Human Health and Ecological Risk Assessment

Chesterfield Power Station Ash Ponds

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Prepared for Southern Environmental Law Center

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ACRONYM LIST

AWQC	-	Ambient Water Quality Criteria for the Protection Of Freshwater Aquatic Life And Their Uses
BCC	-	Bioaccumulative Contaminant of Concern
BTV		Background threshold value
CDI	-	Chronic Daily Intake
COPC	-	Contaminant of Potential Concern
CSM	-	Conceptual Site Model
EcoSSL	-	Ecological Soil Screening Levels
EPC	-	Exposure Point Concentration
HQ	-	Hazard Quotient
HI	-	Hazard Index
MCL	-	Maximum Contaminant Level
ORNL	-	Oak Ridge National Laboratory
OSW	-	Other Surface Waters
PAH	-	Polynuclear Aromatic Hydrocarbon
PWS	-	Public Water Supply
RAGS	-	Risk Assessment Guidance for Superfund
RAIS	-	Risk Assessment Information System
RL	-	Reporting Limit
RME	-	Reasonable Maximum Exposure
RSL	-	Regional Screening Levels
SQC	-	Sediment Quality Criteria
SMCL	-	Secondary Maximum Contaminant Level
TBV		To Be Considered Value
USEPA	-	U.S. Environmental Protection Agency
VDEQ	-	Virginia Department of Environmental Quality
VURAM	-	Virginia Unified Risk Assessment Model
WQC	-	Water Quality Criteria

Executive Summary

The Chesterfield Power Station (the Site) was constructed along the James River approximately 12 miles downstream of the fall line in Richmond, Virginia. Approximately 15 million tons of coal ash is stored in two unlined basins at the Site, known as the Lower and Upper Ash Ponds. Both ponds are located in close proximity to the James River, the original channel of the James River (Farrar Gut), and a tidal lagoon located within the Dutch Gap Conservation Area. The Ash Ponds are bordered primarily by the Dutch Gap Conservation Area.

Surface water and sediment sampling were previously conducted in certain areas of Dutch Gap Conservation Area suspected of coal ash contamination. These areas are easily accessed by recreational visitors hiking, fishing, or boating in the public park. This risk assessment evaluates that sampling data to determine whether recreational visitors who interact with these particular areas face increased health risk. The risk estimates presented herein do not present a site-wide risk assessment of Dutch Gap Conservation Area, which would require additional sampling and analysis.

The cancer risks and noncancer hazard for recreational visitors who engage in activities in contaminated areas, based on exposure to surface water and sediment, are summarized as follows:

Risk Basis	Child	Adult	Target
Noncancer Hazard Index	140	110	≤1.0
Cumulative Cancer Risk	7.0×10^{-4}	9.6×10^{-4}	1.0×10^{-6}

HI= Hazard Index

These risk estimates are in excess of accepted target levels.

The noncancer hazard index (HI) evaluates noncancer health effects that could include neurological, cardiovascular, liver, kidney, and other problems. Noncancer hazards represent a comparison between the contaminant exposure at a site relative to a standard exposure level at which no adverse health effects are expected. Here, the noncancer HI indicates that hazard due to site-related contaminant intakes by children is 140 times higher than those identified as having no adverse health effects. The noncancer HI for adults indicates that site-related contaminant intakes by adults are 110 times higher than those identified as having no adverse health effects.

Cancer risk is a probabilistic measure. The cancer risk indicates whether there are more excess cancers predicted to occur due to exposure to site-related contaminants. The target cancer is risk is 1 excess cancer per 1 million people. The risk management range EPA uses for Superfund projects is 1×10^{-6} to 1×10^{-4} (i.e., 1 excess cancer per 1 million people up to 1 excess cancer per 10,000 people). The cancer risks here of 7×10^{-4} to 9.6×10^{-4} (i.e., 7 to nearly 10 excess cancers per 10,000 people) exceed the target of 1 excess cancer per 1 million people, and also exceed the upper-bound of the risk management range for Superfund projects.

As an alternative, risk estimates were also developed for the Upper and Lower Ash Pond using ground water data, collected by Dominion in 2016 and 2017, and published in ground water reports (Dominion 2018a&b). This alternative risk assessment was performed under the assumption that ground water is the ultimate source for contamination to seeps and sediments. Seeps may occur along embankments, wetlands, or into surface water, leading to incidental ingestion or dermal contact by recreational visitors or contact by ecological receptors. Monitoring wells are located along the Lower and Upper Ash Pond margins, but comparison to surface water data collected nearby strongly suggests a connection to surface water, which is reasonable given the shallow depth of ground water and the radial flow away from the ash ponds towards surface water drainages. Many of the analyte concentrations are significantly elevated above background concentrations in ground water, indicating site conditions are contaminating ground water at levels above background. Although Dominion has claimed that there is no environmental risk or impact to public drinking water supplies, this assumption must be based on there being no potable use of ground water as a domestic drinking water supply in the immediate vicinity. However, there are recreational visitors, and ecological receptors, that are potentially negatively affected by ground water daylighting at seeps or springs.

The risks using this alternative ground water-based assessment based on exposure by ingestion and dermal contact with ground water are as follows:

Upper Ash Pond Ground Water Hazard Indices and Cumulative Caner Risk for Recreational Visitors			
Risk Basis	**Child**	**Adult**	**Target**
Noncancer Hazard Index	1	0.4	≤1.0
Cumulative Cancer Risk	$2x10^{-5}$	$1x10^{-5}$	$1.0x10^{-6}$

Lower Ash Pond Ground Water Hazard Indices and Cumulative Cancer Risk for Recreational Visitors			
Risk Basis	**Child**	**Adult**	**Target**
Noncancer Hazard Index	3	0.8	≤1.0
Cumulative Cancer Risk	$8x10^{-5}$	$5x10^{-5}$	$1.0x10^{-6}$

There are excess noncancer hazards for recreational users exposed periodically at seeps/springs to incidental ingestion or dermal contact with ground water based on the available ground water data collected by Dominion. At the UAP there are no HQs above 1 for children or adults, but the hazard index (HI) is 1. At the LAP there are HQs of 1 or higher for arsenic and cobalt. There are also elevated cancer risks to recreational visitors due to exposure to arsenic and total radium concentrations in ground water at both the UAP and LAP areas.

The risks summarized above indicate that the coal ash ponds at Chesterfield need remediation to stop the flow of coal ash contamination off-site into the Dutch Gap Conservation Area and, at a minimum, more work is needed to fully understand the risks throughout the park. Although the ground water-only analysis indicates lower risk values than that for the sum of all potentially complete exposure pathways for recreational visitors (i.e., surface water, sediment, and dietary exposure pathways), the values are still above the targets for cancer risk, reinforcing the need for additional work.

It is important to note that the surface water and sediment samples underlying this assessment were collected along popular hiking trails, near fishing and birding platforms, and in a lagoon accessible by kayakers and other boaters. Focusing the assessment on these sampling areas is therefore appropriate as exposure to these areas by recreational visitors is a likely occurrence. In the future, additional sampling and analysis could be performed to understand the risks posed to visitors in areas less proximal to the coal ash ponds, and ultimately to generate a site-wide risk estimate. Additional sampling could also be done in more areas near the coal ash ponds to fully delineate the contamination and risks posed thereby, and to further quantify ground water flow and discharge patterns.

It is also important to note that only recreational visitors were evaluated in this risk assessment. Such visitors are considered intermittent receptors since they only visit the area occasionally. If the area was ever developed for residential use, human health risks would be higher because residents would be exposed more frequently. Workers also are exposed more frequently, and also would likely be at increased risk due to exposure to media contaminated from site-related source materials.

