 U	1.8 U	5.5 J
Barium, Dissolved	35.2 J	36.4 J	27.3 J	27 J	23.2 J
Beryllium, Dissolved	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Cadmium, Dissolved	4.3 U	4.3 U	4.3 U	4.3 U	4.3 U
Calcium, Dissolved	158,000	143,000	132,000	132,000	133,000
Chromium, Dissolved	3.3 U	3.3 U	3.3 U	3.3 U	3.3 U
Cobalt, Dissolved	6.3 U	6.3 U	6.3 U	6.3 U	6.3 U
Copper, Dissolved	4.1 U	4.2 J	4.1 U	4.5 J	6.5 J
Iron, Dissolved	56.6 J	53.2 J	92.7 J	86.2 J	208
Lead, Dissolved	1 B	1.5 B	1 U	1.7 B	1.9 B
Magnesium, Dissolved	2,240	3,730	1,600	1,620	1,710
Manganese, Dissolved	164	317	24.1	23.8	25
Mercury, Dissolved	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel, Dissolved	9.6 U	9.6 U	9.6 U	9.6 U	9.6 U
Potassium, Dissolved	1,000 J	2,060 J	869 J	861 J	1,060 J
Selenium, Dissolved	2.2 U	7.5 K	2.2 U	2.2 U	2.2 U
Silver, Dissolved	1 U	1 U	1 U	1 U	1 U
Sodium, Dissolved	6,980	9,840	7,040	6,910	6,080
Thallium, Dissolved	1.2 U	1.2 U	1.2 U	1.2 U	1.2 U
Vanadium, Dissolved	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U
Zinc, Dissolved	7.1 J	8 J	6.8 U	11.8 J	7.5 J

C:\Users\KGraycoc\Desktop\cax_letter\Appendixes\Appendix A - Laboratory Analytical Data\[Appendix A- Analytical Data.xls], Victoria Brynildsen, 12/01/2010

Notes:

Shading indicates detections
NA - Not analyzed
B - Analyte not detected above the level reported in blanks
J - Analyte present, value may or may not be accurate or precise
K - Analyte present, value may be biased high, actual value may be lower
L - Analyte present, value may be biased low, actual value may be higher
R - Unreliable Result
U - The material was analyzed for, but not detected
UJ - Analyte not detected, quantitation limit may be inaccurate
UL - Analyte not detected, quantitation limit is probably higher
UG/L - Micrograms per liter

Appendix B
Human Health Risk Assessment

APPENDIX B

Baseline Human Health Risk Assessment

B.1 Introduction

This attachment presents the baseline human health risk assessment (HHRA) for groundwater at AOC 2, NWS Yorktown Cheatham Annex. 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 groundwater AOC 2. The analytical data evaluated in the HHRA are presented in Appendix A.

The HHRA incorporates the general methodology described in the following U.S. Environmental Protection Agency (EPA) documents:

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

The HHRA consists of the following components:

- Identification of COPCs
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Uncertainty Assessment

These components are described in the following sections. Spreadsheets for AOC 2 were prepared in accordance with *Risk Assessment Guidance for Superfund* (*RAGS), Volume 1, Human Health Evaluation Manual, Part D* (EPA, 2001) to screen for COPCs and to calculate risks estimates associated with the COPCs. These spreadsheets are presented in **Attachment 1**. **Table 1** in **Attachment 1** presents the selection of exposure pathways for AOC 2.

B.2 Identification of COPCs

The identification of COPCs includes data collection, data evaluation, and data screening steps. The data collection and evaluation steps 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 (DQOs). This data set is then further screened against concentrations that are protective of human health to reduce the data set to those constituents of potential concern.

Data Evaluation and Selection

Four groundwater samples identified in **Table B-1** were collected via temporary well using direct push sampling technology during the 1998 field investigation at AOC 2. The samples were analyzed for volatile organic constituents (VOCs), semi-volatile organic constituents (SVOCs), pesticides, PCBs, explosives, unfiltered (total) metals, and filtered (dissolved) metals. No VOCs, pesticides, PCBs, or explosives were detected in the groundwater samples, and only one SVOC was detected. Total and dissolved metals were detected in all of the samples.

All of the data used in the risk assessment have been fully validated and are assumed to represent current conditions. In accordance with the USEPA Region III *Draft Guidance on the Selection of Analytical Metal Results from Monitoring Well Samples for Use in the Quantitative Assessment of Risk* (EPA 1992), filtered groundwater samples were used to determine inorganic constituent exposure concentrations for the residential scenarios because a review of the groundwater data determined a significant difference (an order of magnitude or greater) between the filtered and total results within each sample. Unfiltered groundwater samples were used to determine inorganic constituent exposure concentrations for the construction worker scenario as a construction worker would directly contact the groundwater in an excavation.

The groundwater data were evaluated to determine their reliability for use in the quantitative risk assessments. A review of the data and past discussions with EPA and the Navy identified the following criteria for data usability and usage of qualified data:

Data qualified with a J, K, or L (estimated) 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 primary and duplicate sample was used as the sample concentration.

Selection of COPCs

All of the detected constituents were screened following the procedures described below. The selection of COPCs was based on the criteria presented in the EPA Region III technical guidance manual (EPA, 1993) and *Risk Assessment Guidance for Superfund* (*RAGS), Volume 1, Human Health Evaluation Manual, Part D* (EPA, 2001).

The maximum detected concentration of each constituent in groundwater was compared to the EPA tap water Regional Screening Level (RSL; EPA, 2012a). RSLs that are based on noncarcinogenic effects were divided by 10 to account for exposure to multiple constituents that may affect the same target organ. RSLs based on carcinogenic effects were used as presented in the RSL table and are based on a carcinogenic risk of 10^{-6}. Lead concentrations in groundwater were compared to the Safe Drinking Water Act (SDWA) action level of 15 μg/L (EPA, 2009). 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 retained as COPCs. Groundwater SDWA Maximum Contaminant Levels (MCLs) and Cheatham Annex basewide background value from the Cornwalis Cave aquifer are also included on the screening table (**Attachment 1**, **Tables 2.1** and **2.2**), however these values were not used to identify the COPCs.

Constituents that are considered essential nutrients, present at low concentrations (i.e., only slightly elevated above naturally occurring levels), and 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, iron and manganese were included in the HHRA because toxicity values are available for these two nutrients.

The COPC screening is performed in **Attachment 1**, **Tables 2.1** and **2.2**. **Table B-2** summarizes the constituents that were selected as COPCs from filtered and total groundwater from AOC 2.

B.3 Exposure Assessment

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 conceptual site model for human health
- Calculation of exposure point concentrations
- Development of exposure assumptions for potentially complete exposure pathways
- Calculation of intake for COPCs

Conceptual Site Model

Figure B-1 presents the conceptual exposure model showing potential human health exposure scenarios for current and potential future site use.

AOC 2 is currently located in a wooded area with no designated use. Future land use at AOC 2 is not expected to change and will likely continue as un-zoned use for the foreseeable future. However, to provide a conservative assessment of the groundwater quality at the site and for the purposes of risk characterization, the groundwater was evaluated for future residential potable use.

Calculation of Exposure Point Concentrations

Exposure is quantified by estimating the exposure point concentrations (EPCs) of COPCs and constituent intake by the receptor. EPCs are estimated concentrations that a receptor may contact and are specific to each exposure medium. EPCs may be directly monitored or estimated using environmental models. Constituent concentrations in groundwater were measured for this assessment. No volatile COPCs were retained for groundwater, and therefore, COPCs were not retained for groundwater for exposure while showering or from an excavation pit and environmental models were not needed to estimate EPCs.

The maximum detected concentration was used as the EPC for all COPCs because only four samples were available for groundwater.

The EPCs for the COPCs are presented in **Attachment 1, Tables 3.1** and **3.2**.

Estimation of Chemical Intakes for Individual Pathways

Chemical intake is the amount of the chemical constituent entering the receptor's body. The media-specific and exposure scenario–specific intake equations used in this assessment are provided in the **Table 4.1.RME** and **4.2.CTE** in **Attachment 1**. The intake equation requires specific exposure parameters for each exposure pathway. Exposure parameters are often assumed values, and the magnitude influences the estimates of potential exposure (and risk). The reliability of the values chosen can also contribute to the uncertainty of the resulting risk estimates. Many of the exposure parameters have default values suggested by the EPA, which were used for this assessment. These assumptions, based on estimates of body weights, media intake levels, and exposure frequencies and duration are provided by EPA guidance (EPA, 1989; 1991; 1997a; 2004). Other assumptions (e.g., exposure duration for the construction worker groundwater exposure scenario) required consideration of location-specific information and were determined using professional judgment. The exposure factors used for different scenarios at the site for RME and CTE scenarios are provided in **Attachment 1, Tables 4.1.RME** and **4.1.CTE**. CTE parameters were only provided for scenarios with RME risks above acceptable risk levels.

The dermal exposure model presented in USEPA's dermal exposure assessment guidance (USEPA, 2004) was used to estimate dermal exposure to groundwater. The values for parameters used in this model (i.e., permeability constant) were obtained from this guidance document and are included in the **Tables 7.1.RME Supplement A**, **7.2.RME Supplement B**, and **7.4.RME Supplement A** in **Attachment 1.**

B.4 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 determining the potential adverse effects from exposure to the chemical along with 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.

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

1. Integrated Risk Information System (IRIS) (USEPA, 2012b)
2. Provisional Peer-Reviewed Toxicity Values (PPRTV)
3. Other USEPA and non-USEPA sources, including the National Center for
4. Environmental Assessment (NCEA), Agency for Toxic Substances and Disease Registry (ATSDR), Health Effects Assessment Summary Tables (HEAST; USEPA, 1997b), California EPA (Cal EPA), and USEPA's Office of Water

The use in an HHRA 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.

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.

EPA (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 (i.e., not verified by EPA), were used for the construction worker scenario.

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 (LOAEL), and the dose at which no effect is observed is identified as the no observed adverse effect level (NOAEL). 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 1 to 3,000, and are based on professional judgment. Consequently, there are varying degrees of uncertainty in the toxicity criteria.

EPA-derived oral RfDs, and associated UF and modifying factor (MF) values, available for the COPCs at AOC 2 are presented in **Table 5.1** in **Attachment 1**. Per EPA 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 (EPA, 2004). This adjustment is shown in the **Table 5.1** in **Attachment 1**.

Toxicity Information for Carcinogenic Effects

Potential carcinogenic effects are quantified using CSFs. 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.

EPA-derived CSFs are presented in **Table 6.1** in **Attachment 1**. 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 (EPA, 2004). This adjustment is shown in the **Table 6.1** in **Attachment 1**.

Constituents for Which EPA Toxicity Values Are Not Available

All of the constituents detected in AOC 2 groundwater samples, with the exception of lead, have toxicity factors and EPA RSLs.

Lead, which does not have an RSL or applicable surrogate, is evaluated by USEPA based on blood-lead uptake using a physiologically based pharmakokinetic model called the Integrated Exposure Uptake Biokinetic (IEUBK)

Model used to evaluate lead exposures to children. As a screening tool, lead in groundwater is screened against the SDWA action level for lead of 15 μg/L based on potable use of groundwater. Lead was not detected in the filtered groundwater samples, however, it was detected in unfiltered groundwater samples, which were used to evaluate the construction worker exposure to groundwater scenario. There are no models available to quantitatively evaluate nonresidential adult exposure to lead in groundwater.

B.5 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 used as an integral component in remedial decision making and selection of potential remedies or actions, as necessary.

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.

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 (EPA, 1986). This approach assumes that noncarcinogenic hazards associated with exposure to more than one constituent are additive. 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 to estimate the total noncarcinogenic health effects to a receptor posed by exposure through multiple routes. 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, possibility warranting remedial action. If the HI for each target organ does not exceed 1, noncarcinogenic hazards are not expected.

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 to the background probability of developing cancer.

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 if an individual would be exposed through multiple routes.

As required under the NCP (USEPA, 1994) "[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 (i.e., 10^{-4} ELCR), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) generally requires remedial action to reduce risks at the site.

Risk Assessment Results

The results of the risk characterization are presented below by receptor. A summary of the RME results is presented in **Table B-3**, and the CTE results are summarized in **Table B-4**. The risk calculations are presented **Tables 7.1.RME** through **7.4.RME**, and **7.1.CTE** through **7.3.CTE** in **Attachment 1**. CTE risks were calculated only when the RME hazards exceeded the non-carcinogenic target hazard index (HI) of 1, or the RME carcinogenic risks exceeded the acceptable risk range of 1×10^{-6} to 1×10^{-4} (USEPA 1994). **Tables 9.1.RME** through **9.4.RME** and **9.1.CTE** through **9.3.CTE** in **Attachment 1** 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}.

Future Adult Resident (Non-carcinogenic Hazard, Attachment 1, Table 9.1.RME)

The risk assessment assumed that a future adult resident could be exposed to filtered groundwater used as a potable water supply through ingestion, and dermal contact while bathing. Carcinogenic risks were not calculated for an adult resident, they were calculated for a lifetime child/adult resident following EPA guidance.

The cumulative RME noncarcinogenic hazard to the adult resident (HI = 0.6) is less than the target HI of 1.

Future Child Resident (Non-carcinogenic Hazard, Attachment 1, Table 9.2.RME)

The risk assessment assumed that a future child resident could be exposed to filtered groundwater used as a potable water supply through ingestion, and dermal contact while bathing. Carcinogenic risks were not calculated for a child resident, they were calculated for a lifetime child/adult resident in accordance with EPA guidance.

The cumulative RME noncarcinogenic hazard to the child resident (HI=1) does not exceed the acceptable HI of 1.

Future Lifetime Resident (Carcinogenic Risk, Attachment 1, Table 9.3.RME)

The risk assessment assumed that a future lifetime child/adult resident could be exposed to filtered groundwater used as a potable water supply through ingestion, and dermal contact while bathing.

The cumulative RME carcinogenic risk to the resident (1×10^{-4}) does not exceed the acceptable risk range of 10^{-6} to 10^{-4}.

Future Construction Worker (Attachment 1,Table 9.4.RME)

The risk assessment assumed that a future construction worker could be exposed to unfiltered groundwater in an excavation through dermal contact.

The cumulative RME noncarcinogenic hazard (HI = 3) exceeds the target HI of 1. The noncarcinogenic hazard is associated with chromium, assuming all of the detected chromium is hexavalent chromium, the more toxic form of chromium. Total chromium was only detected in the unfiltered samples; it was not detected in the filtered samples. The use of hexavalent chromium toxicity values for evaluation of total chromium is extremely conservative since the presence of trivalent chromium is strongly favored in natural waters because the concentrations of constituents known to reduce hexavalent chromium to trivalent chromium generally far outweigh the concentrations of the few constituents known to oxidize trivalent chromium to hexavalent chromium. Furthermore, once reduced, trivalent chromium is very stable in aquatic environments and highly unlikely to oxidize to hexavalent chromium. Thus, chromium in groundwater is more likely to be in its trivalent form than its hexavalent form (Fendorf and Zasoski, 1992; Milacic and Stupar, 1995; Weaver and Hochella, 2003).