In addition to the human health risk assessment, an ecological risk screening level risk assessment was performed using the same surface water and sediment sampling data. Based on this assessment, ecological receptors are also threatened by migrating offsite coal ash contamination. Phosphorus in these areas exceeds VDEQ aquatic life criteria. Concentrations of iron, phosphorus, and selenium exceed USEPA chronic ambient water quality criteria. The results indicate excessive nutrification is occurring due to phosphorus from the site.

Other toxicity information utilized in the absence of federal or state criteria indicate that ecological receptors including aquatic life, benthic invertebrates, and semi-aquatic plants and animals are at risk due to elevated metal concentrations. Surface water, sediment, or ground water could negatively affect populations of plants, and also benthic and aquatic life communities near the point(s) of discharge based on the comparison of maximum detected concentrations to criteria and benchmark values.

Ecological risk was summarized by adding the HQs from Tables 6 and 7 of this report across all analytes to obtain a HI, shown below. HI values above 1 suggest site-related contamination is impacting surrounding ecosystems.

Risk Estimates for Ecological Receptors Exposed to Surface Water and Sediment

Risk Basis	Aquatic Life	Benthic Invertebrates	Plants, Birds, Mammals	Target HI
VDEQ AWQC HI	7	-	-	≤1
USEPA AWQC HI	165	-	-	≤1
Other Surface Water Toxicity Values	1245	-	-	≤1
Sediment Quality Criteria HI	-	116	-	≤1
Ecological Screening Levels	-	-	8100	≤1

AWQC – Ambient Water Quality Criteria
USEPA – U.S. Environmental Protection Agency
HI- Hazard Index
VDEQ –Virginia Department of Environmental Quality

Risk Estimates for Aquatic Life Exposed to Ground Water at Seeps and Springs

Risk Basis	Lower Ash Pond	Upper Ash Pond	Target HI
VDEQ AWQC HI	5	12	≤1
USEPA AWQC HI	9	32	≤1
Other Surface Water Toxicity Values	1979	4909	≤1

1. Introduction

This risk assessment evaluates whether the coal ash at Chesterfield Power Station (the Site) impacts human health or ecological receptors, or otherwise affects designated uses. This assessment is consistent with standard USEPA protocols for human health and ecological risk assessments, including but not limited to:

- Risk Assessment Guidance for Superfund (RAGS): Part A. Interim Final EPA/540/1-89/002, December 1989.
- Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). EPA/540/R/99/005, July 2004.
- Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment). Final. EPA-540-R-070-002. January 2009
- Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F, April 1998a.

This risk assessment has the following organization:

- Section 2 – Site Characterization. A description of the site and the surrounding environment, including potential source contributions
- Section 3 – Screening Level Human Health Risk Assessment. An evaluation of the site data compared to USEPA screening levels based on default exposure parameters and factors representing reasonable maximum exposure (RME) scenarios for chronic or long-term exposure. The screening level assessment is based on methods described in USEPA (1991, 1996a, 2002a, and 2018a). Maximum concentrations in site media are compared to screening levels for each medium of concern, and if the site data are higher, it indicates that further evaluation is warranted.
- Section 4 – Screening Level Ecological Risk Assessment*.* An evaluation of the site data compared to USEPA screening levels based on default exposure parameters and factors representing RME scenarios for chronic or long-term exposure by ecological receptors. The screening level ecological risk assessment is designed to provide a high level of confidence that potential adverse ecological effects are not missed (USEPA, 2001). Maximum concentrations in site media are compared to screening levels for each medium of concern, and if the site data are higher, it indicates that further evaluation could be warranted.
- Section 5 – Baseline Human Health Risk Assessment. The baseline human health risk assessment evaluates exposure to receptors likely to occur at the site and incorporates available site-specific data and assumptions into the characterization of risk and identification of uncertainty. Statistics are applied to refine the exposure point concentrations (EPCs) for each contaminant. Exposure assumptions are also refined to the extent that data suggest appropriate. Risk estimates are compared to background levels of risk, and uncertainty is identified.
- Section 6 –Dominion Ground Water Data. This section provides an analysis of ground water data collected at the Upper and Lower Ash Ponds (Dominion 2018a&b), and comparison to the Dominion background wells.

2. Site Characterization

Dominion Energy owns and operates the Chesterfield Power Station, which is located at 500 Coxendale Road, east of I-95 on the south side of the James River, in Chesterfield County. The Chesterfield Power Station was constructed along the James River approximately 12 miles downstream of the fall line in Richmond, Virginia. The James River Basin begins in the Alleghany Mountains and flows southeast towards the Chesapeake Bay. The James River is Virginia's largest river basin and is made up of the Upper, Middle, and Lower James River sub-basins, as well as the Appomattox River sub-basin (VDEQ, 2014). The James River supports multiple designated uses, which are defined as "those uses specified in water quality standards for each water body or segment whether or not they are being attained." All Virginia waters are designated for the following uses, and parts of the James River are also listed as public water supply (PWS):

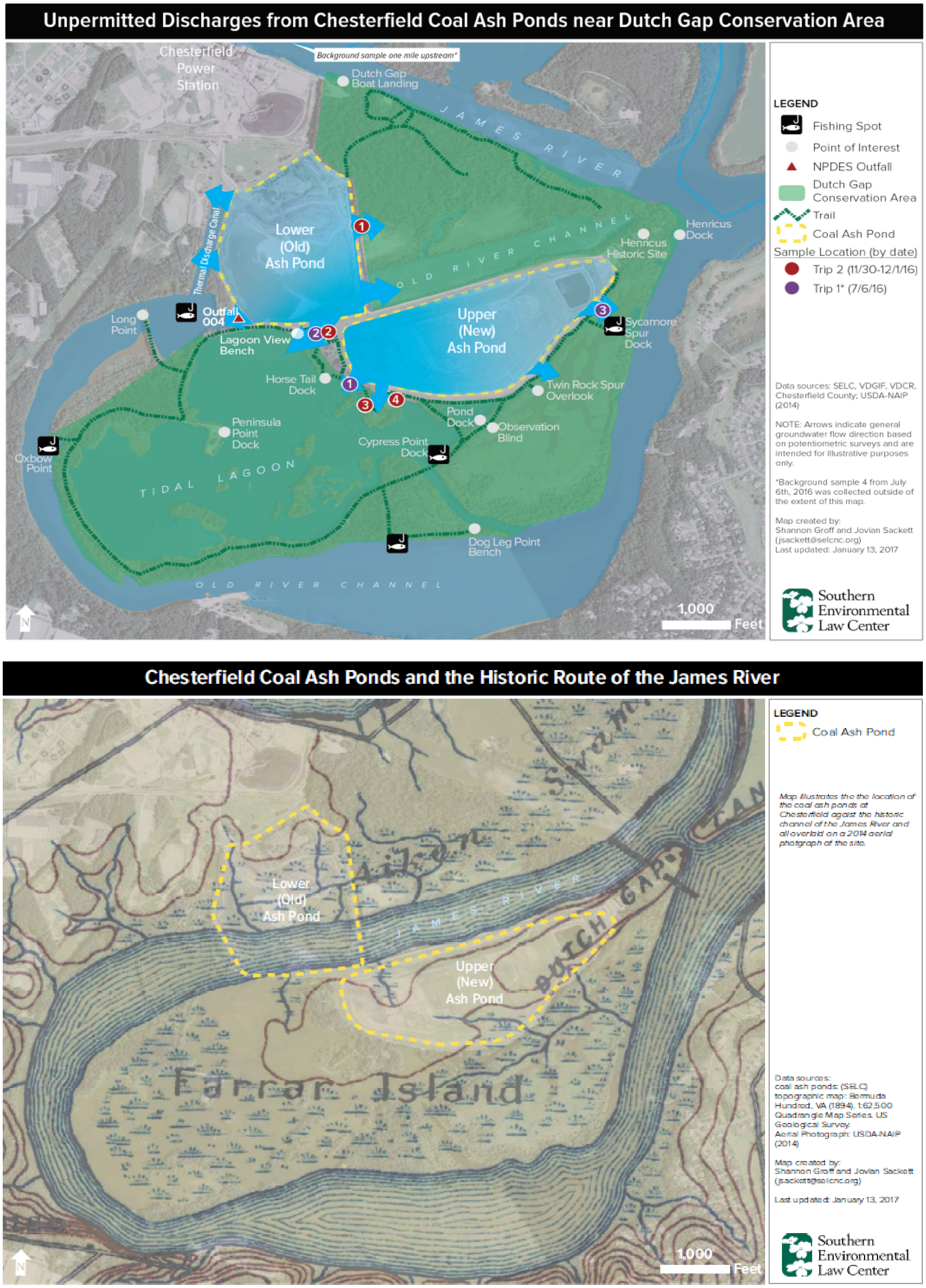
- recreational uses (e.g., swimming and boating);
- propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them;
- wildlife; and
- production of edible and marketable natural resources (e.g., fish and shellfish).