- The cumulative CTE noncarcinogenic hazard (HI = 1) does not exceed the target HI of 1.
- The cumulative RME carcinogenic risk (3×10^{-6}) is within the target risk range of 1×10^{-6} to 1×10^{-4}.

B.6 Uncertainty Associated with Human Health Assessment

The risk measures used in CERCLA 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.

Uncertainty Associated with Data Evaluation and COPC Identification

The groundwater data evaluated in the risk assessment include four direct push groundwater samples. Use of groundwater samples collected using direct push sampling methodology results in uncertainty in the risk calculations as there are often higher levels of particulates and suspended solids associated with direct push groundwater samples as compared to monitoring well groundwater samples. Use of direct push groundwater samples may result in an overestimation of concentrations of COPCs in the groundwater, and therefore, an overestimation of the risks associated with exposure to the groundwater.

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.

To conservatively evaluate unrestricted land use, it was assumed that the site may be used for residential purposes in the future, though this is not a likely scenario. It is also not likely that groundwater from the shallow aquifer would ever be used as a potable water supply because of the availability of better water supplies with respect to both water quality and quantity.

Uncertainty Associated with Toxicity Assessment

Uncertainty associated with the noncarcinogenic toxicity factors is included in the toxicity tables for AOC 2 in **Attachment 1**. Several UFs were applied to extrapolate dose points from animal studies to humans. These UFs range between 1 and 3,000. Additional modification factors are used on the basis of EPA's professional judgment. 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 EPA 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).

Use of provisional or withdrawn toxicity factors increases the uncertainty of the quantitative hazard and risk estimates. 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

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.

B.7 Human Health Risk Summary

The HHRA was conducted to evaluate the potential human health risks associated with exposure to groundwater at AOC 2 based on potential but unlikely and conservative receptor populations and exposure scenarios assuming no additional remedial action is implemented at the site.

Tables B-3 and **B-4**, and **Attachment 1**, **Tables 9.1.RME** through **9.4.RME** and **Tables 9.1.CTE** through **9.3.CTE** summarize the RME and CTE potential hazards and risks to each receptor. **Tables 10.1.RME** and **10.1.CTE** in **Attachment 1** show the receptor scenarios with total target organ HIs greater than 1, or total carcinogenic risks greater than 1×10^{-4}. The COCs that contribute target organ HIs greater than 0.1 or carcinogenic risks greater than 1×10^{-6} are included in the tables. Risk estimates are summarized below.

- Resident (adult and child)
- Future exposure to groundwater used as potable water supply.
- HIs and ELCRs (RME) associated with exposure to groundwater within acceptable levels
- Construction worker
- Future exposure to groundwater in excavation.
- ELCRs (RME) associated with exposure to groundwater within acceptable levels
- HIs (RME) associated with exposure to groundwater exceed 1, however since no target organ HIs exceed 1.
- HI exceedence of 1 associated with chromium, and assumption that all chromium present is hexavalent chromium. As discussed in text, this is unlikely.
- ELCRs and HIs calculated using groundwater data from direct push groundwater samples. This likely overestimates the risk.
- CTE HI associated with exposure to groundwater within acceptable levels.

B.8 References

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Attachment

1 Human Health Risk Assessment Calculation Tables

Tables

B-1 Summary of Data Quantitatively Used in HHRA
B-2 Summary of Chemicals of Potential Concern for the Baseline Risk Assessment
B-3 Summary of RME Cancer Risks and Hazard Indices
B-4 Summary of CTE Cancer Risks and Hazard Indices

Figures

B-1 Conceptual Site Model for HHRA

Tables

TABLE B-1

Summary of Data Quantitatively Used in HHRA

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Medium	Date of Sampling	Sample Location	Sample	Parameters
Shallow Aquifer Groundwater				
Groundwater	10/22/1998	CAA02-A2DPW01	CAA02-A2DPW01-1098	VOCs, SVOCs, Pesticides/PCBs, Explosives, Total Metals, Dissolved Metals
	10/22/1998	CAA02-A2DPW02	CAA02-A2DPW02-1098	VOCs, SVOCs, Pesticides/PCBs, Explosives, Total Metals, Dissolved Metals
	10/22/1998	CAA02-A2DPW03	CAA02-A2DPW03-1098	VOCs, SVOCs, Pesticides/PCBs, Explosives, Total Metals, Dissolved Metals
	10/22/1998	CAA02-A2DPW03	CAA02-A2DPW03P-1098[1]	VOCs, SVOCs, Pesticides/PCBs, Explosives, Total Metals, Dissolved Metals
	10/22/1998	CAA02-A2DPW04	CAA02-A2DPW04-1098	VOCs, SVOCs, Pesticides/PCBs, Explosives, Total Metals, Dissolved Metals

Notes:

VOCs - Volatile organic constituents

SVOCs - Semi-volatile organic constituents

PCBs - Polychlorinated biphenyls

[1] Duplicate of sample listed above.

TABLE B-2

Summary of Chemicals of Potential Concern for the Baseline Risk Assessment

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Groundwater - Shallow Aquifer - Filtered

Arsenic, Dissolved
Manganese, Dissolved

Groundwater - Shallow Aquifer - Unfiltered

Aluminum	Copper
Antimony	Iron
Arsenic	Lead
Barium	Manganese
Beryllium	Nickel
Cadmium	Thallium
Chromium	Vanadium
Cobalt	Zinc

TABLE B-3
Summary of RME Cancer Risks and Hazard Indices
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks $>10^{-4}$	Chemicals with Cancer Risks $>10^{-5}$ and $<10^{-4}$	Chemicals with Cancer Risks $>10^{-6}$ and $<10^{-5}$	Hazard Index	Chemicals with HI>1
Future Adult Resident	Groundwater Shallow Aquifer	Ingestion	N/A				0.6	
		Dermal Contact	N/A				0.003	
		Inhalation	N/A				N/A	
		Total	N/A				0.6	
	All Media	Total	N/A				0.6	
Future Child Resident	Groundwater Shallow Aquifer	Ingestion	N/A				1	
		Dermal Contact	N/A				0.009	
		Inhalation	N/A				N/A	
		Total	N/A				1	
	All Media	Total	N/A				1	
Future Child/Adult Resident	Groundwater Shallow Aquifer	Ingestion	1E-04		Arsenic - Dissolved		N/A	
		Dermal Contact	7E-07				N/A	
		Inhalation	N/A				N/A	
		Total	1E-04		Arsenic - Dissolved		N/A	
	All Media	Total	1E-04				N/A	
Future Construction Worker Adult	Groundwater Shallow Aquifer	Ingestion	N/A				N/A	
		Dermal Contact	8E-05		Chromium	Arsenic	3	Chromium
		Inhalation	N/A				N/A	
		Total	8E-05		Chromium	Arsenic	3	Chromium
	All Media	Total	8E-05				3	

N/A = not applicable; not available

TABLE B-4

Summary of CTE Cancer Risks and Hazard Indices

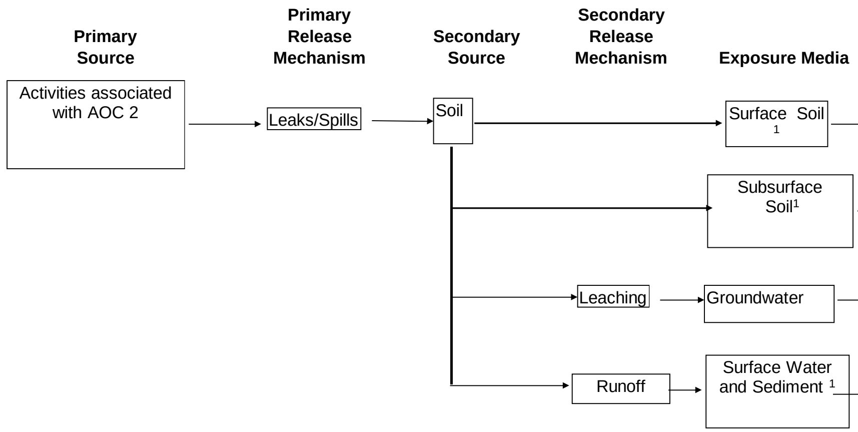
AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks >10^{-4}	Chemicals with Cancer Risks >10^{-5} and <10^{-4}	Chemicals with Cancer Risks >10^{-6} and <10^{-5}	Hazard Index	Chemicals with HI>1
Future	Groundwater	Ingestion	N/A				1	
Child Resident	Shallow Aquifer	Dermal Contact	N/A				0.002	
		Inhalation	N/A				N/A	
		Total	N/A				1	
	All Media	Total	N/A				1	
Future	Groundwater	Ingestion	4E-05		Arsenic - Dissolved		N/A	
Child/Adult Resident	Shallow Aquifer	Dermal Contact	1E-07				N/A	
		Inhalation	N/A				N/A	
		Total	4E-05		Arsenic - Dissolved		N/A	
	All Media	Total	4E-05				N/A	
Future	Groundwater	Ingestion	N/A				N/A	
Construction Worker	Shallow Aquifer	Dermal Contact	4E-05		Chromium		1	
Adult		Inhalation	N/A				N/A	
		Total	4E-05		Chromium		1	
	All Media	Total	4E-05				1	

N/A = not applicable; not available

Figure



Potential Human Receptors

Exposure Route	Current/Future				Future	
	Recreational Users/Visitors	**Trespassers**	**Maintenance Worker**	**Industrial Worker**	**Residents**	**Construction Worker**
Ingestion	X	X	X	X	X	X
Dermal Contact	X	X	X	X	X	X
Inhalation	X	X	X	X	X	X
Ingestion	X	X	X	X	X	X
Dermal Contact	X	X	X	X	X	X
Inhalation	X	X	X	X	X	X
Ingestion	NA	NA	NA	NA	X	NA
Dermal Contact	NA	NA	NA	NA	X	X
Inhalation	NA	NA	NA	NA	X	X
Ingestion	X	X	NA	NA	NA	NA
Dermal Contact	X	X	NA	NA	NA	NA
Inhalation	NA	NA	NA	NA	NA	NA

`

[1] Previously evaluated. Not included in this evaluation
NA - Not Applicable or pathway is incomplete
X - Potentially complete exposure pathways

FIGURE B-1
Conceptual Site Model for HHRA
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Attachment 1
Human Health Risk Assessment Calculation Tables

Table 1

SELECTION OF EXPOSURE PATHWAYS

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future	Groundwater	Groundwater	Shallow Aquifer - Tap Water	Resident*	Adult	Dermal Absorption	On-site	Quant	Groundwater is not currently used on-site as a water supply and the site is not expected to be developed for residential use; however, residential potable use of groundwater is included for a conservative evaluation of unrestricted land use.
						Ingestion	On-site	Quant	
					Child	Dermal Absorption	On-site	Quant	
						Ingestion	On-site	Quant	
					Child/Adult	Dermal Absorption	On-site	Quant	
						Ingestion	On-site	Quant	
			Shallow Aquifer - Water in Excavation Trench	Construction Worker	Adult	Dermal	On-site	Quant	Construction workers could be exposed to shallow groundwater during construction and excavation activities.
						Ingestion	On-site	None	Incidental ingestion of groundwater by construction workers would be minima during construction or excavation activities
		Air	Shallow Aquifer - Water Vapors at Showerhead	Resident*	Adult	Inhalation	On-site	None	No VOCs were detected in groundwater, therefore the inhalation pathway is not evaluated.
					Child	Inhalation	On-site	None	No VOCs were detected in groundwater, therefore the inhalation pathway is not evaluated.
					Child/Adult	Inhalation	On-site	None	No VOCs were detected in groundwater, therefore the inhalation pathway is not evaluated.
			Shallow Aquifer - Water Vapors in Excavation Trench	Construction Worker	Adult	Inhalation	On-site	None	No VOCs were detected in groundwater, therefore the inhalation pathway is not evaluated.

* Noncarcinogenic hazard evaluated separately for adult and child residential receptors, combined lifetime carcinogenic risk evaluated on an age-adjusted basis for residential scenario.

Table 2.1

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Shallow Aquifer - Tap Water	84-66-2	Diethylphthalate	1.0E+00 J	1.0E+00 J	UG/L	CAA02-A2DPW01-1098	1/4	10 - 10	1.0E+00	N/A	1.1E+03 N	N/A		NO	BSL
	7429-90-5	Aluminum, Dissolved	1.6E+02 J	2.1E+02	UG/L	CAA02-A2DPW01-1098	4/4	14 - 14	2.1E+02	N/A	1.6E+03 N	50 to 200	SMCL	NO	BSL
	7440-38-2	**Arsenic, Dissolved**	**2.4E+00 J**	**5.5E+00 J**	**UG/L**	**CAA02-A2DPW04-1098**	**3/4**	**1.8 - 1.8**	**5.5E+00**	**1.4E+00**	**4.5E-02 C**	**1.0E+01**	**MCL**	**YES**	**ASL**
	7440-39-3	Barium, Dissolved	2.3E+01 J	3.6E+01 J	UG/L	CAA02-A2DPW02-1098	4/4	7.4 - 7.4	3.6E+01	1.3E+02	2.9E+02 N	2.0E+03	MCL	NO	BSL
	7440-70-2	Calcium, Dissolved	1.3E+05	1.6E+05	UG/L	CAA02-A2DPW01-1098	4/4	21.3 - 21.3	1.6E+05	1.5E+05	N/A	N/A		NO	NUT
	7440-50-8	Copper, Dissolved	4.2E+00 J	6.5E+00 J	UG/L	CAA02-A2DPW04-1098	3/4	4.1 - 4.1	6.5E+00	N/A	6.2E+01 N	1.3E+03	MCL	NO	BSL
	7439-89-6	Iron, Dissolved	5.3E+01 J	2.1E+02	UG/L	CAA02-A2DPW04-1098	4/4	13 - 13	2.1E+02	6.3E+00	1.1E+03 N	3.0E+02	SMCL	NO	BSL
	7439-95-4	Magnesium, Dissolved	1.6E+03	3.7E+03	UG/L	CAA02-A2DPW02-1098	4/4	32.9 - 32.9	3.7E+03	3.9E+03	N/A	N/A		NO	NUT
	7439-96-5	**Manganese, Dissolved**	**2.4E+01**	**3.2E+02**	**UG/L**	**CAA02-A2DPW02-1098**	**4/4**	**1 - 1**	**3.2E+02**	**5.0E+01**	**3.2E+01 N**	**5.0E+01**	**SMCL**	**YES**	**ASL**
	7440-09-7	Potassium, Dissolved	8.7E+02 J	2.1E+03 J	UG/L	CAA02-A2DPW02-1098	4/4	84.2 - 84.2	2.1E+03	1.7E+03	N/A	N/A		NO	NUT
	7782-49-2	Selenium, Dissolved	7.5E+00 K	7.5E+00 K	UG/L	CAA02-A2DPW02-1098	1/4	2.2 - 2.2	7.5E+00	N/A	7.8E+00 N	5.0E+01	MCL	NO	BSL
	7440-23-5	Sodium, Dissolved	6.1E+03	9.8E+03	UG/L	CAA02-A2DPW02-1098	4/4	28.1 - 28.1	9.8E+03	1.0E+04	N/A	N/A		NO	NUT
	7440-66-6	Zinc, Dissolved	7.1E+00 J	1.2E+01 J	UG/L	CAA02-A2DPW03P-1098	4/4	6.8 - 6.8	1.2E+01	N/A	4.7E+02 N	5.0E+03	SMCL	NO	BSL

[1] Minimum/Maximum detected concentration. Filtered results were used for metals since in general significant difference between filtered and unfiltered.

[2] Maximum concentration is used for screening.

[3] Background values from June 2012, CAX Cornwalis Cave groundwater background; values represent the 95% UTL.

[4] Oak Ridge National Laboratory (ORNL). May 2012. Regional Screening Levels for Chemical Contaminants at Superfund Sites. [Online]. Tap Water
Available: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm
Concentrations based on non-carcinogenic health effects are adjusted to an HI=0.1 (divided by 10).

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)

Deletion Reason: No Toxicity Information (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

COPC = Chemical of Potential Concern
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered
C = Carcinogenic
J = Estimated Value
K = Biased High
MCL = Maximum Contaminant Level
N = Noncarcinogenic
N/A = Not available
SMCL = Maximum Contaminant Level, Secondary Drinking Water Standards
UG/L = micrograms per liter

Table 2.2

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Shallow Aquifer - Water in Excavation Trench	84-66-2	Diethylphthalate	1.0E+00 J	1.0E+00 J	UG/L	CAA02-A2DPW01-1098	1/4	10 - 10	1.0E+00	N/A	1.1E+03 N	N/A		NO	BSL
	7429-90-5	Aluminum	2.2E+03	1.9E+05	UG/L	CAA02-A2DPW01-1098	4/4	14 - 14	1.9E+05	2.2E+03	1.6E+03 N	50 to 200	SMCL	YES	ASL
	7440-36-0	Antimony	7.7E+00	1.4E+01	UG/L	CAA02-A2DPW01-1098	3/4	2.4 - 2.4	1.4E+01	N/A	6.0E-01 N	6.0E+00	MCL	YES	ASL
	7440-38-2	Arsenic	5.1E+00 J	4.3E+02	UG/L	CAA02-A2DPW04-1098	4/4	1.8 - 1.8	4.3E+02	2.3E+00	4.5E-02 C	1.0E+01	MCL	YES	ASL
	7440-39-3	Barium	3.8E+01 J	5.1E+02	UG/L	CAA02-A2DPW01-1098	4/4	7.4 - 7.4	5.1E+02	1.2E+02	2.9E+02 N	2.0E+03	MCL	YES	ASL
	7440-41-7	Beryllium	3.3E+00 J	9.6E+00	UG/L	CAA02-A2DPW01-1098	3/4	0.2 - 0.2	9.6E+00	2.5E+00	1.6E+00 N	4.0E+00	MCL	YES	ASL
	7440-43-9	Cadmium	5.9E+00	8.7E+00	UG/L	CAA02-A2DPW01-1098	3/4	4.3 - 4.3	8.7E+00	6.1E-01	6.9E-01 N	5.0E+00	MCL	YES	ASL
	7440-70-2	Calcium	1.6E+05	2.5E+06	UG/L	CAA02-A2DPW01-1098	4/4	21.3 - 21.3	2.5E+06	1.6E+05	N/A	N/A		NO	NUT
	7440-47-3	Chromium	1.0E+01	6.0E+02	UG/L	CAA02-A2DPW01-1098	4/4	3.3 - 3.3	6.0E+02	1.5E+01	3.1E-02 C	1.0E+02	MCL	YES	ASL
	7440-48-4	Cobalt	3.2E+01 J	7.4E+01	UG/L	CAA02-A2DPW01-1098	3/4	6.3 - 6.3	7.4E+01	2.1E+01	4.7E-01 N	N/A		YES	ASL
	7440-50-8	Copper	3.7E+01	1.0E+02	UG/L	CAA02-A2DPW01-1098	3/4	4.1 - 4.1	1.0E+02	N/A	6.2E+01 N	1.3E+03	MCL	YES	ASL
	7439-89-6	Iron	5.6E+03	3.8E+05	UG/L	CAA02-A2DPW01-1098	4/4	13 - 13	3.8E+05	3.6E+03	1.1E+03 N	3.0E+02	SMCL	YES	ASL
	7439-92-1	Lead	3.6E+01	9.5E+01	UG/L	CAA02-A2DPW01-1098	3/4	1 - 1	9.5E+01	N/A	1.5E+01 NL	1.5E+01	MCL	YES	ASL
	7439-95-4	Magnesium	2.3E+03	5.2E+04	UG/L	CAA02-A2DPW01-1098	4/4	32.9 - 32.9	5.2E+04	3.6E+03	N/A	N/A		NO	NUT
	7439-96-5	Manganese	3.8E+01	1.4E+03	UG/L	CAA02-A2DPW01-1098	4/4	1 - 1	1.4E+03	5.8E+01	3.2E+01 N	5.0E+01	SMCL	YES	ASL
	7440-02-0	Nickel	7.1E+01	1.7E+02	UG/L	CAA02-A2DPW01-1098	3/4	9.6 - 9.6	1.7E+02	1.1E+01	3.0E+01 N	N/A		YES	ASL
	7440-09-7	Potassium	1.8E+03 J	5.5E+04	UG/L	CAA02-A2DPW01-1098	4/4	84.2 - 84.2	5.5E+04	3.5E+03	N/A	N/A		NO	NUT
	7782-49-2	Selenium	2.9E+00 K	4.6E+00 K	UG/L	CAA02-A2DPW02-1098	2/4	2.2 - 2.2	4.6E+00	N/A	7.8E+00 N	5.0E+01	MCL	NO	BSL
	7440-23-5	Sodium	7.3E+03	1.9E+04	UG/L	CAA02-A2DPW01-1098	4/4	28.1 - 28.1	1.9E+04	9.9E+03	N/A	N/A		NO	NUT
	7440-28-0	Thallium	1.2E+00 L	2.0E+00 J	UG/L	CAA02-A2DPW02-1098	2/4	1.2 - 1.2	2.0E+00	N/A	1.6E-02 N	2.0E+00	MCL	YES	ASL
	7440-62-2	Vanadium	6.1E+00 J	4.2E+02	UG/L	CAA02-A2DPW01-1098	4/4	3.2 - 3.2	4.2E+02	2.6E+01	7.8E+00 N	N/A		YES	ASL
	7440-66-6	Zinc	1.4E+01 J	6.7E+02	UG/L	CAA02-A2DPW01-1098	4/4	6.8 - 6.8	6.7E+02	4.5E+00	4.7E+02 N	5.0E+03	SMCL	YES	ASL

[1] Minimum/Maximum detected concentration. Unfiltered results were used for metals since in construction worker would be not exposed to filtered groundwater.

[2] Maximum concentration is used for screening.

[3] Background values from June 2012, CAX Cornwalis Cave groundwater background; values represent the 95% UTL.

[4] Oak Ridge National Laboratory (ORNL). May 2012. Regional Screening Levels for Chemical Contaminants at Superfund Sites. [Online]. Tap Water
Available: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm
RSL value for Chromium(VI) used as surrogate for chromium.
Concentrations based on non-carcinogenic health effects are adjusted to an HI=0.1 (divided by 10).
The tap water value of 15 ug/L for lead is the action level provided in the Drinking Water Regulations and Health Advisories.

[5] Rationale Codes
Selection Reason: Above Screening Levels (ASL)
Deletion Reason: No Toxicity Information (NTX)
Essential Nutrient (NUT)

COPC = Chemical of Potential Concern
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered
C = Carcinogenic
J = Estimated Value
K = Biased High
MCL = Maximum Contaminant Level
N = Noncarcinogenic
N/A = Not available
NL = Noncarcinogenic lead tap water RSL not adjusted by dividing by 10.
SMCL = Maximum Contaminant Level, Secondary Drinking Water Standards
UG/L = micrograms per liter

Table 3.1.RME

MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY

AOC 2

NWS Yorktown Cheatham Annex, Willimasburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (Distribution)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic	Rationale
Shallow Aquifer - Tap Water	Arsenic, Dissolved	UG/L	3.8E+00	N/A	5.5E+00 J	5.5E+00	UG/L	Max	5
	Manganese, Dissolved	UG/L	1.3E+02	N/A	3.2E+02	3.2E+02	UG/L	Max	5

Options: Maximum Detected Concentration (Max)

(1) Shapiro-Wilk W Test/Lilliefors test indicates data are log-normally distributed.
(2) Shapiro-Wilk W Test/Lilliefors indicates data are normally distributed.
(3) Test indicates data are gamma distributed.
(4) Distribution tests are inconclusive
(5) Maximum detected concentration used because sample size is less than 5.

J = Estimated Value
UG/L = micrograms per liter
N/A = Not Applicable

Table 3.2.RME
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY
AOC 2
NWS Yorktown Cheatham Annex, Willimasburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (Distribution)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic	Rationale
Water in Excavation Trench	Aluminum	UG/L	8.7E+04	N/A	1.9E+05	1.9E+05	UG/L	Max	5
	Antimony	UG/L	8.8E+00	N/A	1.4E+01	1.4E+01	UG/L	Max	5
	Arsenic	UG/L	1.8E+02	N/A	4.3E+02	4.3E+02	UG/L	Max	5
	Barium	UG/L	2.5E+02	N/A	5.1E+02	5.1E+02	UG/L	Max	5
	Beryllium	UG/L	4.7E+00	N/A	9.6E+00	9.6E+00	UG/L	Max	5
	Cadmium	UG/L	6.4E+00	N/A	8.7E+00	8.7E+00	UG/L	Max	5
	Chromium	UG/L	3.0E+02	N/A	6.0E+02	6.0E+02	UG/L	Max	5
	Cobalt	UG/L	3.9E+01	N/A	7.4E+01	7.4E+01	UG/L	Max	5
	Copper	UG/L	4.7E+01	N/A	1.0E+02	1.0E+02	UG/L	Max	5
	Iron	UG/L	2.0E+05	N/A	3.8E+05	3.8E+05	UG/L	Max	5
	Lead	UG/L	6.1E+01	N/A	9.5E+01	6.1E+01	UG/L	Mean	6
	Manganese	UG/L	6.2E+02	N/A	1.4E+03	1.4E+03	UG/L	Max	5
	Nickel	UG/L	9.0E+01	N/A	1.7E+02	1.7E+02	UG/L	Max	5
	Thallium	UG/L	1.4E+00	N/A	2.0E+00 J	2.0E+00	UG/L	Max	5
	Vanadium	UG/L	2.3E+02	N/A	4.2E+02	4.2E+02	UG/L	Max	5
	Zinc	UG/L	3.4E+02	N/A	6.7E+02	6.7E+02	UG/L	Max	5

Options: Maximum Detected Concentration (Max); Mean Detected Concentration (Mean)

(1) Shapiro-Wilk W Test/Lilliefors test indicates data are log-normally distributed.
(2) Shapiro-Wilk W Test/Lilliefors indicates data are normally distributed.
(3) Test indicates data are gamma distributed.
(4) Distribution tests are inconclusive
(5) Maximum detected concentration used because sample size is less than 5.
(6) Mean lead concentration used for the lead model.

J = Estimated Value
UG/L = micrograms per liter
N/A = Not Applicable

TABLE 4.1.RME

VALUES USED FOR DAILY INTAKE CALCULATIONS

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Resident	Adult	Shallow Aquifer - Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR-W	Ingestion Rate of Water	2	liters/day	EPA, 1997	CW x IR-W x EF x ED x CF2 x 1/BW x 1/AT
				EF	Exposure Frequency	350	days/year	EPA, 1991	
				ED	Exposure Duration	24	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				BW	Body Weight	70	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	8,760	days	EPA, 1989	
		Child	Shallow Aquifer - Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) =
				IR-W	Ingestion Rate of Water	1	liters/day	EPA, 1997	CW x IR-W x EF x ED x CF2 x 1/BW x 1/AT
				EF	Exposure Frequency	350	days/year	EPA, 1991	
				ED	Exposure Duration	6	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				BW	Body Weight	15	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989	
		Child/Adult	Shallow Aquifer - Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) =
				IR-W-A	Ingestion Rate of Water, Adult	2	liters/day	EPA, 1997	CW x IR-W-Adj x EF x CF2 x 1/AT
				IR-W-C	Ingestion Rate of Water, Child	1	liters/day	EPA, 1997	
				IR-W-Adj	Ingestion Rate of Water, Age-adjusted	1.09	liter-year/kg-day	calculated	IR-W-Adj (liter-year/kd-day) =
				EF	Exposure Frequency	350	days/year	EPA, 1991	(ED-C x IR-W-C / BW-C) +
				ED-A	Exposure Duration, Adult	24	years	EPA, 1991	(ED-A x IR-W-A / BW-A)
				ED-C	Exposure Duration, Child	6	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				BW-A	Body Weight , Adult	70	kg	EPA, 1991	
				BW-C	Body Weight, Child	15	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	

TABLE 4.1.RME

VALUES USED FOR DAILY INTAKE CALCULATIONS

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Resident	Adult	Shallow Aquifer - Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) =
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm^2-event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	Organics :
				t_{event}	Event Time	0.58	hr/event	EPA, 2004	t_{event}<t*: DAevent (mg/cm^2-event) =
				SA	Skin Surface Area Available for Contact	18,000	cm^2	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				EV	Event Frequency	1	events/day	EPA, 2004	x CF2 x CF3
				EF	Exposure Frequency	350	days/year	EPA, 2004	
				ED	Exposure Duration	24	years	EPA, 2004	t_{event}>t*: DAevent (mg/cm^2-event) =
				BW	Body Weight	70	kg	EPA, 1991	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	((1 + 3B + $3B^2$)/$(1+B)^2$)) x CF2 x CF3
				AT-N	Averaging Time (Non-Cancer)	8,760	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	
		Child	Shallow Aquifer - Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) =
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm^2-event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	Organics :
				t_{event}	Event Time	1.0	hr/event	EPA, 2004	t_{event}<t*: DAevent (mg/cm^2-event) =
				SA	Skin Surface Area Available for Contact	6,600	cm^2	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				EV	Event Frequency	1	events/day	EPA, 2004	x CF2 x CF3
				EF	Exposure Frequency	350	days/year	EPA, 2004	
				ED	Exposure Duration	6	years	EPA, 2004	t_{event}>t*: DAevent (mg/cm^2-event) =
				BW	Body Weight	15	kg	EPA, 1991	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	((1 + 3B + $3B^2$)/$(1+B)^2$)) x CF2 x CF3
				AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	