Dominion stores approximately 15 million tons of coal ash in two unlined basins at the Site. The Lower Ash Pond was constructed in the 1960s and the Upper Ash Pond was constructed in the 1980s (together, the Ash Ponds). Both ponds are located in close proximity to the James River, the original channel of the James River (Farrar Gut), and a tidal lagoon located within the Dutch Gap Conservation Area. The southern portion of the Lower Ash Pond is situated in the original channel of the James River.

Permitted outfalls discharge to the James River and Farrar Gut, and contaminated ground water also discharges to wetlands east of the Site and to surface water. Figure 1 shows the Power Station and various surface water features that may be impacted by the Site. Sample location number 4, which is not pictured in Figure 1 but is located upstream of the Site along the James River, is considered representative of background or ambient conditions.

As shown in Figure 1, the Ash Ponds are bordered primarily by the Dutch Gap Conservation Area (Dutch Gap). Dutch Gap is a public recreation and conservation area consisting of approximately 810 acres maintained by Chesterfield County. Visitors are encouraged to use the maintained trails for hiking, biking, and horseback riding. These trails are in close proximity to the Ash Ponds and surrounding surface waters. Dutch Gap is also a popular destination for kayakers and canoers, and the County offers family kayak tours and other boating excursions. A number of water instruction courses are also offered in the tidal lagoon at Dutch Gap, such as stand-up paddle boarding and whitewater kayaking, which includes instruction on rolling. Visitors are encouraged to fish throughout the conservation area, including at the five maintained docks. Primitive overnight camping is also offered.

Figure 1. Map of Chesterfield Power Station Ash Ponds and Sampling Locations



3. Screening Level Human Health Risk Assessment

A screening level risk assessment was performed as the initial step in evaluating potential risks associated with areas of direct coal ash contamination. State and Federal values were used as benchmarks by which to compare the surface water and sediment data. It is important to use conservative or protective values at this stage of the risk assessment in order to avoid rejecting analytes that might be of concern. In other words, the results of this initial screening should only exclude analytes where the data clearly do not present a concern; if the data suggests a potential concern or is inconclusive or incomplete in some way, the analyte should be included for more detailed evaluation during subsequent steps in the baseline human health risk assessment. This methodology ensures that all potential analytes of concern are evaluated in a more detailed manner during the baseline risk assessment. After the more detailed baseline evaluation, some of these analytes are likely not to raise concerns and may fall out of the analysis, but some may in fact pose a risk. Thus, prematurely rejecting analytes at the screening level stage can result in an inaccurate, understated risk.

Similarly, constituents should not be excluded from further analysis based on a comparison to background concentrations at the screening-level stage. It is considered more appropriate and standard practice to retain all constituents until after baseline risk assessment calculations are completed, and at that point compare concentrations to ambient conditions. This is consistent with USEPA (2002b), which describes the approach used at Superfund sites, and recommends that in a baseline risk assessment all constituents that exceed risk-based screening concentrations are retained, and compared to site-specific background in the risk characterization, which is the final section of the risk assessment.

Figure 2 shows the conceptual site model (CSM) for the screening level human health risk assessment. This figure visually outlines the various pathways that contaminants may take from the primary source, the Ash Ponds, to one or more human receptors.

3.1. Water Quality Criteria Used as Screening Levels

Several water quality criteria (WQC) were selected as screening levels. The public water supply (PWS), risk-based tapwater regional screening levels (tapwater RSLs), and maximum contaminant levels (MCLs) were used as screening levels, in addition to the VA Other Surface Waters (OSW) criteria on the assumption that if the waters were acceptable as a long term drinking water source, all potentially relevant contaminants of potential concern (COPCs) would be identified. Any constituents measured above these various drinking water standards or criteria were then evaluated in-depth in the baseline risk assessment. This approach is consistent with the standard practice of applying conservative assumptions in a screening-level risk assessment, which ensures that only analytes that clearly present no risk are excluded from more detailed evaluation. The various criteria and standards used in the human health screening level risk assessment are presented in Table 1.

3.1.1. State Criteria

The PWS and Surface Water criteria from VDEQ were utilized as screening levels in the risk assessment. PWS criteria have been calculated to protect human health from toxic effects through both drinking water and fish consumption, unless otherwise noted, and apply in those river segments designated as PWS in 9VAC25-260-390 to 540.

OSW criteria have been calculated to protect human health from toxic effects through fish consumption, unless otherwise noted, and apply in all other surface waters not designated as PWS in 9VAC25-260-390 to 540. Many of the analytes lack these OSW criteria, and therefore it is important to use the more stringent criteria in order to conservatively conduct the screening level risk assessment.

The PWS values are considered to conservatively represent recreational contact since the OSW criteria do not have a surface water consumption component. During swimming, boating, fishing, and other water

Figure 2. Human Health Conceptual Site Model

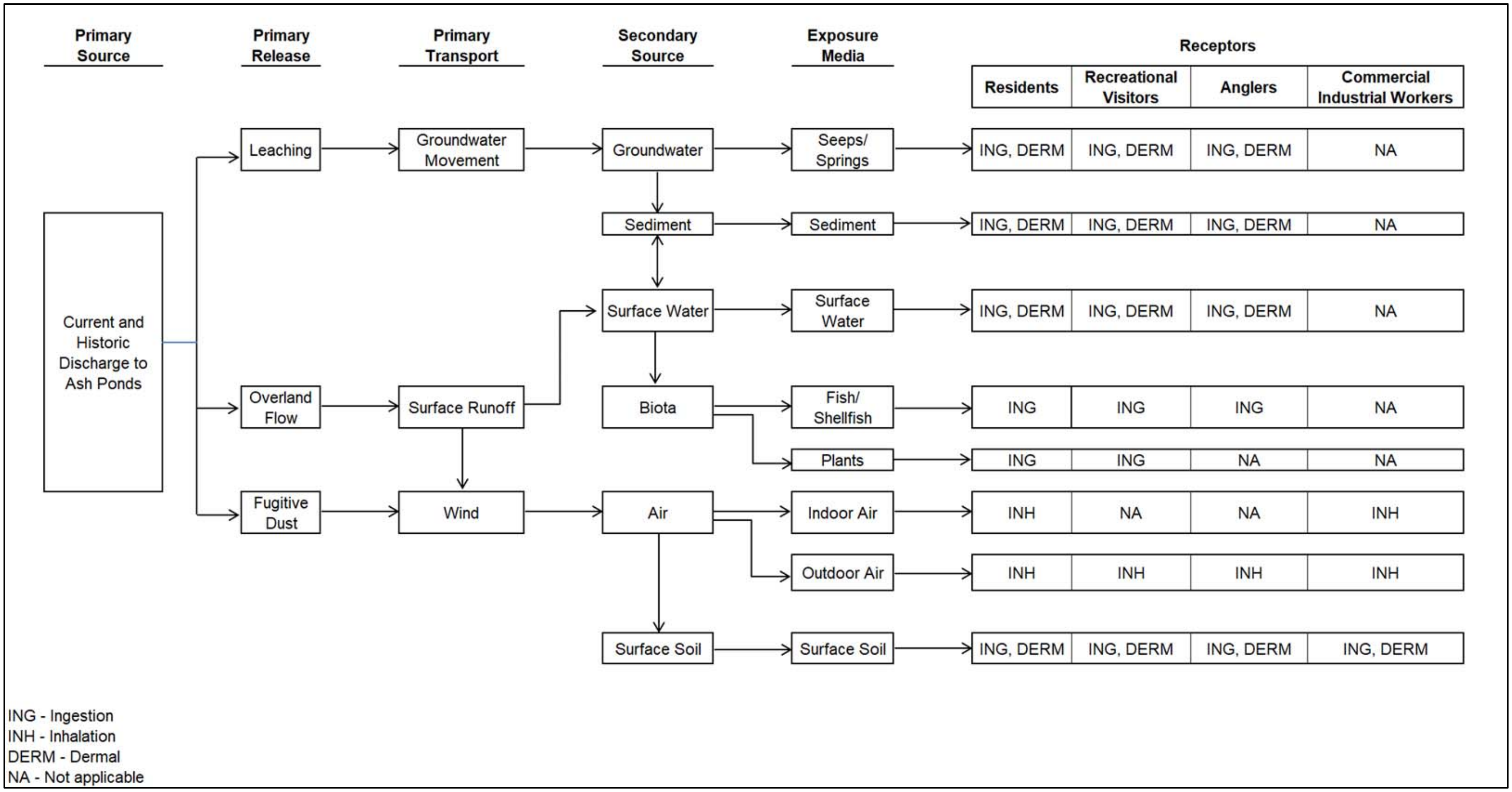


Table 1. Human Health Screening Levels

Analyte	CAS No.	Water Quality Criteria and Standards						Sediment Screening Levels	
		VA PWS (mg/L)	VA Other Surface Water (mg/L)	EPA Tapwater RSL (mg/L)		EPA WQS (mg/L)		Residential Soil RSLs (mg/kg)	
Inorganics									
Aluminum	7429-90-5	NV	NV	2.0	n	0.2	2	7700	n
Antimony	7440-36-0	0.006	0.64	0.00078	n	0.006		3.1	n
Arsenic	7440-38-2	0.01	NV	0.00005	c*	0.01		0.68	c**R
Barium	7440-39-3	2.00	NV	0.38	n	2		1500	n
Beryllium	7440-41-7	NV	NV	0.0025	n	0.004		16	n
Boron	7440-42-8	NV	NV	0.4	n	NV		1600	n
Cadmium	7440-43-9	0.005	NV	0.0009	n	0.005		7.1	n
Calcium	7440-70-2	NV	NV	NV		NV		NV	
Chloride	16887-00-6	250	NV	NV		250	2	NV	
Chromium	16065-83-1	0.10	NV	2.2	n	0.1		12000	n
Cobalt	7440-48-4	NV	NV	0.0006	n	NV		2.3	n
Copper	7440-50-8	1.30	NV	0.08	n	1.3		310	n
Dissolved Solids		500	NV	NV		500	2	NV	
Hexavalent Chromium	18540-29-9	NV	NV	0.00004	c	NV		0.3	c*
Iron	7439-89-6	0.30	NV	1.4	n	0.3	2	5500	n
Lead	7439-92-1	0.015	NV	0.015	L	0.015		400	L
Lithium	7439-93-2	NV	NV	0.004	n	NV		16	n
Magnesium	7439-95-4	NV	NV	NV		NV		NV	
Manganese	7439-96-5	0.05	NV	0.043	n	0.05	2	180	n
Mercury	7439-97-6	NV	NV	0.00057	n	0.002		2.3	n
Molybdenum	7439-98-7	NV	NV	0.010	n	NV		39	n
Nickel	7440-02-0	0.61	4.6	0.039	n	NV		150	n
Nitrate-Nitrite		NV	NV	NV		10		NV	
Phosphorus,Total	7723-14-0	NV	NV	NV		NV		NV	
Selenium	7782-49-2	0.17	4.2	0.01	n	0.05		39	n
Silicon	7440-21-3	NV	NV	NV		NV		NV	
Sodium	7440-23-5	NV	NV	NV		NV		NV	
Strontium	7440-24-6	NV	NV	1.2	n	NV		4700	n
Sulfate	14808-79-8	250	NV	NV		250	2	NV	
Sulfur	7704-34-9	NV	NV	NV		NV		NV	
Thallium	7440-28-0	0.00024	0.00047	0.00002	n	0.002		0.078	n
Vanadium	7440-62-2	NV	NV	0.0086	n	NV		39	n
Zinc	7440-66-6	7.40	26.00	0.6000	n	5	2	2300	n
Organics									
1-Methylnaphthalene	90-12-0	NA	NA	NA		NA		18	c*
2-Chloronaphthalene	91-58-7	NA	NA	NA		NA		480	n
2-Methylnaphthalene	91-57-6	NA	NA	NA		NA		24	n
Acenaphthene	83-32-9	NA	NA	NA		NA		360	n
Acenaphthylene	208-96-8	NA	NA	NA		NA		NV	
Anthracene	120-12-7	NA	NA	NA		NA		1800	n
Benz(a)anthracene	56-55-3	NA	NA	NA		NA		0.16	c
Benz(g,j,i)perylene	191-24-2	NA	NA	NA		NA		NV	
Benzo(a)pyrene	50-32-8	NA	NA	NA		NA		0.016	c
Benzo(b)fluoranthene	205-99-2	NA	NA	NA		NA		0.16	c
Benzo(k)fluoranthene	207-08-9	NA	NA	NA		NA		1.6	c
Chrysene	218-01-9	NA	NA	NA		NA		16	c
Dibenz(a,h)anthracene	53-70-3	NA	NA	NA		NA		0.016	c
Fluoranthene	206-44-0	NA	NA	NA		NA		240	n
Fluorene	86-73-7	NA	NA	NA		NA		240	n
Indeno(1,2,3-c,d)pyrene	193-39-5	NA	NA	NA		NA		0.16	c
Naphthalene	91-20-3	NA	NA	NA		NA		3.8	c**
Phenanthrene	85-01-8	NA	NA	NA		NA		NV	
Pyrene	129-00-0	NA	NA	NA		NA		180	n

Table 1. Human Health Screening Levels, cont.

Abbreviations:

* - n screening level < 100 times the cancer screening level
** - n screening level < 10 time the cancer screening level
2 - Seconday drinking water standard (SMCL) based on taste, odor, or aesthetics
c - cancer effect
MCL - maximum contaminant level
mg/kg - milligram per kilogram
mg/L - milligram per liter
n - noncancer effect
NA - Not applicable; analyte not measured in surface water medium
NV - no value
PWS - public water supply
R - relative bioavailability factor applied
RSL - regional screening level
WQS - water quality standard is the MCL unless otherwise noted

Source:

VA PWS, VA OSW	9VAC25-260-140. Criteria for surface water. http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140
USEPA RSLs, MCLs	EPA RSLs MAY 2016 https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016
USEPA SMCLs	Secondary Drinking Water Standards: Guidance for Nuisance Chemicals. January 6, 2016. https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

contact activities—activities that are all offered at Dutch Gap—small amounts of water can be ingested, and skin exposure can allow uptake of some contaminants as well. In addition, people visiting or camping in the area could wash their hands, bodies, or camp dishes using the surface water. Therefore, using the PWS to assess potential screening level risks due to incidental contact is appropriate.