TABLE 4.1.RME

VALUES USED FOR DAILY INTAKE CALCULATIONS

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Resident	Child/Adult	Shallow Aquifer - Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) = DA-Adj x EF x 1/AT
				DAevent-A	Dermally Absorbed Dose per Event, Adult	calculated	mg/cm^2-event	calculated	
				DAevent-C	Dermally Absorbed Dose per Event, Child	calculated	mg/cm^2-event	calculated	DA-Adj = (Daevent-A x SA-A x ED-A x 1/BW-A)
				DA-Adj	Dermally Absorbed Dose, Age-adjusted	calculated	mg-year/event-kg	calculated	+ (Daevent-C x SA-C x ED-C x 1/BW-C)
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	Organics :
				t_{event}-A	Event Time, Adult	0.58	hr/event	EPA, 2004	t_{event}<t*: DAevent (mg/cm^2-event) =
				t_{event}-C	Event Time, Child	1.0	hr/event	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				SA-A	Skin Surface Area, Adult	18,000	cm^2	EPA, 2004	x CF2 x CF3
				SA-C	Skin Surface Area, Child	6,600	cm^2	EPA, 2004	
				EV	Event Frequency	1	events/day	EPA, 2004	t_{event}>t*: DAevent (mg/cm^2-event) =
				EF	Exposure Frequency	350	days/year	EPA, 2004	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				ED-A	Exposure Duration, Adult	24	years	EPA, 2004	((1 + 3B + 3B^2)/(1+B)^2)) x CF2 x CF3
				ED-C	Exposure Duration, Child	6	years	EPA, 2004	
				BW-A	Body Weight, Adult	70	kg	EPA, 1991	
				BW-C	Body Weight, Child	15	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	

TABLE 4.1.RME

VALUES USED FOR DAILY INTAKE CALCULATIONS

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Construction Worker	Adult	Shallow Aquifer - Water in Excavation Trench	CW	Chemical Concentration in Water	See Table 3.2	µg/l	See Table 3.2	CDI (mg/kg-day) =
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm^2-event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	Organics :
				t_{event}	Event Time	8	hr/day	(1)	t_{event}<t*: DAevent (mg/cm^2-event) =
				SA	Skin Surface Area Available for Contact	5,700	cm^2	EPA, 2004, (2)	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				EV	Event Frequency	1	events/day	EPA, 2004	x CF2 x CF3
				EF	Exposure Frequency	125	days/year	VDEQ, 2003	
				ED	Exposure Duration	1	years	EPA, 1991	t_{event}>t*: DAevent (mg/cm^2-event) =
				BW	Body Weight	70	kg	EPA, 1991	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	((1 + 3B + $3B^2$)/$(1+B)^2$)) x CF2 x CF3
				AT-N	Averaging Time (Non-Cancer)	365	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	

(1) Professional judgment based on construction activities that would occur 8 hrs per day for the RME.

(2) Skin surface area in contact with groundwater assumed to be head, hands, forearms, lower legs, and feet.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.

EPA, 1991: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual - Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.

EPA, 1997: Exposure Factors Handbook. EPA/600/P-95/002Fa.

EPA, 2004 . Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment (Final). EPA/540/R/99/005. July 2004.

VDEQ, 2003: Virginia Department of Environmental Quality, Voluntary Remediation Program Risk Assessment Guidance. Dec. 2003

TABLE 4.1.CTE

VALUES USED FOR DAILY INTAKE CALCULATIONS

CENTRAL TENDENCY EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Resident	Child	Shallow Aquifer	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) =
			Tap Water	IR-W	Ingestion Rate of Water	1	liters/day	EPA, 1997	CW x IR-W x EF x ED x CF2 x 1/BW x 1/AT
				EF	Exposure Frequency	234	days/year	EPA, 1993	
				ED	Exposure Duration	6	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				BW	Body Weight	15	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989	
		Child/Adult	Shallow Aquifer	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) =
			Tap Water	IR-W-A	Ingestion Rate of Water, Adult	1.4	liters/day	EPA, 1993	CW x IR-W-Adj x EF x CF2 x 1/AT
				IR-W-C	Ingestion Rate of Water, Child	1	liters/day	EPA, 1997	
				IR-W-Adj	Ingestion Rate of Water, Age-adjusted	0.58	liter-year/kg-day	calculated	IR-W-Adj (liter-year/kg-day) =
				EF	Exposure Frequency	234	days/year	EPA, 1993	(ED-C x IR-W-C / BW-C) +
				ED-A	Exposure Duration, Adult	9	years	EPA, 1993	(ED-A x IR-W-A / BW-A)
				ED-C	Exposure Duration, Child	6	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				BW-A	Body Weight , Adult	70	kg	EPA, 1991	
				BW-C	Body Weight, Child	15	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
Dermal	Resident	Child	Shallow Aquifer	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) =
			Tap Water	DAevent	Dermally Absorbed Dose per Event	Calculated	mg/cm^2-event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	Chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	Chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	Chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	Chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	Chemical specific	dimensionless	EPA, 2004	Organics :
				t_{event}	Event Time	0.33	hr/event	EPA, 2004	t_{event}<t*: DAevent (mg/cm^2-event) =
				SA	Skin Surface Area Available for Contact	6,600	cm^2	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				EV	Event Frequency	1	events/day	EPA, 2004	x CF2 x CF3
				EF	Exposure Frequency	234	days/year	EPA, 1993	
				ED	Exposure Duration	6	years	EPA, 2001	t_{event}>t*: DAevent (mg/cm^2-event) =
				BW	Body Weight	15	kg	EPA, 1991	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	((1 + 3B + $3B^2$)/$(1+B)^2$)) x CF2 x CF3
				AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	

TABLE 4.1.CTE

VALUES USED FOR DAILY INTAKE CALCULATIONS

CENTRAL TENDENCY EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Resident	Child/Adult	Shallow Aquifer Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	CDI (mg/kg-day) = DA-Adj x EF x 1/AT
				DAevent-A	Dermally Absorbed Dose per Event, Adult	Calculated	mg/cm^2-event	calculated	
				DAevent-C	Dermally Absorbed Dose per Event, Child	Calculated	mg/cm^2-event	calculated	DA-Adj = (Daevent-A x SA-A x ED-A x 1/BW-A)
				DA-Adj	Dermally Absorbed Dose, Age-adjusted	Calculated	mg-year/event-kg	calculated	+ (Daevent-C x SA-C x ED-C x 1/BW-C)
				FA	Fraction absorbed water	Chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	Chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	Chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	Chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	Chemical specific	dimensionless	EPA, 2004	Organics :
				t_{event}-A	Event Time, Adult	0.25	hr/event	EPA, 2004	t_{event}<t*: DAevent (mg/cm^2-event) =
				t_{event}-C	Event Time, Child	0.33	hr/event	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				SA-A	Skin Surface Area, Adult	18,000	cm^2	EPA, 2004	x CF2 x CF3
				SA-C	Skin Surface Area, Child	6,600	cm^2	EPA, 2004	
				EV	Event Frequency	1	events/day	EPA, 2004	t_{event}>t*: DAevent (mg/cm^2-event) =
				EF	Exposure Frequency	234	days/year	EPA, 1993	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				ED-A	Exposure Duration, Adult	9	years	EPA, 2001	((1 + 3B + $3B^2$)/$(1+B)^2$)) x CF2 x CF3
				ED-C	Exposure Duration, Child	6	years	EPA, 2001	
				BW-A	Body Weight, Adult	70	kg	EPA, 1991	
				BW-C	Body Weight, Child	15	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	
	Construction Worker	Adult	Shallow Aquifer - Water in Excavation Trench	CW	Chemical Concentration in Water	See Table 3.2	µg/l	See Table 3.2	CDI (mg/kg-day) =
				DAevent	Dermally Absorbed Dose per Event	Calculated	mg/cm^2-event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	Chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	Chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	Chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	Chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	Chemical specific	dimensionless	EPA, 2004	Organics :
				t_{event}	Event Time	4	hr/day	(1)	t_{event}<t*: DAevent (mg/cm^2-event) =
				SA	Skin Surface Area Available for Contact	5,700	cm^2	EPA, 2004, (2)	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				EV	Event Frequency	1	events/day	EPA, 2004	x CF2 x CF3
				EF	Exposure Frequency	125	days/year	VDEQ, 2003	
				ED	Exposure Duration	1	years	EPA, 1991	t_{event}>t*: DAevent (mg/cm^2-event) =
				BW	Body Weight	70	kg	EPA, 1991	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	((1 + 3B + $3B^2$)/$(1+B)^2$)) x CF2 x CF3
				AT-N	Averaging Time (Non-Cancer)	365	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	

TABLE 4.1.CTE
VALUES USED FOR DAILY INTAKE CALCULATIONS
CENTRAL TENDENCY EXPOSURE
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name

(1) Assumed construction workers could spend 4 hours/day near the excavation trench.
(2) Skin surface area in contact with groundwater assumed to be head, hands, forearms, lower legs, and feet.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA, 1991: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual - Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.
EPA, 1993: Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure.
EPA, 1997: Exposure Factors Handbook. EPA/600/P-95/002Fa.
EPA, 2004 . Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment (Final). EPA/540/R/99/005. July 2004.
VDEQ, 2003: Virginia Department of Environmental Quality, Voluntary Remediation Program Risk Assessment Guidance. Dec. 2003

TABLE 5.1.RME

Non-Cancer Toxicity Data -- Oral/Dermal

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal RfD (2)	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ (3) (MM/DD/YY)
Aluminum	Chronic	1.0E+00	mg/kg-day	100%	1.0E+00	mg/kg-day	Neurological	100	PPRTV	10/23/2006
	Subchronic	1.0E+00	mg/kg-day	100%	1.0E+00	mg/kg-day	Neurological	30	ATSDR	9/2008
Antimony	Chronic	4.0E-04	mg/kg-day	15%	6.0E-05	mg/kg-day	Longevity, Blood	1000	IRIS	8/17/2012
	Subchronic	4.0E-04	mg/kg-day	15%	6.0E-05	mg/kg-day	Whole Body, Blood	1000	PPRTV	7/29/2008
Arsenic	Chronic	3.0E-04	mg/kg-day	95%	3.0E-04	mg/kg-day	Skin, Vascular	3/1	IRIS	8/17/2012
	Subchronic	3.0E-04	mg/kg-day	95%	3.0E-04	mg/kg-day	Skin	3	HEAST	7/01/1997
Barium	Chronic	2.0E-01	mg/kg-day	7%	1.4E-02	mg/kg-day	Kidney	300	IRIS	8/17/2012
	Subchronic	2.0E-01	mg/kg-day	7%	1.4E-02	mg/kg-day	Kidney	100	ATSDR	8/2007
Beryllium	Chronic	2.0E-03	mg/kg-day	0.7%	1.4E-05	mg/kg-day	Gastrointestinal	300	IRIS	8/17/2012
	Subchronic	5.0E-03	mg/kg-day	0.7%	3.5E-05	mg/kg-day	None Observed	100	HEAST	7/1997
Cadmium (water)	Chronic	5.0E-04	mg/kg-day	5%	2.5E-05	mg/kg-day	Kidney	10	IRIS	8/17/2012
	Subchronic	N/A		N/A	N/A					
Chromium (hexavalent)	Chronic	3.0E-03	mg/kg-day	2.5%	7.5E-05	mg/kg-day	Not identified	300	IRIS	8/17/2012
	Subchronic	5.0E-03	mg/kg-day	2.5%	1.3E-04	mg/kg-day	Blood	100	ATSDR	9/2008
Cobalt	Chronic	3.0E-04	mg/kg-day	100%	3.0E-04	mg/kg-day	Thyroid	3000	PPRTV	8/25/2008
	Subchronic	3.0E-03	mg/kg-day	100%	3.0E-03	mg/kg-day	Thyroid	300	PPRTV	8/25/2008
Copper	Chronic	4.0E-02	mg/kg-day	100%	4.0E-02	mg/kg-day	Gastrointestinal	NA	HEAST (4)	8/10/2012
	Subchronic	4.0E-02	mg/kg-day	100%	4.0E-02	mg/kg-day	Gastrointestinal	NA	HEAST (4)	8/10/2012
Iron	Chronic	7.0E-01	mg/kg-day	100%	7.0E-01	mg/kg-day	GI System	1.5	PPRTV	9/11/2006
	Subchronic	7.0E-01	mg/kg-day	100%	7.0E-01	mg/kg-day	GI System	1.5	PPRTV	9/11/2006
Lead	Chronic	N/A		N/A	N/A					
	Subchronic	N/A		N/A	N/A					
Manganese	Chronic	1.4E-01	mg/kg-day	100%	1.4E-01	mg/kg-day	CNS	1	IRIS	8/17/2012
	Subchronic	1.4E-01	mg/kg-day	100%	1.4E-01	mg/kg-day	CNS	1	HEAST	7/1997
Nickel	Chronic	2.0E-02	mg/kg-day	4%	8.0E-04	mg/kg-day	Decreased body and organ weights	300	IRIS	8/17/2012
	Subchronic	2.0E-02	mg/kg-day	4%	8.0E-04	mg/kg-day	Decreased body and organ weights	300	HEAST	7/1997
Thallium	Chronic	1.0E-05	mg/kg-day	100%	1.0E-05	mg/kg-day	Hair	3000	PPRTV	10/8/2010
	Subchronic	4.0E-05	mg/kg-day	100%	4.0E-05	mg/kg-day	Hair	1000	PPRTV	10/8/2010
Vanadium	Chronic	5.0E-03	mg/kg-day	100%	5.0E-03	mg/kg-day	Hair	1000	IRIS/RSL	8/17/2012
	Subchronic	7.0E-03	mg/kg-day	100%	7.0E-03	mg/kg-day	Lifetime	100	HEAST	7/01/1997
Zinc	Chronic	3.0E-01	mg/kg-day	100%	3.0E-01	mg/kg-day	Blood	3	IRIS	8/17/2012
	Subchronic	3.0E-01	mg/kg-day	100%	3.0E-01	mg/kg-day	Blood	3	HEAST	7/01/1997

(1) Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evolution Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Final. Section 4.2 and Exhibit 4-1. USEPA recommends that the oral RfD should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 50%.

(2) Adjusted Dermal RfD = RfD (oral) x Oral to Dermal Adjustment Factor

(3) For ATSDR, date of ATSDR toxicity profile
For IRIS values, date IRIS was searched.
For HEAST values, date of HEAST.
For PPRTV values, date of the PPRTV toxicity profile.
For RSL values, the date of the RSL Table.

(4) As provided in the RSL Table.

Definitions:
ATSDR = Agency for Toxic Substances and Disease Registry
HEAST= Health Effects Assessment Summary Tables
IRIS = Integrated Risk Information System
N/A = Not available/not applicable
PPRTV = Provisional Peer-Reviewed Toxicity Values
RSL = Regional Screening Level Table

TABLE 6.1.RME

Cancer Toxicity Data -- Oral/Dermal

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal Cancer Slope Factor (2)	Units	EPA Carcinogen Group	Source	Date (MM/DD/YY)
Aluminum	N/A	N/A	N/A				
Antimony	N/A	N/A	N/A				
Arsenic	1.5E+00	95%	1.5E+00	$(mg/kg\text{-}day)^{-1}$	A	IRIS	8/17/2012
Barium	N/A	N/A	N/A		D	IRIS	8/17/2012
Beryllium	N/A	N/A	N/A				
Cadmium (water)	N/A	N/A	N/A				
Chromium (hexavalent)	5.0E-01	2.5%	2.0E+01	$(mg/kg\text{-}day)^{-1}$	D	New Jersey	8/17/2012
Cobalt	N/A	N/A	N/A				
Copper	N/A	N/A	N/A				
Iron	N/A	N/A	N/A				
Lead	N/A	N/A	N/A				
Manganese	N/A	N/A	N/A		D	IRIS	8/17/2012
Nickel	N/A	N/A	N/A				
Thallium	N/A	N/A	N/A				
Vanadium	N/A	N/A	N/A				
Zinc	N/A	N/A	N/A		D	IRIS	8/17/2012

(1) Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. Section 4.2 and Exhibit 4-1. USEPA recommends that the oral slope factor should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 50%. Constituents that do not have oral absorption efficiencies reported on this table were assumed to have an oral absorption efficiency of 100%.

(2) Adjusted based on RAGS Part E.

Weight of Evidence definitions:

Group A - Human Carcinogen

Group D - Not Classifiable as to Human Carcinogenicity.

Definitions:

N/A = Not Available, Not Applicable

IRIS = Integrated Risk Information System

New Jersey = New Jersey EPA

TABLE 7.1.RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Ingestion	Arsenic, Dissolved	5.5E+00	ug/L	N/A		N/A		N/A	1.5E-04	mg/kg/day	3.0E-04	mg/kg/day	5.0E-01
				Manganese, Dissolved	3.2E+02	ug/L	N/A		N/A		N/A	8.7E-03	mg/kg/day	1.4E-01	mg/kg/day	6.2E-02
			Exp. Route Total								N/A					5.6E-01
			Dermal Absorption	Arsenic, Dissolved	5.5E+00	ug/L	N/A		N/A		N/A	7.9E-07	mg/kg/day	3.0E-04	mg/kg/day	2.6E-03
				Manganese, Dissolved	3.2E+02	ug/L	N/A		N/A		N/A	4.5E-05	mg/kg/day	1.4E-01	mg/kg/day	3.2E-04
			Exp. Route Total								N/A					2.9E-03
		Exposure Point Total									N/A					5.7E-01
	Exposure Medium Total										N/A					5.7E-01
Shallow Aquifer Groundwater Total											N/A					5.7E-01
										Total of Receptor Risks Across All Media	N/A				Total of Receptor Hazards Across All Media	5.7E-01

Notes-

N/A =Not available; Not applicable.

DA_{event} for dermal exposure to groundwater calculated on Tables 7.1.RME Supplement A.

Table 7.1.RME Supplement A
Calculation of DAevent
Resident Adult Shallow Groundwater
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (µg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ_{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm^2-event)	Eq
Arsenic, Dissolved	5.5E+00	1.0E-03	N/A	N/A	N/A	N/A	0.58	3.2E-09	1
Manganese, Dissolved	3.2E+02	1.0E-03	N/A	N/A	N/A	N/A	0.58	1.8E-07	1

Inorganics: DAevent (mg/cm2-event) =

$$DA_{event} = \quad Kp \times CW \times tevent \times 0.001\ mg/ug \times 0.001\ l/cm^3 \qquad \text{(Eq 1)}$$

Notes:
N/A - Not applicable
Permeability constants and other input parameter values from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final).* EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this document.
B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).
t* - Time to reach steady-state

TABLE 7.2.RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Ingestion	Arsenic, Dissolved	5.5E+00	ug/L	N/A		N/A		N/A	3.5E-04	mg/kg/day	3.0E-04	mg/kg/day	1.2E+00
				Manganese, Dissolved	3.2E+02	ug/L	N/A		N/A		N/A	2.0E-02	mg/kg/day	1.4E-01	mg/kg/day	1.4E-01
			Exp. Route Total								N/A					1.3E+00
			Dermal Absorption	Arsenic, Dissolved	5.5E+00	ug/L	N/A		N/A		N/A	2.3E-06	mg/kg/day	3.0E-04	mg/kg/day	7.7E-03
				Manganese, Dissolved	3.2E+02	ug/L	N/A		N/A		N/A	1.3E-04	mg/kg/day	1.4E-01	mg/kg/day	9.6E-04
			Exp. Route Total								N/A					8.7E-03
		Exposure Point Total									N/A					1.3E+00
	Exposure Medium Total										N/A					1.3E+00
Shallow Aquifer Groundwater Total											N/A					1.3E+00
										Total of Receptor Risks Across All Media	N/A				Total of Receptor Hazards Across All Media	1.3E+00

Notes-

N/A =Not available; Not applicable.

DA_{event} for dermal exposure to groundwater calculated on Tables 7.2.RME Supplement A.

Table 7.2.RME Supplement A
Calculation of DAevent
Resident Child Shallow Groundwater
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (µg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ_{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm^2-event)	Eq
Arsenic, Dissolved	5.5E+00	1.0E-03	N/A	N/A	N/A	N/A	1	5.5E-09	1
Manganese, Dissolved	3.2E+02	1.0E-03	N/A	N/A	N/A	N/A	1	3.2E-07	1

Inorganics: DAevent (mg/cm2-event) =

DA_{event} = Kp x CW x tevent x 0.001 mg/ug x 0.001 l/cm^3 (Eq 1)

Notes:
N/A - Not applicable
Permeability constants and other input parameter values from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final).* EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this document.
B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).
t* - Time to reach steady-state

TABLE 7.3.RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Ingestion	Arsenic, Dissolved	5.5E+00	ug/L	8.2E-05	mg/kg/day	1.5E+00	mg/kg/day	1.2E-04	N/A		N/A		N/A
				Manganese, Dissolved	3.2E+02	ug/L	4.7E-03	mg/kg/day	N/A		N/A	N/A		N/A		N/A
			Exp. Route Total								1.2E-04					N/A
			Dermal Absorption	Arsenic, Dissolved	5.5E+00	ug/L	4.7E-07	mg/kg/day	1.5E+00	mg/kg/day	7.0E-07	N/A		N/A		N/A
				Manganese, Dissolved	3.2E+02	ug/L	2.7E-05	mg/kg/day	N/A		N/A	N/A		N/A		N/A
			Exp. Route Total								7.0E-07					N/A
		Exposure Point Total									1.2E-04					N/A
	Exposure Medium Total										1.2E-04					N/A
Shallow Aquifer Groundwater Total											1.2E-04					N/A
							Total of Receptor Risks Across All Media				1.2E-04	Total of Receptor Hazards Across All Media				N/A

Notes-

N/A =Not available; Not applicable.

DA_{event} for dermal exposure to groundwater calculated on Tables 7.1.RME Supplement A and 7.2.RME Supplement A.

TABLE 7.4.RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Shallow Aquifer - Water in Excavation Trench	Dermal Absorption	Aluminum	1.9E+05	ug/L	6.0E-04	mg/kg/day	N/A		N/A	4.2E-02	mg/kg/day	1.0E+00	mg/kg/day	4.2E-02
				Antimony	1.4E+01	ug/L	4.4E-08	mg/kg/day	N/A		N/A	3.1E-06	mg/kg/day	6.0E-05	mg/kg/day	5.1E-02
				Arsenic	4.3E+02	ug/L	1.4E-06	mg/kg/day	1.5E+00	mg/kg/day	2.1E-06	9.6E-05	mg/kg/day	3.0E-04	mg/kg/day	3.2E-01
				Barium	5.1E+02	ug/L	1.6E-06	mg/kg/day	N/A		N/A	1.1E-04	mg/kg/day	1.4E-02	mg/kg/day	8.1E-03
				Beryllium	9.6E+00	ug/L	3.1E-08	mg/kg/day	N/A		N/A	2.1E-06	mg/kg/day	3.5E-05	mg/kg/day	6.1E-02
				Cadmium	8.7E+00	ug/L	2.8E-08	mg/kg/day	N/A		N/A	1.9E-06	mg/kg/day	2.5E-05	mg/kg/day	7.8E-02
				Chromium	6.0E+02	ug/L	3.8E-06	mg/kg/day	2.0E+01	mg/kg/day	7.6E-05	2.7E-04	mg/kg/day	1.3E-04	mg/kg/day	2.1E+00
				Cobalt	7.4E+01	ug/L	9.4E-08	mg/kg/day	N/A		N/A	6.6E-06	mg/kg/day	3.0E-03	mg/kg/day	2.2E-03
				Copper	1.0E+02	ug/L	3.2E-07	mg/kg/day	N/A		N/A	2.2E-05	mg/kg/day	4.0E-02	mg/kg/day	5.5E-04
				Iron	3.8E+05	ug/L	1.2E-03	mg/kg/day	N/A		N/A	8.5E-02	mg/kg/day	7.0E-01	mg/kg/day	1.2E-01
				Manganese	1.4E+03	ug/L	4.3E-06	mg/kg/day	N/A		N/A	3.0E-04	mg/kg/day	1.4E-01	mg/kg/day	2.2E-03
				Nickel	1.7E+02	ug/L	1.1E-07	mg/kg/day	N/A		N/A	7.6E-06	mg/kg/day	8.0E-04	mg/kg/day	9.5E-03
				Thallium	2.0E+00	ug/L	6.4E-09	mg/kg/day	N/A		N/A	4.5E-07	mg/kg/day	4.0E-05	mg/kg/day	1.1E-02
				Vanadium	4.2E+02	ug/L	1.3E-06	mg/kg/day	N/A		N/A	9.3E-05	mg/kg/day	7.0E-03	mg/kg/day	1.3E-02
				Zinc	6.7E+02	ug/L	1.3E-06	mg/kg/day	N/A		N/A	8.9E-05	mg/kg/day	3.0E-01	mg/kg/day	3.0E-04
			Exp. Route Total								7.8E-05					2.8E+00
		Exposure Point Total									7.8E-05					2.8E+00
	Exposure Medium Total										7.8E-05					2.8E+00
Shallow Aquifer Groundwater Total											7.8E-05					2.8E+00
									Total of Receptor Risks Across All Media		7.8E-05		Total of Receptor Hazards Across All Media			2.8E+00

Notes-

Table 7.4.RME Supplement A
Calculation of DAevent
Construction Worker Shallow Ground Water
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (μg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ_{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm^2-event)	Eq
Aluminum	1.9E+05	1.0E-03	N/A	N/A	N/A	N/A	8	1.5E-03	1
Antimony	1.4E+01	1.0E-03	N/A	N/A	N/A	N/A	8	1.1E-07	1
Arsenic	4.3E+02	1.0E-03	N/A	N/A	N/A	N/A	8	3.4E-06	1
Barium	5.1E+02	1.0E-03	N/A	N/A	N/A	N/A	8	4.1E-06	1
Beryllium	9.6E+00	1.0E-03	N/A	N/A	N/A	N/A	8	7.7E-08	1
Cadmium	8.7E+00	1.0E-03	N/A	N/A	N/A	N/A	8	7.0E-08	1
Chromium (hexavalent)	6.0E+02	2.0E-03	N/A	N/A	N/A	N/A	8	9.5E-06	1
Cobalt	7.4E+01	4.0E-04	N/A	N/A	N/A	N/A	8	2.4E-07	1
Copper	1.0E+02	1.0E-03	N/A	N/A	N/A	N/A	8	8.0E-07	1
Iron	3.8E+05	1.0E-03	N/A	N/A	N/A	N/A	8	3.0E-03	1
Manganese	1.4E+03	1.0E-03	N/A	N/A	N/A	N/A	8	1.1E-05	1
Nickel	1.7E+02	2.0E-04	N/A	N/A	N/A	N/A	8	2.7E-07	1
Thallium	2.0E+00	1.0E-03	N/A	N/A	N/A	N/A	8	1.6E-08	1
Vanadium	4.2E+02	1.0E-03	N/A	N/A	N/A	N/A	8	3.3E-06	1
Zinc	6.7E+02	6.0E-04	N/A	N/A	N/A	N/A	8	3.2E-06	1

Inorganics: DAevent (mg/cm2-event) =

$DA_{event} =$ Kp x CW x tevent x 0.001 mg/ug x 0.001 l/cm^3 (Eq 1)

Notes:
N/A - Not applicable
Permeability constants and other input parameter values from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part Supplemental Guidance for Dermal Risk Assessment - Final).* EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this documen
B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).
t* - Time to reach steady-state

TABLE 7.1.CTE

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

CENTRAL TENDENCY EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Ingestion	Arsenic, Dissolved	5.5E+00	ug/L	N/A		N/A		N/A	2.4E-04	mg/kg/day	3.0E-04	mg/kg/day	7.8E-01
				Manganese, Dissolved	3.2E+02	ug/L	N/A		N/A		N/A	1.4E-02	mg/kg/day	1.4E-01	mg/kg/day	9.7E-02
			Exp. Route Total								N/A					8.8E-01
			Dermal Absorption	Arsenic, Dissolved	5.5E+00	ug/L	N/A		N/A		N/A	5.1E-07	mg/kg/day	3.0E-04	mg/kg/day	1.7E-03
				Manganese, Dissolved	3.2E+02	ug/L	N/A		N/A		N/A	3.0E-05	mg/kg/day	1.4E-01	mg/kg/day	2.1E-04
			Exp. Route Total								N/A					1.9E-03
		Exposure Point Total									N/A					8.8E-01
	Exposure Medium Total										N/A					8.8E-01
Shallow Aquifer Groundwater Total											N/A					8.8E-01
									Total of Receptor Risks Across All Media		N/A	Total of Receptor Hazards Across All Media				8.8E-01

Notes-

N/A =Not available; Not applicable.

DA_{event} for dermal exposure to groundwater calculated on Tables 7.1.CTE Supplement A.