3.1.2. Federal Criteria

Three types of USEPA values were applied as screening levels for surface water. These are the primary drinking water maximum contaminant levels (MCLs), secondary standards, and the risk-based tapwater regional screening levels (RSLs).

USEPA established National Primary Drinking Water Regulation MCLs (USEPA, 2018a), which are legally enforceable standards that apply to public water systems, protecting drinking water quality by limiting specific potentially toxic contaminants that could occur in public water supplies. These MCLs are intended to protect the public against consumption of contaminants in drinking water that could present a risk to human health.

USEPA also established “secondary maximum contaminant levels” (SMCLs) that it does not enforce (USEPA, 2016b). The SMCLs are guidelines for managing drinking water to meet aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL; however, they are used herein to indicate that recreational uses could become impaired above these levels.

3.1. Soil Criteria Used as Screening Levels for Sediment Data

3.1.1. State Criteria

Virginia does not have human health standards for evaluating sediment risk. The VDEQ risk model (VURAM) evaluates sediment toxicity only for recreational purposes, and does not address soils. Screening values for sediments are not yet available as of January 2018. The most recent version of VURAM is 1.12 from March 2017.

3.1.2. Federal Criteria

The residential soil RSLs were used as conservative screening levels for evaluating potential human health risk for contacts with sediments. Humans would not be expected to contact sediments with the same frequency and duration with which they contact soils, and so this is appropriately conservative for the screening level stage. There is residential use on the opposite side of the James River from the Upper Ash Pond (Figure 1). This suggests that nearby residents will also be frequent recreational visitors in the area potentially impacted by the Site for activities like swimming, boating, and fishing.

The MCLs are standards that apply to public water supplies to protect drinking water potable uses (USEPA, 2018a). They may or may not be risk-based as they incorporate considerations of treatment feasibility. The tapwater RSLs are risk-based criteria derived from toxicity values and based on a *de minimus* cancer risk of 10^{-6} and a noncancer hazard quotient (HQ) of 0.1 (USEPA, 2018a).

3.2. Data Evaluation

In July of 2016, surface water samples were collected from four locations (see Figure 1). Three samples were collected from areas impacted by the Site, including one sample (Sample 3) from a permitted outfall. One sample (Sample 4) was collected upstream of the Site to represent background or ambient conditions. Additionally, a sediment sample was collected from the Sample 2 Red Cove location. In November and

December 2016, additional surface water and sediment samples were collected (see Figure 1). Appendix B presents the raw sample data.

The maximum value, whether detected or the reporting limit, was considered to be the representative exposure point concentration (EPC) for the screening level effort. If all the data were non-detect for a given analyte, the maximum reporting limit (RL) was used as the proxy for evaluation. Using the RL in this way allows for a determination to be made that the reporting limits were adequate to determine potential risk for all samples with nondetected data, as in using screening levels to select appropriate RLs before sampling (USEPA, 2018a). If RLs are above screening levels, concentrations could occur in the environment between the risk-based screening level (at which risk is negligent) and the reporting limit, and if the RLs are very high, potential risks could be high as well. Conversely, if RLs are less than the screening level, it can be assumed that the analyte is not present at levels of potential concern (USEPA, 2015).

The maximum value for each analyte in surface water was compared to the VA and Federal WQC to determine potential adverse effects on humans contacting or ingesting the water. The maximum value in surface water was used to evaluate potential risk from ingesting fish from these waters.

3.3. Human Health Screening-Level Risk Assessment Conclusions

COPCs were identified by comparing the EPC for a particular contaminant to its screening level. If the ratio of the site concentration to the screening level—also called the hazard quotient (HQ)—is greater than one, the contaminant was identified as a COPC.

Numerous COPCs were identified in surface water (Table 2), with risk ratios above 1 for noncancer and cancer effects. Arsenic, total dissolved solids (TDS), iron, lead, manganese, sulfate, and thallium exceeded VA PWS drinking water standards. Thallium exceeded the VA OSW standard, suggesting uptake by fish should be more fully evaluated. Aluminum, arsenic, iron, lead, and manganese exceeded MCLs or SMCLs and also the tapwater RSL for cancer or noncancer effects (Table 2). Numerous other analytes are identified as COPCs because of exceeding either the tapwater RSL or the USEPA WQS. Numerous COPCs were also identified for human exposure to sediments (Table 3).

The list of COPCs, and the media for which they are identified as above the human health screening levels, is as follows:

COPC Name	**Medium of Concern**
▪ Aluminum	SW, Sed
▪ Antimony	SW
▪ Arsenic	SW, Sed
▪ Boron	SW
▪ Cadmium	SW
▪ Cobalt	SW, Sed
▪ Dissolved Solids	SW
▪ Hexavalent Chromium	SW, Sed
▪ Iron	SW, Sed
▪ Lead	SW
▪ Lithium	SW
▪ Manganese	SW, Sed
▪ Molybdenum	SW, Sed
▪ Nickel	SW
▪ Selenium	Sed

▪ Strontium	SW
▪ Sulfate	SW
▪ Thallium	SW, Sed
▪ Vanadium	SW, Sed

SW – surface water; Sed – sediment

As indicated in Table 2, arsenic was over 1000 times higher in surface water than the USEPA residential drinking water screening level, and seven times higher than the VA PWS. Iron, manganese, and hexavalent chromium were also much higher than drinking water criteria or standards. Each of these COPCs, as identified in Table 2, is carried forward for further evaluation.

Numerous analytes also exceeded sediment quality benchmarks as represented by soil screening levels (Table 3). This suggests that human contact with sediments should be further evaluated for receptors that could reasonably be considered to frequently contact sediments. At this site, the James River is used extensively for recreational purposes. Therefore, a recreational visitor should be evaluated.

Table 2. Comparison of Surface Water Exposure Point Concentrations to Human Health Screening Levels.

Analyte	Surface Water EPC		Water Quality Criteria						Hazard Quotients			
	Maximum Value (mg/L)	Basis	VA PWS (mg/L)	VA Surface Water (mg/L)	EPA Tapwater RSL (mg/L)		EPA WQS (mg/L)		VA PWS HQ	VA Surface Water HQ	USEPA Tapwater RSL HQ	USEPA WQS HQ
Aluminum	9.49		NV	NV	2.0	n	0.2	2	NV	NV	5	47
Antimony	0.002	U	0.006	0.64	0.00078	n	0.006		0.4	0.003	3	0.3
Arsenic	0.0741		0.01	NV	0.00005	c*	0.01		7	NV	1425	7
Barium	0.201		2.00	NV	0.38	n	2		0.1	NV	0.5	0.10
Beryllium	0.0011		NV	NV	0.0025	n	0.004		NV	NV	0.4	0.28
Boron	1.99		NV	NV	0.4	n	NV		NV	NV	5	NV
Cadmium	0.001	U	0.005	NV	0.0009	n	0.005		0.2	NV	1	0.2
Calcium	217		NV	NV	NV		NV		NV	NV	NV	NV
Chloride	42.5		250	NV	NV		250	2	0.2	NV	NV	0.17
Chromium	0.0154		0.10	NV	2.2	n	0.1		0.2	NV	0.007	0.2
Chromium, Hexavalent	0.0046		NV	NV	0.00004	c	NV		NV	NV	131	NV
Cobalt	0.024		NV	NV	0.0006	n	NV		NV	NV	40	NV
Copper	0.0249		1.30	NV	0.08	n	1.3		0.02	NV	0.3	0.02
Dissolved Solids	1100		500	NV	NV		500	2	2	NV	NV	2
Iron	91.3		0.30	NV	1.4	n	0.3	2	304	NV	65	304
Lead	0.0163		0.015	NV	0.015	L	0.015		1	NV	1	1
Lithium	0.25	U	NV	NV	0.004	n	NV		NV	NV	63	NV
Magnesium	44.2		NV	NV	NV		NV		NV	NV	NV	NV
Manganese	11		0.05	NV	0.043	n	0.05	2	220	NV	256	220
Mercury	0.0002	U	NV	NV	0.00057	n	0.002		NV	NV	0.4	0.1
Molybdenum	0.0431		NV	NV	0.010	n	NV		NV	NV	4	NV
Nickel	0.0537		0.61	4.6	0.039	n	NV		0.1	0.01	1	NV
Nitrate-Nitrite	0.354		NV	NV	NV		10		NV	NV	NV	0.04
Phosphorus,Total	0.526		NV	NV	NV		NV		NV	NV	NV	NV
Selenium	0.0026		0.17	4.2	0.01	n	0.05		0.02	0.0006	0.3	0.05
Silicon	13		NV	NV	NV		NV		NV	NV	NV	NV
Sodium	23.1		NV	NV	NV		NV		NV	NV	NV	NV
Strontium	5.73		NV	NV	1.2	n	NV		NV	NV	5	NV
Sulfate	594		250	NV	NV		250	2	2	NV	NV	2
Thallium	0.001	U	0.00024	0.00047	0.00002	n	0.002		4	2	50	0.5
Vanadium	0.0366		NV	NV	0.0086	n	NV		NV	NV	4	NV
Zinc	0.209		7.40	26.00	0.6000	n	5	2	0.0	0.01	0.3	0.04