Table 7.1.CTE Supplement A
Calculation of DAevent
Resident Child Shallow Groundwater
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (µg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ_{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm²-event)	Eq
Arsenic, Dissolved	5.5E+00	1.0E-03	N/A	N/A	N/A	N/A	0.33	1.8E-09	1
Manganese, Dissolved	3.2E+02	1.0E-03	N/A	N/A	N/A	N/A	0.33	1.0E-07	1

Inorganics: DAevent (mg/cm2-event) =

DA_{event} = Kp x CW x tevent x 0.001 mg/ug x 0.001 l/cm ^{3} (Eq 1)

Notes:
N/A - Not applicable
Permeability constants and other input parameter values from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final).* EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this document.
B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).
t* - Time to reach steady-state

TABLE 7.2.CTE

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

CENTRAL TENDENCY EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC Value	EPC Units	Cancer Risk Calculations: Intake/Exposure Concentration Value	Intake/Exposure Concentration Units	CSF/Unit Risk Value	CSF/Unit Risk Units	Cancer Risk	Non-Cancer Hazard Calculations: Intake/Exposure Concentration Value	Intake/Exposure Concentration Units	RfD/RfC Value	RfD/RfC Units	Hazard Quotient
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Ingestion	Arsenic, Dissolved	5.5E+00	ug/L	2.9E-05	mg/kg/day	1.5E+00	mg/kg/day	4.4E-05	N/A		N/A		N/A
				Manganese, Dissolved	3.2E+02	ug/L	1.7E-03	mg/kg/day	N/A		N/A	N/A		N/A		N/A
			Exp. Route Total								4.4E-05					N/A
			Dermal Absorption	Arsenic, Dissolved	5.5E+00	ug/L	7.3E-08	mg/kg/day	1.5E+00	mg/kg/day	1.1E-07	N/A		N/A		N/A
				Manganese, Dissolved	3.2E+02	ug/L	4.2E-06	mg/kg/day	N/A		N/A	N/A		N/A		N/A
			Exp. Route Total								1.1E-07					N/A
		Exposure Point Total									4.4E-05					N/A
	Exposure Medium Total										4.4E-05					N/A
Shallow Aquifer Groundwater Total											4.4E-05					N/A
								Total of Receptor Risks Across All Media			4.4E-05	Total of Receptor Hazards Across All Media				N/A

Notes-

N/A =Not available; Not applicable.

DA_{event} for dermal exposure to groundwater calculated on Tables 7.1.CTE Supplement A and 7.2.CTE Supplement A.

Table 7.2.CTE Supplement A
Calculation of DAevent
Resident Adult Shallow Groundwater
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (μg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ_{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm^2-event)	Eq
Arsenic, Dissolved	5.5E+00	1.0E-03	N/A	N/A	N/A	N/A	0.25	1.4E-09	1
Manganese, Dissolved	3.2E+02	1.0E-03	N/A	N/A	N/A	N/A	0.25	7.9E-08	1

Inorganics: DAevent (mg/cm2-event) =

DA_{event} = Kp x CW x tevent x 0.001 mg/ug x 0.001 l/cm^3 (Eq 1)

Notes:
N/A - Not applicable
Permeability constants and other input parameter values from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final).* EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this document.
B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).
t* - Time to reach steady-state

TABLE 7.3.RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

CENTRAL TENDENCY EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Shallow Aquifer - Water in Excavation Trench	Dermal Absorption	Aluminum	1.9E+05	ug/L	3.0E-04	mg/kg/day	N/A		N/A	2.1E-02	mg/kg/day	1.0E+00	mg/kg/day	2.1E-02
				Antimony	1.4E+01	ug/L	2.2E-08	mg/kg/day	N/A		N/A	1.5E-06	mg/kg/day	6.0E-05	mg/kg/day	2.6E-02
				Arsenic	4.3E+02	ug/L	6.9E-07	mg/kg/day	1.5E+00	mg/kg/day	1.0E-06	4.8E-05	mg/kg/day	3.0E-04	mg/kg/day	1.6E-01
				Barium	5.1E+02	ug/L	8.1E-07	mg/kg/day	N/A		N/A	5.7E-05	mg/kg/day	1.4E-02	mg/kg/day	4.1E-03
				Beryllium	9.6E+00	ug/L	1.5E-08	mg/kg/day	N/A		N/A	1.1E-06	mg/kg/day	3.5E-05	mg/kg/day	3.1E-02
				Cadmium	8.7E+00	ug/L	1.4E-08	mg/kg/day	N/A		N/A	9.7E-07	mg/kg/day	2.5E-05	mg/kg/day	3.9E-02
				Chromium	6.0E+02	ug/L	1.9E-06	mg/kg/day	2.0E+01	mg/kg/day	3.8E-05	1.3E-04	mg/kg/day	1.3E-04	mg/kg/day	1.1E+00
				Cobalt	7.4E+01	ug/L	4.7E-08	mg/kg/day	N/A		N/A	3.3E-06	mg/kg/day	3.0E-03	mg/kg/day	1.1E-03
				Copper	1.0E+02	ug/L	1.6E-07	mg/kg/day	N/A		N/A	1.1E-05	mg/kg/day	4.0E-02	mg/kg/day	2.8E-04
				Iron	3.8E+05	ug/L	6.1E-04	mg/kg/day	N/A		N/A	4.2E-02	mg/kg/day	7.0E-01	mg/kg/day	6.1E-02
				Manganese	1.4E+03	ug/L	2.2E-06	mg/kg/day	N/A		N/A	1.5E-04	mg/kg/day	1.4E-01	mg/kg/day	1.1E-03
				Nickel	1.7E+02	ug/L	5.4E-08	mg/kg/day	N/A		N/A	3.8E-06	mg/kg/day	8.0E-04	mg/kg/day	4.7E-03
				Thallium	2.0E+00	ug/L	3.2E-09	mg/kg/day	N/A		N/A	2.2E-07	mg/kg/day	4.0E-05	mg/kg/day	5.6E-03
				Vanadium	4.2E+02	ug/L	6.6E-07	mg/kg/day	N/A		N/A	4.7E-05	mg/kg/day	7.0E-03	mg/kg/day	6.6E-03
				Zinc	6.7E+02	ug/L	6.4E-07	mg/kg/day	N/A		N/A	4.5E-05	mg/kg/day	3.0E-01	mg/kg/day	1.5E-04
			Exp. Route Total								3.9E-05					1.4E+00
		Exposure Point Total									3.9E-05					1.4E+00
	Exposure Medium Total										3.9E-05					1.4E+00
Shallow Aquifer Groundwater Total											3.9E-05					1.4E+00
							Total of Receptor Risks Across All Media				3.9E-05	Total of Receptor Hazards Across All Media				1.4E+00

Notes-

Table 7.3.CTE Supplement A
Calculation of DAevent
Construction Worker Shallow Ground Water
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (μg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ_{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm^2-event)	Eq
Aluminum	1.9E+05	1.0E-03	N/A	N/A	N/A	N/A	4	7.6E-04	1
Antimony	1.4E+01	1.0E-03	N/A	N/A	N/A	N/A	4	5.5E-08	1
Arsenic	4.3E+02	1.0E-03	N/A	N/A	N/A	N/A	4	1.7E-06	1
Barium	5.1E+02	1.0E-03	N/A	N/A	N/A	N/A	4	2.0E-06	1
Beryllium	9.6E+00	1.0E-03	N/A	N/A	N/A	N/A	4	3.8E-08	1
Cadmium	8.7E+00	1.0E-03	N/A	N/A	N/A	N/A	4	3.5E-08	1
Chromium (hexavalent)	6.0E+02	2.0E-03	N/A	N/A	N/A	N/A	4	4.8E-06	1
Cobalt	7.4E+01	4.0E-04	N/A	N/A	N/A	N/A	4	1.2E-07	1
Copper	1.0E+02	1.0E-03	N/A	N/A	N/A	N/A	4	4.0E-07	1
Iron	3.8E+05	1.0E-03	N/A	N/A	N/A	N/A	4	1.5E-03	1
Manganese	1.4E+03	1.0E-03	N/A	N/A	N/A	N/A	4	5.4E-06	1
Nickel	1.7E+02	2.0E-04	N/A	N/A	N/A	N/A	4	1.4E-07	1
Thallium	2.0E+00	1.0E-03	N/A	N/A	N/A	N/A	4	8.0E-09	1
Vanadium	4.2E+02	1.0E-03	N/A	N/A	N/A	N/A	4	1.7E-06	1
Zinc	6.7E+02	6.0E-04	N/A	N/A	N/A	N/A	4	1.6E-06	1

Inorganics: DAevent (mg/cm2-event) =

DA_{event} = Kp x CW x tevent x 0.001 mg/ug x 0.001 l/cm^3 (Eq 1)

Notes:
N/A - Not applicable
Permeability constants and other input parameter values from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part Supplemental Guidance for Dermal Risk Assessment - Final).* EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this documen
B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).
t* - Time to reach steady-state

TABLE 9.1.RME

SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Arsenic, Dissolved	N/A	N/A	N/A	N/A	Skin, Vascular	5E-01	N/A	3E-03	5E-01
			Manganese, Dissolved	N/A	N/A	N/A	N/A	CNS	6E-02	N/A	3E-04	6E-02
			Chemical Total	N/A	N/A	N/A	N/A		6E-01	N/A	3E-03	6E-01
		Exposure Point Total					N/A					6E-01
	Exposure Medium Total						N/A					6E-01
Shallow Aquifer Groundwater Total							N/A					6E-01
Receptor Total							N/A				Receptor HI Total	6E-01

Notes:

N/A = Not applicable

HI = Hazard Index

CNS = Central Nervous System

Total Skin HI Across All Media =	5E-01
Total Vascular HI Across All Media =	5E-01
Total CNS HI Across All Media =	6E-02

TABLE 9.2.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Arsenic, Dissolved	N/A	N/A	N/A	N/A	Skin, Vascular	1E+00	N/A	8E-03	1E+00
			Manganese, Dissolved	N/A	N/A	N/A	N/A	CNS	1E-01	N/A	1E-03	1E-01
			Chemical Total	N/A	N/A	N/A	N/A		1E+00	N/A	9E-03	1E+00
		Exposure Point Total					N/A					1E+00
	Exposure Medium Total						N/A					1E+00
Shallow Aquifer Groundwater Total							N/A					1E+00
Receptor Total							N/A				Receptor HI Total	1E+00

Notes:
N/A = Not applicable
HI = Hazard Index
CNS = Central Nervous System

Total Skin HI Across All Media =	1E+00
Total Vascular HI Across All Media =	1E+00
Total CNS HI Across All Media =	1E-01

TABLE 9.3.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Arsenic, Dissolved	1E-04	N/A	7E-07	1E-04	Skin, Vascular	N/A	N/A	N/A	N/A
			Manganese, Dissolved	N/A	N/A	N/A	N/A	CNS	N/A	N/A	N/A	N/A
			Chemical Total	1E-04	N/A	7E-07	1E-04		N/A	N/A	N/A	N/A
		Exposure Point Total					1E-04					N/A
	Exposure Medium Total						1E-04					N/A
Shallow Aquifer Groundwater Total							1E-04					N/A
Receptor Total							1E-04				Receptor HI Total	N/A

Notes:
N/A = Not applicable
HI = Hazard Index
CNS = Central Nervous System

TABLE 9.4.RME

SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Aluminum	N/A	N/A	N/A	N/A	Neurological	N/A	N/A	4E-02	4E-02
			Antimony	N/A	N/A	N/A	N/A	Whole Body, Blood	N/A	N/A	5E-02	5E-02
			Arsenic	N/A	N/A	2E-06	2E-06	Skin	N/A	N/A	3E-01	3E-01
			Barium	N/A	N/A	N/A	N/A	Kidney	N/A	N/A	8E-03	8E-03
			Beryllium	N/A	N/A	N/A	N/A	None Observed	N/A	N/A	6E-02	6E-02
			Cadmium	N/A	N/A	N/A	N/A	Kidney	N/A	N/A	8E-02	8E-02
			Chromium	N/A	N/A	8E-05	8E-05	Blood	N/A	N/A	2E+00	2E+00
			Cobalt	N/A	N/A	N/A	N/A	Thyroid	N/A	N/A	2E-03	2E-03
			Copper	N/A	N/A	N/A	N/A	Gastrointestinal	N/A	N/A	6E-04	6E-04
			Iron	N/A	N/A	N/A	N/A	Gastrointestinal	N/A	N/A	1E-01	1E-01
			Manganese	N/A	N/A	N/A	N/A	CNS	N/A	N/A	2E-03	2E-03
			Nickel	N/A	N/A	N/A	N/A	Decreased body and organ weights	N/A	N/A	9E-03	9E-03
			Thallium	N/A	N/A	N/A	N/A	Hair	N/A	N/A	1E-02	1E-02
			Vanadium	N/A	N/A	N/A	N/A	Lifetime	N/A	N/A	1E-02	1E-02
			Zinc	N/A	N/A	N/A	N/A	Blood	N/A	N/A	3E-04	3E-04
			Chemical Total	N/A	N/A	8E-05	8E-05		N/A	N/A	3E+00	3E+00
		Exposure Point Total					8E-05					3E+00
	Exposure Medium Total						8E-05					3E+00
Shallow Aquifer Groundwater Total							8E-05					3E+00
Receptor Total							8E-05				Receptor HI Total	3E+00

Notes:

N/A = Not applicable

HI = Hazard Index

CNS = Central Nervous System

Total Neurological/CNS HI Across All Media =	4E-02
Total Whole Body HI Across All Media =	5E-02
Total Blood HI Across All Media =	2E+00
Total Skin HI Across All Media =	3E-01
Total Kidney HI Across All Media =	9E-02
Total Thyroid HI Across All Media =	2E-03
Total Gastrointestinal HI Across All Media =	1E-01
Total Decreased body and organ weights Across All Media =	9E-03
Total Hair HI Across All Media =	1E-02
Total Lifetime HI Across All Media =	1E-02

TABLE 9.1.CTE
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
CENTRAL TENDENCY EXPOSURE
AOC 2
NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Arsenic, Dissolved	N/A	N/A	N/A	N/A	Skin, Vascular	8E-01	N/A	2E-03	8E-01
			Manganese, Dissolved	N/A	N/A	N/A	N/A	CNS	1E-01	N/A	2E-04	1E-01
			Chemical Total	N/A	N/A	N/A	N/A		9E-01	N/A	2E-03	9E-01
		Exposure Point Total					N/A					9E-01
	Exposure Medium Total						N/A					9E-01
Shallow Aquifer Groundwater Total							N/A					9E-01
Receptor Total							N/A				Receptor HI Total	9E-01

Notes:

N/A = Not applicable

HI = Hazard Index

CNS = Central Nervous System

Total Skin HI Across All Media =	8E-01
Total Vascular HI Across All Media =	8E-01
Total CNS HI Across All Media =	1E-01