Notes:

Red highlighted cells have HQs>1 and indicate the analyte is a contaminant of potential concern (COPC) for further evaluation

Abbreviations:

* = n screening level < 100 times the cancer screening level
2 - secondary water quality standard (SMCL)
c - cancer effect
EPC - exposure point concentration
HQ - hazard quotient
MCL - maximum contaminant level
mg/L - milligram per liter
n - noncancer effect
NV - no value
PWS - public water supply
RSL - regional screening level
U - nondetect
WQS - water quality standard is the MCL unless noted otherwise

Source:

VWQC, PWS, Surface Water 9VAC25-260-140. Criteria for surface water. http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140

EPA RSLs, MCLs EPA RSLs MAY 2016 https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016

Table 3. Comparison of Sediment Exposure Point Concentrations to Human Health Screening Levels.

Analyte Name	CAS No.	Units	Sediment EPC	Basis	Human Health		
					Residential RSL (mg/kg)		Residential HQ
Inorganics							
Aluminum	7429-90-5	mg/kg	8380		7700	n	1
Antimony	7440-36-0	mg/kg	0.849		3.1	n	0.27
Arsenic	7440-38-2	mg/kg	292		0.68	c**R	429
Barium	7440-39-3	mg/kg	42.6		1500	n	0.03
Beryllium	7440-41-7	mg/kg	0.527		16	n	0.03
Boron	7440-42-8	mg/kg	144	U	1600	n	0.09
Cadmium	7440-43-9	mg/kg	6.7		7.1	n	0.94
Calcium	7440-70-2	mg/kg	7130		NV	NV	NV
Chloride	16887-00-6	mg/kg	125		NV	NV	NV
Chromium	16065-83-1	mg/kg	14.4	U	12000	n	0.0012
Chromium, Hexavalent	18540-29-9	mg/kg	3.66	U	0.3	c*	12
Cobalt	7440-48-4	mg/kg	69.1		2.3	n	30
Copper	7440-50-8	mg/kg	56.3		310	n	0.18
Iron	7439-89-6	mg/kg	178000		5500	n	32
Lead	7439-92-1	mg/kg	28.9	U	400	L	0.07
Lithium	7439-93-2	mg/kg	7.21		16	n	0.45
Magnesium	7439-95-4	mg/kg	1440	U	NV	NV	NV
Manganese	7439-96-5	mg/kg	807		180	n	4
Mercury	7439-97-6	mg/kg	0.0178		2.3	n	0.01
Molybdenum	7439-98-7	mg/kg	98.6		39	n	3
Nickel	7440-02-0	mg/kg	60.2		150	n	0.40
Nitrate-Nitrite	NA	mg/kg	3.66	U	NV	NV	NV
Phosphorus,Total	7723-14-0	mg/kg	1.83	U	NV	NV	NV
Selenium	7782-49-2	mg/kg	43.3	U	39	n	1
Silicon	7440-21-3	mg/kg	11400		NV	NV	NV
Sodium	7440-23-5	mg/kg	916	U	NV	NV	NV
Strontium	7440-24-6	mg/kg	192		4700	n	0.04
Sulfate	14808-79-8	mg/kg	616		NV	NV	NV
Sulfur	7704-34-9	mg/kg	1740		NV	NV	NV
Thallium	7440-28-0	mg/kg	0.352		0.078	n	5
Vanadium	7440-62-2	mg/kg	40.8		39	n	1
Zinc	7440-66-6	mg/kg	114		2300	n	0.05
Organics							
1-Methylnaphthalene	90-12-0	mg/kg	0.0366	U	18	c*	0.002
2-Chloronaphthalene	91-58-7	mg/kg	0.0366	U	480	n	0.00008
2-Methylnaphthalene	91-57-6	mg/kg	0.0366	U	24	n	0.002
Acenaphthene	83-32-9	mg/kg	0.011	U	360	n	0.00003
Acenaphthylene	208-96-8	mg/kg	0.011	U	NV	NV	NV
Anthracene	120-12-7	mg/kg	0.011	U	1800	n	0.00001
Benzo(A)Anthracene	56-55-3	mg/kg	0.00567		0.16	c	0.04
Benzo(A)Pyrene	50-32-8	mg/kg	0.00594		0.016	c	0.37
Benzo(B)Fluoranthene	205-99-2	mg/kg	0.00864		0.16	c	0.05
Benzo(G,H,I)Perylene	191-24-2	mg/kg	0.00493		NV	NV	NV
Benzo(K)Fluoranthene	207-08-9	mg/kg	0.0022		1.6	c	0.001
Chrysene	218-01-9	mg/kg	0.00553		16	c	0.0003
Dibenz(A,H)Anthracene	53-70-3	mg/kg	0.00114		0.016	c	0.07
Fluoranthene	206-44-0	mg/kg	0.00817		240	n	0.00003
Fluorene	86-73-7	mg/kg	0.011	U	240	n	0.00005
Indeno(1,2,3-Cd)Pyrene	193-39-5	mg/kg	0.00388		0.16	c	0.02
Naphthalene	91-20-3	mg/kg	0.0366	U	3.8	c**	0.01
Phenanthrene	85-01-8	mg/kg	0.00217		NV	NV	NV
Pyrene	129-00-0	mg/kg	0.00848		180	n	0.00005

Table 3. Comparison of Sediment Exposure Point Concentrations to Human Health Screening Levels, cont.

Notes:
Mercury screening levels based on elemental Hg (7439-97-6)
Highlighted cells indicate the EPC exceeds the screening level (a HQ or risk ratio above 1)

Abbreviations:
** = n SL < 10X c SL
* = n SL < 100X c SL
c = cancer
EPC - exposure point concentration
HQ - hazard quotient or screening-level risk ratio
mg/kg - milligram per kilogram
n = noncancer
NA - not applicable
NV - no value
R = RBA applied
RSL - regional screening level
SL - screening level
U - nondetect

Source:

EPA RSLs	EPA RSLs MAY 2016	https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016

4. Screening Level Ecological Risk Assessment

In addition to the screening performed for human risk described in the previous section, a screening level ecological risk assessment was performed as the initial step in evaluating potential risks associated with the areas of coal ash contamination to ecological receptors. State and Federal values were used as benchmarks by which to compare the surface water and sediment data. As with the human health screening level risk assessment, it is important to use conservative or protective values at this stage of the risk assessment in order to avoid rejecting analytes that might be of concern. Using conservative screening benchmarks ensures that only analytes that clearly pose no risk are excluded from further evaluation. Figure 3 presents the CSM for the ecological risk assessment.

4.1. Water Quality Criteria Used for Screening Levels

Aquatic life criteria (AWQC) for the protection of freshwater aquatic life and their uses are based on the maximum pollutant concentration in water not expected to pose a significant risk to the majority of species in a given aquatic environment; AWQC may also be based on a narrative description of the desired conditions of a water body being "free from" certain negative conditions (USEPA, 2016c). Virginia State and Federal criteria were used in the screening level risk assessment.

4.1.1. State Criteria

Narrative criteria include general protective statements known as the "free froms." The narrative criteria state that "all state waters shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life". There are *chlorophyll a* criteria to protect the James River tidal zones from nutrient over-enrichment, indicating that nutrient enrichment may be of at least seasonal concern.

The numeric state chronic criteria used as screening levels (Table 4) are four-day average concentration not to be exceeded more than once every 3 years on the average. Only chronic criteria were used in the screening level risk assessment. This is because input from the ash ponds likely is a daily, long-term event resulting in chronic exposure. In addition, if water quality meets chronic conditions, then it would meet the less stringent acute standards.

4.1.1. Federal Criteria

Surface Water

Numeric ambient water quality criteria (AWQC) for the protection of freshwater aquatic life and their uses were obtained from USEPA (2016c). The sample-specific water hardness was calculated from calcium and magnesium concentrations and used to develop sample-specific AWQC for the hardness dependent metals. Hardness ranged from 64.3 to 924 mg/L $CaCO_3$. The equations are only applicable up to a hardness of 400 mg/L $CaCO_3$. Therefore, for the sample with the highest hardness, a value of 400 mg/L was substituted. The AWQC are summarized in Table 4, where the AWQC for hardness dependent metals are shown at a hardness of 100 mg/L.

EPA has developed a set of recommendations for two causal variables linked to nutrient enrichment, total nitrogen and total phosphorus (USEPA, 2000). EPA's recommended ecoregional nutrient criteria represent conditions of surface waters that have minimal impacts caused by human activities. Therefore, when these criteria are applied, the waters are protected from the harmful consequences of nutrient over-enrichment. State water quality inventories and listings of impaired waters consistently rank nutrient