TABLE 9.2.CTE

SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs

CENTRAL TENDENCY EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Arsenic, Dissolved	4E-05	N/A	1E-07	4E-05	Skin, Vascular	N/A	N/A	N/A	N/A
			Manganese, Dissolved	N/A	N/A	N/A	N/A	CNS	N/A	N/A	N/A	N/A
			Chemical Total	4E-05	N/A	1E-07	4E-05		N/A	N/A	N/A	N/A
		Exposure Point Total					4E-05					N/A
	Exposure Medium Total						4E-05					N/A
Shallow Aquifer Groundwater Total							4E-05					N/A
Receptor Total							4E-05				Receptor HI Total	N/A

Notes:

N/A = Not applicable

HI = Hazard Index

CNS = Central Nervous System

TABLE 9.3.CTE

SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs

CENTRAL TENDENCY EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Aluminum	N/A	N/A	N/A	N/A	Neurological	N/A	N/A	2E-02	2E-02
			Antimony	N/A	N/A	N/A	N/A	Whole Body, Blood	N/A	N/A	3E-02	3E-02
			Arsenic	N/A	N/A	1E-06	1E-06	Skin	N/A	N/A	2E-01	2E-01
			Barium	N/A	N/A	N/A	N/A	Kidney	N/A	N/A	4E-03	4E-03
			Beryllium	N/A	N/A	N/A	N/A	None Observed	N/A	N/A	3E-02	3E-02
			Cadmium	N/A	N/A	N/A	N/A	Kidney	N/A	N/A	4E-02	4E-02
			Chromium	N/A	N/A	4E-05	4E-05	Blood	N/A	N/A	1E+00	1E+00
			Cobalt	N/A	N/A	N/A	N/A	Thyroid	N/A	N/A	1E-03	1E-03
			Copper	N/A	N/A	N/A	N/A	Gastrointestinal	N/A	N/A	3E-04	3E-04
			Iron	N/A	N/A	N/A	N/A	Gastrointestinal	N/A	N/A	6E-02	6E-02
			Manganese	N/A	N/A	N/A	N/A	CNS	N/A	N/A	1E-03	1E-03
			Nickel	N/A	N/A	N/A	N/A	Decreased body and organ weights	N/A	N/A	5E-03	5E-03
			Thallium	N/A	N/A	N/A	N/A	Hair	N/A	N/A	6E-03	6E-03
			Vanadium	N/A	N/A	N/A	N/A	Lifetime	N/A	N/A	7E-03	7E-03
			Zinc	N/A	N/A	N/A	N/A	Blood	N/A	N/A	1E-04	1E-04
			Chemical Total	N/A	N/A	4E-05	4E-05		N/A	N/A	1E+00	1E+00
		Exposure Point Total					4E-05					1E+00
	Exposure Medium Total						4E-05					1E+00
Shallow Aquifer Groundwater Total							4E-05					1E+00
Receptor Total							4E-05				Receptor HI Total	1E+00

Notes:

N/A = Not applicable

HI = Hazard Index

CNS = Central Nervous System

Total Neurological/CNS HI Across All Media =	2E-02
Total Whole Body HI Across All Media =	3E-02
Total Blood HI Across All Media =	1E+00
Total Skin HI Across All Media =	2E-01
Total Kidney HI Across All Media =	4E-02
Total Thyroid HI Across All Media =	1E-03
Total Gastrointestinal HI Across All Media =	6E-02
Total Decreased body and organ weights Across All Media =	5E-03
Total Hair HI Across All Media =	6E-03
Total Lifetime HI Across All Media =	7E-03

TABLE 10.1.RME

RISK SUMMARY

REASONABLE MAXIMUM EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Arsenic	N/A	N/A	2E-06	2E-06	Skin	N/A	N/A	3E-01	3E-01
			Chromium	N/A	N/A	8E-05	8E-05	Blood	N/A	N/A	2E+00	2E+00
			Manganese	N/A	N/A	N/A	N/A	CNS	N/A	N/A	2E-03	2E-03
			Chemical Total	N/A	N/A	8E-05	8E-05		N/A	N/A	2E+00	2E+00
		Exposure Point Total					8E-05					2E+00
	Exposure Medium Total						8E-05					2E+00
Shallow Aquifer Groundwater Total							8E-05					2E+00
Receptor Total							8E-05				Receptor HI Total	2E+00

Notes:

N/A = Not applicable

HI = Hazard Index

CNS = Central Nervous System

Total Neurological/CNS HI Across All Media =	2E-03
Total Blood HI Across All Media =	2E+00
Total Skin HI Across All Media =	3E-01

TABLE 10.1.CTE

SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs

CENTRAL TENDENCY EXPOSURE

AOC 2

NWS Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Shallow Aquifer - Tap Water	Arsenic	N/A	N/A	1E-06	1E-06	Skin	N/A	N/A	2E-01	2E-01
			Chromium	N/A	N/A	4E-05	4E-05	Blood	N/A	N/A	1E+00	1E+00
			Manganese	N/A	N/A	N/A	N/A	CNS	N/A	N/A	1E-03	1E-03
			Chemical Total	N/A	N/A	4E-05	4E-05		N/A	N/A	1E+00	1E+00
		Exposure Point Total					4E-05					1E+00
	Exposure Medium Total						4E-05					1E+00
Shallow Aquifer Groundwater Total							4E-05					1E+00
Receptor Total							4E-05				Receptor HI Total	1E+00

Notes:

N/A = Not applicable

HI = Hazard Index

CNS = Central Nervous System

Total Neurological/CNS HI Across All Media =	1E-03
Total Blood HI Across All Media =	1E+00
Total Skin HI Across All Media =	2E-01

Appendix C
Ecological Risk Assessment

APPENDIX C

Ecological Risk Assessment

C.1 Introduction

This appendix contains a Screening-level Ecological Risk Assessment (SERA), constituting Step 1 of the ERA process, for AOC 2 groundwater. This ERA provides detail and documentation of the ecological risk screening performed for groundwater as part of the final SI (CH2M HILL, May 2012), which concluded no unacceptable ecological risk associated with AOC 2 groundwater.

C.1.1 Ecological Risk Assessment Process

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). The Navy ERA policy and guidance, which describe a process consisting of eight steps organized into three tiers, are conceptually similar to the 8-step ERA process outlined in USEPA ERA guidance for the Superfund program (USEPA, 1997). For both sets of guidance, Steps 1 and 2 involve conducting a SERA using very conservative assumptions. The BERA represents Steps 3 through 7. The BERA uses less conservative (but more realistic) assumptions and site-specific data to refine the risk estimates from the SERA for components that fail the initial screening. Step 8 addresses risk management issues. The major differences between the Navy ERA policy/guidance and the USEPA ERA guidance are:

- Navy policy/guidance provides clearly defined criteria for exiting the ERA process at specific points
- Navy policy/guidance divides Step 3 (the first step of the BERA) into two distinct sub-steps (Steps 3A and 3B), with a potential exit point after Step 3A
- Navy policy/guidance incorporates risk management considerations throughout all tiers of the ERA process

ERAs are conducted using a tiered, step-wise approach and are punctuated with Scientific Management Decision Points (SMDPs). SMDPs represent points in the ERA process where agreement on conclusions, actions, or methodologies is needed so that the ERA process can continue (or terminate) in a technically defensible manner. The results of the ERA at a particular SMDP are used to determine how the ERA process should proceed, for example, to the next step in the process or directly to a later step. The process continues until a final decision has been reached (remedial action if unacceptable risks are identified, or no further action if risks are acceptable). The process can also be iterative if data needs are identified at any step; the needed data are collected and the process starts again at the point appropriate to the type of data collected.

The screening (preliminary) problem formulation is the first step of an ERA and establishes the goals, scope, and focus of the SERA. Step 1 of the ERA process is intended to answer two main questions:

- Do complete exposure pathways exist?
- Are sufficient data available to conduct the SERA?

If no complete exposure pathways exist, the ERA process terminates at Step 1 with a conclusion of negligible (acceptable) risk because exposure, and thus potential risk, can only occur if complete exposure pathways exist. If one or more complete exposure pathways are known to exist, or are likely to exist, the ERA process continues to Step 2 but only evaluates those pathways that have been determined to be "critical" (ecologically important), that is, represent exposures to sensitive receptors that are associated with the predominant fate and transport mechanisms at the site (USEPA, 1997). An evaluation of the available data is then conducted to determine if they are adequate to support the SERA. If not, additional data are collected before the ERA process continues. The second step of the ERA process involves conducting a screening exposure assessment, a screening effects assessment, and a screening risk calculation (risk characterization).

The results of the SERA are used to evaluate the potential for unacceptable ecological risks based upon very conservative assumptions. If the results of the SERA suggest that further ecological risk evaluation is warranted, the ERA process proceeds to the BERA (Steps 3 through 7), which is a more detailed phase of the ERA process, for the pathways, chemicals, receptors, and areas identified in the SERA. As previously indicated, the first step of the BERA (Step 3) is divided into two distinct sub-steps (3A and 3B) in Navy ERA guidance.

Step 3 of the USEPA ERA guidance consists of the following activities (USEPA, 1997):

1. Refinement of the chemicals of potential concern (COPCs) from the SERA
2. Further characterizing the potential ecological effects of contaminants
3. Refining information on contaminant fate and transport, complete exposure pathways, and receptors potentially at risk
4. Selecting assessment endpoints
5. Refining the conceptual model and risk hypotheses from the SERA

Step 3A of the Navy policy/guidance (refinement of conservative exposure assumptions) corresponds to the first activity, previously listed, for the USEPA ERA guidance. In Step 3A, a refined evaluation of exposure estimates is conducted using less conservative (but more realistic) assumptions and additional methodologies relative to those used in the SERA, which is intended to be a very conservative assessment (NAVFAC, 2003). Examples of less conservative (but more realistic) exposure assumptions include using central tendency (mean) estimates (rather than maximums) for media concentrations, bioaccumulation factors (BAFs), and exposure parameters. Examples of additional methodologies include the consideration of background concentrations, bioavailability, and detection frequency (CNO, 1999; NAVFAC, 2003).

If risk estimates (and their associated uncertainty) are acceptable following Step 3A, the site will meet the conditions of the exit criterion specified in the Navy policy/guidance. If the Step 3A evaluation does not support a determination of acceptable risk within acceptable uncertainty, the site continues to Step 3B.

Step 3B of the Navy policy/guidance (problem formulation) corresponds conceptually to the last four activities, previously listed, for Step 3 of the USEPA ERA guidance. In Step 3B, the preliminary conceptual model from the SERA is refined based upon the results of the Step 3A evaluation to develop a revised list of key receptors, critical exposure pathways, key COPCs, assessment endpoints, measurement endpoints, and risk hypotheses. Based upon the refined conceptual model, the lines of evidence to be used in characterizing risk are determined. Agreement on the refined conceptual model, COPCs, exposure pathways, endpoints, and risk hypotheses constitutes the SMDP at the end of Step 3 in both Navy and USEPA ERA guidance.

Following the completion of Step 3, a decision point is reached with two potential outcomes. If the refined risk estimates are acceptable for each selected assessment endpoint, the investigation proceeds to risk characterization (Step 7) to document this conclusion, and the ERA process terminates. If the uncertainties associated with the refined risk estimates are unacceptable and/or the risk estimates indicate that unacceptable risks may exist, site-specific studies might be required and the ERA process continues (Steps 4 through 6). Step 4 is a work planning step where additional site-specific studies are scoped and designed. Step 5 consists of the verification of the field sampling design developed in Step 4 while Step 6 constitutes the site investigation and data analysis phase of the process. The scope (the spatial extent of sampling) and components (the collection of biological data such as tissue samples, toxicity testing, and so forth) of any site-specific studies are determined by the conclusions of Step 3 and the pathways/endpoints associated with the potential unacceptable risks.

Step 7 consists of the documentation and synthesis of the information and data identified in Steps 1 through 3 (no additional study) or Steps 1 through 6 (additional study). In this step, risk is evaluated and characterized using both quantitative and qualitative methods. Conclusions are made as to whether or not there is a reasonable potential for unacceptable ecological risk, and if there is a potential for unacceptable ecological risk, the magnitude of that risk. The results of the completed BERA (Step 7) are used to make any necessary risk management decisions (Step 8) related to current or future risks. Possible decisions include:

- Adequate information is available to conclude that no unacceptable ecological risks exist. The assessment should stop at Step 7.
- Adequate information is available to conclude that unacceptable ecological risks exist for which remedial actions or controls are warranted. Whether remedial actions or controls are taken, and the specific actions or controls taken, will depend upon a number of risk management factors such as the results of any human health risk assessments (if applicable) and the potential impact of the remedial action or control itself on the habitats and biota present. This analysis would occur as part of Step 8.
- Adequate information is not available to estimate risk or the risk estimate is believed to be too conservative or uncertain to recommend remediation. The assessment should be refined.

C.2 Problem Formulation

Problem formulation establishes the goals, scope, and focus of the ERA. As part of problem formulation, the ecological setting of AOC 2 is characterized in terms of the habitats and biota known or likely to be present. The types and concentrations of chemicals that are present in ecologically relevant media are also described based upon available analytical data for complete exposure pathways. Groundwater is the subject of this ERA; soils at the site are being evaluated separately.

A conceptual model is developed that describes source areas, transport pathways and exposure media, exposure pathways and routes, and receptors. Assessment endpoints, measurement endpoints, and risk hypotheses are developed to evaluate those receptors for which critical (complete and significant) exposure pathways exist. The fate, transport, and toxicological properties of the chemicals present at AOC 2 are also considered during this process.

C.2.1 Environmental Setting

AOC 2 is located along the southern perimeter of CAX (Figure 1 of the Consensus Statement). AOC 2 was identified during site visits by the Navy, USEPA, VDEQ, and Baker in late 1997 and early 1998 and consists of several rows of concrete foundation piers that at one time supported a Shipping House associated with the former Penniman Shell Loading Plant (PSLP). The majority of structures associated with the PSLP were demolished between 1918 and 1925. Grass-covered lanes leading to the site area are likely locations of former rail lines that have been removed. Several partially buried glass bottles (many of which were labeled “dextrose”) and unlabeled drums were discovered in the area. Several mounds present in the area were suspected to contain buried debris. In 1999-2000, 43 drums (all empty), including unearthed drums and drums collected from the ground surface, as well as 280 dextrose bottles (whose contents were emptied into drums on site), were removed for off-site disposal. As part of the final SI (CH2M HILL, May 2012), an interim removal action was recommended to remove additional debris, consisting of respirator cartridges and empty 55- gallon drums, in other areas of the site (Area 2-– Figure 3 of the Consensus Statement).

AOC 2 is a small (less than 1 acre) wooded site that contains no wetlands or other water bodies. The topography of AOC 2 is predominantly flat. There are no nearby water bodies downgradient of the site. Surface runoff at the site is anticipated to pond and infiltrate into the soil. The shallow aquifer underlying AOC 2 is the Cornwallis Cave Aquifer. Groundwater depths during the 1998 Field Investigation ranged from 22 to 33 feet bgs. Based upon groundwater elevation data collected in 1998, groundwater flow is to the southeast, toward King Creek, which is located approximately 2,000 feet southeast of AOC 2 (Figure 1 of the Consensus Statement).

AOC 2 is located in a wooded area with no specified designated use. AOC 2 is not surrounded by a gate or fencing, but it is within the confines of CAX and access for the general public is restricted. Navy and DoD personnel have access to the area, and there are nearby tree stands used for hunting. Future land use at AOC 2 is not expected to change and will likely continue as wooded/green space for the foreseeable future.

C.2.2 Conceptual Model

The conceptual model relates potentially exposed receptor populations with potential source areas based upon physical site characteristics and complete exposure pathways. Important components of the conceptual model are the identification of potential source areas, transport pathways, exposure media, exposure pathways and routes, and receptors. Actual or potential exposures of ecological receptors associated with a site are determined by identifying the most likely, and most important, mechanisms and pathways of contaminant release and transport. A complete exposure pathway has three components: (1) a source or sources of contamination that results in a release to the environment; (2) a pathway and mechanism of chemical transport through an environmental medium; and (3) an exposure or contact point for an ecological receptor. Key components of this conceptual model are discussed in the following subsections.

C.2.2.1. Source Areas

The source of potential contamination at AOC 2 is the historical debris that has been found at this site, some of which has been removed with additional removals planned.

C.2.2.2. Transport Pathways and Exposure Media

A transport pathway describes the mechanisms whereby site-related chemicals, once released, may be transported from a source to ecologically relevant media where exposures may occur. Groundwater is generally considered only as a transport medium since there are no ecological exposures to groundwater until it discharges to a water body or surfaces as a seep. The primary potential release mechanisms and transport pathways at the site related to groundwater include:

- Infiltration, percolation, and leaching of contaminants to groundwater and subsequent discharge to the surface water and sediment of downgradient water bodies

Given the small size of the site, the relatively small amount of documented debris, and the nature of the debris (as described in **Section C.2.1**), as well as the distance from AOC 2 to the nearest water body (King Creek; about 2,000 feet to the southeast), the potential for significant transport of site-related constituents to King Creek via groundwater is not considered significant. Thus, this transport pathway is not considered to be complete and significant for ecological receptors.

C.2.2.3. Exposure Pathways and Routes

There are no complete and significant exposure pathways to AOC 2 groundwater for ecological receptors. Thus, based upon ERA guidance (see **Section C.1.1**), the ERA process terminates with a conclusion of no unacceptable risk.

C.2.3 Risk Summary and Conclusions

Groundwater is not a significant transport medium for site-related constituents to King Creek as this pathway is not considered to be complete and significant for ecological receptors.

C.3 References

CH2M HILL, Inc. 2012. *Site Inspection Report, Areas of Concern 1, 2, 6, 7, and 8. Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia*. May.

Chief of Naval Operations (CNO). 1999. *Navy policy for conducting ecological risk assessments.* Memorandum from Chief of Naval Operations to Commander, Naval Facilities Engineering Command. Ser N453E/9U595355. April 5, 1999.

Naval Facilities Engineering Command (NAVFAC). 2003. *Navy guidance for conducting ecological risk assessments.* http://web.ead.anl.gov/ecorisk/. February.

U.S. Environmental Protection Agency (USEPA). 1997. *Ecological risk assessment guidance for Superfund: process for designing and conducting ecological risk assessments.* Interim Final. EPA/540/R-97/006.

Responses to Comments

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

March 21, 2013

Mr. Scott Park
NAVFAC MIDLANT, Building N-26, Room 3208
Attention: Code OPHE3, Mr. Scott Park
9742 Maryland Avenue
Norfolk, VA 23511-3095

Subject: Draft No Action Consensus Letter for Groundwater at AOC 2, Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia, January 2013

Mr. Park:

Thank you for the opportunity to review the subject document. EPA would like to provide the following comments at this time.

1. On page 2, the consensus letter (CL) states that concentrations of inorganic constituents were generally within the range of background concentrations for groundwater. However, on page 3, the CL states that 15 total inorganic constituents and two dissolved inorganic constituents exceeded background concentrations in groundwater. These statements appear contradictory. This issue should be clarified. Background data need to be included in this report.

2. On page 5, the CL states that given the small size of the site, the relatively small amount of documented debris, and the nature of the debris, as well as the distance from AOC 2 to the nearest water body (King Creek; about 2,000 feet southeast of AOC 2), the potential for substantive transport of site-related constituents to King Creek via groundwater is not considered significant. Information on the area of groundwater contamination exceeding ecological screening levels should also be provided. If this information suggests that contamination above ecological screening levels in groundwater has moved beyond the site boundary, additional information will need to be provided to justify no action, including the rate of groundwater migration and the estimated concentration relative to ecological screening levels at the groundwater/surface water interface.

If you have any questions, please contact me at 215-814-3394.

Sincerely,

Susanne Haug, P.E.
NPL/BRAC Federal Facilities Branch

cc: Wade Smith, VDEQ

Response to Comments
Draft No Action Consensus Letter for Groundwater at AOC 2
Naval Weapons Station Yorktown Cheatham Annex
Williamsburg, VA
March 28, 2013

Comments received by email on March 21, 2013 from Susanne Haug, Environmental Protection Agency, Region 3.

EPA Comment #1: On page 2, the consensus letter (CL) states that concentrations of inorganic constituents were generally within the range of background concentrations for groundwater. However, on page 3, the CL states that 15 total inorganic constituents and two dissolved inorganic constituents exceeded background concentrations in groundwater. These statements appear contradictory. This issue should be clarified. Background data need to be included in this report.

Navy Response: The sentence referred to on page 2, was included as part of the summary of previous groundwater investigations at AOC 2. However, since no risk due to exposure to groundwater was identified (as presented in the CL), this sentence was deleted from the text to eliminate the apparent contradiction. In addition, the current background dataset values (95% UTL values) were included in Table 1.

EPA Comment #2: On page 5, the CL states that given the small size of the site, the relatively small amount of documented debris, and the nature of the debris, as well as the distance from AOC 2 to the nearest water body (King Creek; about 2,000 feet southeast of AOC 2), the potential for substantive transport of site-related constituents to King Creek via groundwater is not considered significant. Information on the area of groundwater contamination exceeding ecological screening levels should also be provided. If this information suggests that contamination above ecological screening levels in groundwater has moved beyond the site boundary, additional information will need to be provided to justify no action, including the rate of groundwater migration and the estimated concentration relative to ecological screening levels at the groundwater/surface water interface.

Navy Response: The approach used in the CL was the same as that used in the Final SI report for AOC 2 because the ecological conceptual model for the site has not changed. Thus, this potential transport pathway is still not considered to be complete and significant. Further, only one organic chemical (diethyl phthalate) was detected in AOC 2 groundwater samples and it was at concentrations less than ecological screening values (ESVs). Only three metals (aluminum, copper, and manganese) exceeded ESVs and background UTLs based upon maximum dissolved concentrations in AOC 2 groundwater, and all exceeded ESVs or UTLs at ratios of less than a factor of 2 based on mean concentrations. Also, none of these three metals exceeded ESVs and UTLs in site surface or subsurface soils, suggesting that they are not site related. Therefore, there are no site-related contaminants migrating offsite. No changes were made to the CL.

Sawyer, Stephanie/VBO

From: Smith, Wade (DEQ) [Wade.Smith@deq.virginia.gov]
Sent: Friday, March 01, 2013 10:02 AM
To: scott.park@navy.mil
Cc: Ivester, Marlene/VBO; Sawyer, Stephanie/VBO; Haug.Susanne@epamail.epa.gov
Subject: CAX: AOC 2 No Action Consensus Letter for Groundwater - DEQ Comments

Thank you for giving the DEQ the opportunity to comment on the January 18, 2013 Draft No Action Consensus Letter for Groundwater for AOC 2 at CAX.

The Draft NA Consensus Letter was received by the DEQ on January 22, 2013.

Based on review of this NA Consensus Letter and previous team discussions and site visits, the DEQ has no comments.

Upon your submittal of the Draft Final or Final, the DEQ will issue an official letter for your files.

Please let me know if you have any questions.

Sincerely,

Wade M. Smith
Remediation Project Manager
Virginia Department of Environmental Quality
Office of Remediation Programs
Phone: (804) 698-4125
wade.smith@deq.virginia.gov

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

April 29, 2013

Mr. Scott Park
NAVFAC MIDLANT, Building N-26, Room 3208
Attention: Code OPHE3, Mr. Scott Park
9742 Maryland Avenue
Norfolk, VA 23511-3095

Subject: Response to Comments, Draft No Action Consensus Letter for Groundwater at AOC 2, Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia, March 28, 2012

Mr. Park:

Thank you for the opportunity to review the subject document. The responses to comments are acceptable except for the one listed below which requires further discussion.

> EPA Comment 2 recommended that additional information on the area of groundwater contamination exceeding ecological screening levels (ESLs), the rate of groundwater migration, and the estimated concentration relative to ESLs at the groundwater/surface water interface be provided to support the conclusion that the potential for substantive transport of site-related constituents to King Creek via groundwater is not considered significant. The RTC states that only three metals (aluminum, copper, and manganese) exceeded ESLs and background, and because none of these metals exceeded ESLs in soils, these metals are not site-related and thus no site-related contaminants are migrating off-site. The RTC does not provide the requested information on the extent of contamination, the rate of groundwater migration and estimated concentration at the groundwater/surface water interface to support the conclusion. In addition, if these metals above background and ESLs are not related to AOC 2, an explanation on where these elevated metals in groundwater originated should be provided. This additional information should be provided to support the no further action for groundwater at AOC 2.

If you have any questions, please contact me at 215-814-3394.

Sincerely,

Susanne Haug, P.E.
NPL/BRAC Federal Facilities Branch

cc: Wade Smith, VDEQ

-----Original Message-----
From: Park, Scott R CIV NAVFAC MIDLANT, EV [mailto:scott.park@navy.mil]
Sent: Tuesday, May 21, 2013 12:11 PM
To: Haug.Susanne@epa.gov
Cc: Ivester, Marlene/VBO
Subject: AOC 2 RTCs

Sue,

It was nice talking to you. Trying to get this matter resolved before you get away for several days. Below is the EPA comment with following Navy response.
Some of the key points are:
1 - The approach is the same as the Final SI for AOC 2 because the eco conceptual model hasn't changed.
2 - The nearest water body (King Creek) is 2000 feet away.
3 - The 3 inorganics (aluminum, copper, and manganese) exceeded the ecological screening values (ESVs) or UTLs at ratios of less than a factor of 2 based on mean concentrations.
4 - The 3 inorganics are naturally occurring and not site related i.e. location unknown. Cost and time to search for these 3 is unwarranted. Funds are unprogrammed and unavailable due in part to sequestration.
5 - None of the 3 exceeded ESVs and UTLs in site surface or subsurface soils
6 - It is reasonable to assume any COC concentrations in GW would be diluted and attenuated to some degree while migrating 2,000 ft to Kings Creek and due to dilution when discharged to Kings Creek surface water.

If possible ask your hydro to look at item 6 above and see if he/she agrees.
Below is the EPA comment and Navy response.

EPA Comment #2: On page 5, the CL states that given the small size of the site, the relatively small amount of documented debris, and the nature of the debris, as well as the distance from AOC 2 to the nearest water body (King Creek; about 2,000 feet southeast of AOC 2), the potential for substantive transport of site-related constituents to King Creek via groundwater is not considered significant.
Information on the area of groundwater contamination exceeding ecological screening levels should also be provided. If this information suggests that contamination above ecological screening levels in groundwater has moved beyond the site boundary, additional information will need to be provided to justify no action, including the rate of groundwater migration and the estimated concentration relative to ecological screening levels at the groundwater/surface water interface.

Navy Response: The approach used in the CL was the same as that used in the Final SI report for AOC
2 because the ecological conceptual model for the site has not changed. Thus, this potential transport pathway is still not considered to be complete and significant. Further, only one organic chemical (diethyl phthalate) was detected in AOC 2 groundwater samples and it was at

concentrations less than ecological screening values (ESVs). Only three metals (aluminum, copper, and manganese) exceeded ESVs and background UTLs based upon maximum dissolved concentrations in AOC 2 groundwater, and all exceeded ESVs or UTLs at ratios of less than a factor of 2 based on mean concentrations.
Also, none of these three metals exceeded ESVs and UTLs in site surface or subsurface soils, suggesting that they are not site related. Therefore, there are no site-related contaminants migrating offsite. No changes were made to the CL.

I'm with you, resolution within the Team without Tier 2 involvement is our best route.
If I don't get to talk to you again, have a safe and enjoyable trip during your time off.

Thanks in advance for your efforts to get this resolved.

Scott

Regulatory Acceptance

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

August 19, 2013

Mr. Scott Park
NAVFAC MIDLANT, Building N-26, Room 3208
Attention: Code OPHE3, Mr. Scott Park
9742 Maryland Avenue
Norfolk, VA 23511-3095

Subject: Draft No Action Consensus Letter for Groundwater at AOC 2, Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Mr. Park:

I have reviewed EPA's letter on the subject document dated April 29, 2013 along with your email response to Sue Haug dated May 21, 2013. Based on the information provided in that correspondence, EPA has no further comments on this document. Please submit a final copy of the subject document for our records.

If you have any questions, please contact me at 215-814-2077.

Sincerely,

Gerald F. Hoover

Gerald F. Hoover, RPM
NPL/BRAC Federal Facilities Branch

cc: Wade Smith, VDEQ

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
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David K. Paylor
Director

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August 20, 2013

Mr. Scott Park
NAVFAC MIDLANT, Building N-26
Hampton Roads Restoration Product Line, Code OPHREV4
9742 Maryland Avenue
Norfolk, VA 23511-3095

No Action Consensus Letter for Groundwater
AOC 2 – Dextrose Dump
Naval Weapons Station Yorktown
Cheatham Annex
Williamsburg, Virginia

Dear Mr. Park:

The Virginia Department of Environmental Quality (DEQ) has received the *Red-line Final No Action Consensus Letter for Groundwater at AOC 2* (Consensus Letter) for Naval Weapons Station Yorktown, Cheatham Annex (CAX), Williamsburg, Virginia. The Consensus Letter, prepared by CH2M HILL, was received by the DEQ (electronically) on August 20, 2013.

Thank you for providing the DEQ's Office of Remediation Programs the opportunity to review the above-referenced Consensus Letter. Subsequent to DEQ's internal review, this office concurs with the proposed text revisions and recommends submittal of the *Final No Action Consensus Letter for Groundwater at AOC 2* for signature.

Please contact me at (804) 698-4125 or wade.smith@deq.virginia.gov with any additional questions.

Sincerely,

Wade M. Smith
Remediation Project Manager
Office of Remediation Programs

cc: Jerry Hoover, EPA