Figure 3. Ecological Risk Assessment Conceptual Site Model

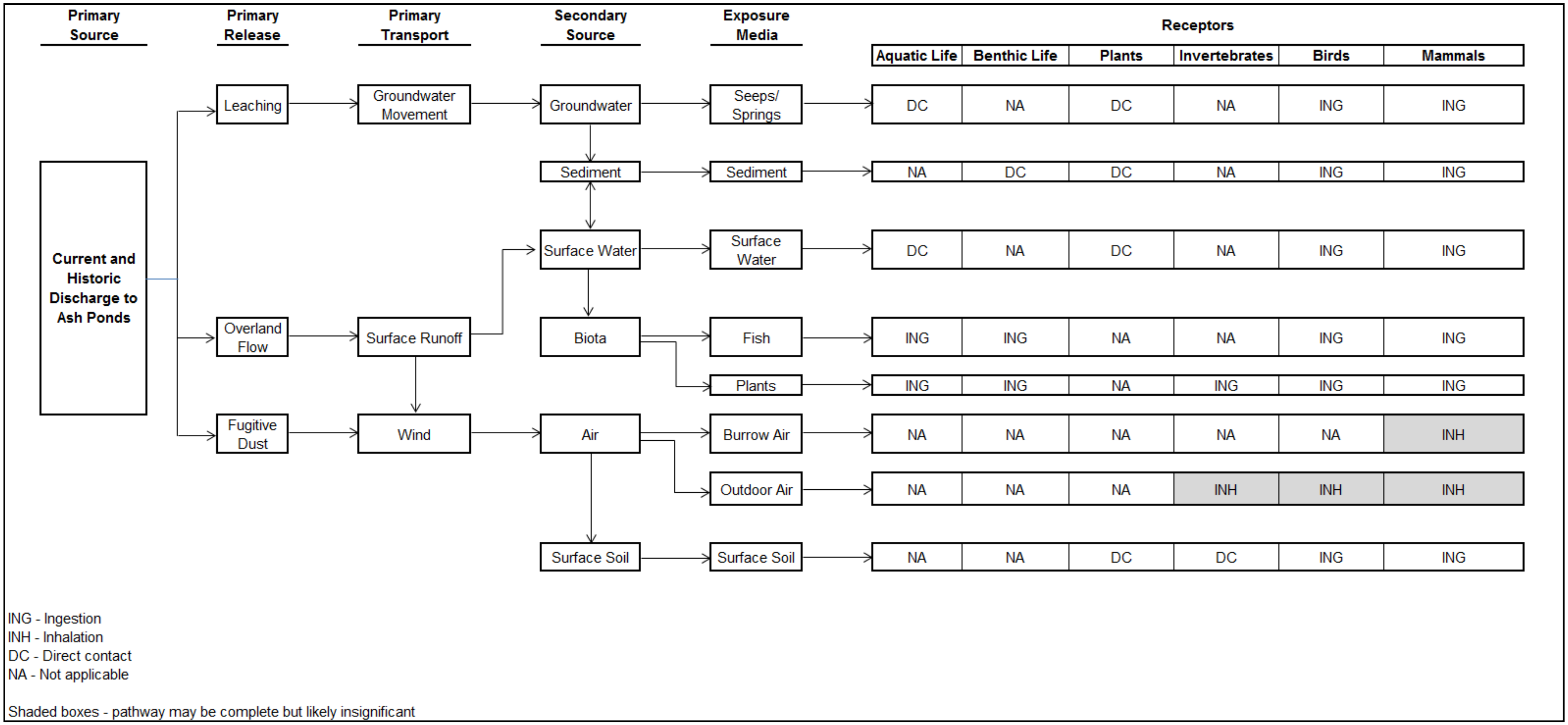


Table 4. Summary of Ecological Risk Assessment Screening Levels

Analyte Name	CAS No.	Surface Water		Sediment	Terrestrial Ecological Receptors			
		VA Chronic Aquatic Life (mg/L)	EPA Chronic AWQC (mg/L)	Benthic Sediment Quality Criteria (mg/kg)	Plant SL (mg/kg)	Invertebrate SL (mg/kg)	Avian SL (mg/kg)	Mammalian SL (mg/kg)
Inorganics								
Aluminum	7429-90-5	NV	0.087	58000	50	50	50	50
Antimony	7440-36-0	NV	NV	2	0.142	0.142	0.142	0.142
Arsenic	7440-38-2	0.15	0.15	5.9	5.7	5.7	5.7	5.7
Barium	7440-39-3	NV	NV	NV	1.04	1.04	1.04	1.04
Beryllium	7440-41-7	NV	NV	NV	1.06	1.06	1.06	1.06
Boron	7440-42-8	NV	NV	NV	0.5	0.5	0.5	0.5
Cadmium	7440-43-9	0.0011	0.00072	0.596	0.00222	0.00222	0.00222	0.00222
Calcium	7440-70-2	NV	NV	NV	NV	NV	NV	NV
Chloride	16887-00-6	230	230	NV	NV	NV	NV	NV
Chromium	16065-83-1	0.074	0.074	26	NV	0.4	0.4	0.4
Cobalt	7440-48-4	NV	NV	50	0.14	0.14	0.14	0.14
Copper	7440-50-8	0.009	0.009	16	5.4	5.4	5.4	5.4
Dissolved Solids		NV	1000	NA	NA	NA	NA	NA
Hexavalent Chromium	18540-29-9	0.011	0.011	NV	1	0.4	NV	130
Iron	7439-89-6	NV	1	20000	200	200	200	200
Lead	7439-92-1	0.014	0.003	30.2	0.0537	0.0537	0.0537	0.0537
Lithium	7439-93-2	NV	NV	NV	2	2	2	2
Magnesium	7439-95-4	NV	NV	NV	NV	NV	NV	NV
Manganese	7439-96-5	NV	NV	460	100	100	100	100
Mercury	7439-97-6	0.00077	0.00077	0.13	0.1	0.1	0.1	0.1
Molybdenum	7439-98-7	NV	NV	NV	2	2	2	2
Nickel	7440-02-0	0.020	0.052	15.9	13.6	13.6	13.6	13.6
Nitrate-Nitrite		NV	0.009	NV	NV	NV	NV	NV
Phosphorus, Total	7723-14-0	0.1	0.01	600	NV	NV	NV	NV
Selenium	7782-49-2	0.005	0.0015	2	0.0276	0.0276	0.0276	0.0276
Silicon	7440-21-3	NV	NV	NV	NV	NV	NV	NV
Sodium	7440-23-5	NV	NV	NV	NV	NV	NV	NV
Strontium	7440-24-6	NV	NV	NV	NV	NV	NV	NV
Sulfate	14808-79-8	NV	NV	NV	NV	NV	NV	NV
Sulfur	7704-34-9	NV	NV	NV	2	2	2	2
Thallium	7440-28-0	NV	NV	NV	0.0569	0.0569	0.0569	0.0569
Vanadium	7440-62-2	NV	NV	NV	1.59	1.59	1.59	1.59
Zinc	7440-66-6	0.12	0.12	120	6.62	6.62	6.62	6.62
Organics								
1-Methylnaphthalene	90-12-0	NA	NA	0.0202	NV	3.24	3.24	3.24
2-Chloronaphthalene	91-58-7	NA	NA	0.41723	0.0122	0.0122	0.0122	0.0122
2-Methylnaphthalene	91-57-6	NA	NA	0.0202	3.24	3.24	3.24	3.24
Acenaphthene	83-32-9	NA	NA	0.0067	20	20	20	20
Acenaphthylene	208-96-8	NA	NA	0.00587	682	682	682	682
Anthracene	120-12-7	NA	NA	0.0469	0.1	0.1	0.1	0.1
Benz(a)anthracene	56-55-3	NA	NA	0.0317	5.21	5.21	5.21	5.21
Benz(g,h,i)perylene	191-24-2	NA	NA	0.17	119	119	119	119
Benzo(a)pyrene	50-32-8	NA	NA	0.0319	0.1	0.1	0.1	0.1
Benzo(b)fluoranthene	205-99-2	NA	NA	0.0272	59.8	59.8	59.8	59.8
Benzo(k)fluoranthene	207-08-9	NA	NA	0.0272	148	148	148	148
Chrysene	218-01-9	NA	NA	0.0571	4.73	4.73	4.73	4.73
Dibenz(a,h)anthracene	53-70-3	NA	NA	0.00622	18.4	18.4	18.4	18.4
Fluoranthene	206-44-0	NA	NA	0.111	0.1	0.1	0.1	0.1
Fluorene	86-73-7	NA	NA	0.019	30	30	30	30
Indeno(1,2,3-c,d)pyrene	193-39-5	NA	NA	0.017	109	109	109	109
Naphthalene	91-20-3	NA	NA	0.0346	0.0994	0.0994	0.0994	0.0994
Phenanthrene	85-01-8	NA	NA	0.0419	0.1	0.1	0.1	0.1
Pyrene	129-00-0	NA	NA	0.053	0.1	0.1	0.1	0.1

Table 4. Summary of Ecological Risk Assessment Screening Levels, cont.

Notes:

The dissolved solids criterion was derived from the narrative standard. It states that 10,000 mg/L are "survivable by a few species" of aquatic life. Divided by an uncertainty factor of 10 for "survivable by a few species" to a presumed no effect level for many species. Note that water with >500 mg/L may adversely affect crops if used for irrigation, so this level could still be toxic to plants growing nearby.

Blue highlighted cells represent hardness dependent criteria shown at 100 mg/L CaCO3.

Abbreviations:

AWQC - ambient water quality criteria for the protection of freshwater aquatic life and their uses
mg/kg - milligram per kilogram
mg/L - milligram per liter
NA - not applicable
NV - no value

Source:

RAIS (2016). Risk Assessment Information System. Ecological Benchmark Tool. University of Tennessee. https://rais.ornl.gov/tools/eco_search.php

USEPA (2016c). National Recommended Water Quality Criteria (AWQC) - Aquatic Life Criteria Table. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table

VA Chronic Aquatic Life. 2010. 9VAC25-260-140. Criteria for surface water. http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140

over-enrichment as a top contributor to use impairments. EPA's water quality standards regulations at 40 CFR §131.11(a) require States and Tribes to adopt criteria that contain sufficient parameters and constituents to protect the designated uses of their waters. In addition, States and Tribes need quantifiable targets for nutrients in their standards to assess attainment of uses, develop water quality-based permit limits and source control plans, and establish targets for total maximum daily loads (TMDLs).

The Chesterfield Power Station lies within the Eastern Temperate Forests, Southeastern USA Plains, Southeastern Temperate Forested Plains and Hills (IX) aggregate ecoregion. Aggregate Ecoregion IX is composed of irregular plains and hills (USEPA, 2000). The Level III ecoregion where Chesterfield occurs is the Southeastern Plains (Ecoregion 65). There is a mosaic of cropland, pasture, woodland, and forest in this ecoregion. Natural vegetation is primarily composed of oak-hickory-pine and Southern mixed forest.

Streams in this area are fairly low-gradient and have sandy bottoms. Lateritic soils are common, unlike soils of the surrounding ecoregions. Streams draining relatively undisturbed and forested watersheds have low median concentrations of fecal coliform bacteria, sulfate, dissolved solids, and phosphorus. There are also criteria for response variables (turbidity and chlorophyll a), but data were not available or analyzed at this time. The values for total nitrogen and total phosphorus were used in this risk assessment to predict the potential for nutrient enrichment. The 25^{th} percentile reference condition Level III lakes and reservoirs for NO2-NO3 is **0.009 mg/L** and total phosphorus is **0.010 mg/L**. These values were used as the screening levels for nitrate-nitrite and phosphorus.

Sediments

The sediment quality criteria (SQCs) for benthic invertebrates are the minimum value of the sediment screening benchmarks available on the Risk Assessment Information System (RAIS) website (Appendix A.3). This includes values from Oak Ridge National Laboratories (ORNL), USEPA, and Canada. The values used in the screening level ecological risk assessment are summarized in Table 4.

Terrestrial plants or wildlife that depend on or frequent the aquatic ecosystem as habitat could be exposed to either sediments or soils. The criteria used to assess potential risk due to contaminants in soils were used for sediments for plants, terrestrial invertebrates, birds, and mammals. These values include the USEPA EcoSSLs, ORNL values, and values from various USEPA regions (Appendix A.3). The minimum value for each taxa was used as the screening value (Table 4). If the general soil screening benchmark from USEPA Region 4 or Region 5 was the only available data point, it was used to represent all taxa.

Soils

Soils in the area of the Site have not been sampled. However, shallow sediments or sediments along banks may be accessed by primarily terrestrial or aquatic dependent wildlife. As water levels fall, sediments can be exposed and serve as a solid exposure media just as soils can. Terrestrial plants or wildlife could also be exposed to soils contaminated by runoff. The same values applied to these taxa for sediments (Table 3) were used to evaluate potential risk due to sediment exposure.

Fish Tissue

Few values are available for screening the presence of contaminants in fish tissue with respect to protecting wildlife or aquatic predators (Appendix A.3). Fish can take up contaminants into tissue at levels that could be toxic to higher trophic level animals consuming them. Therefore, the bioconcentration potential (Table 5) of each of the analytes was considered prior to dropping analytes as COPCs. Any analytes that were listed as bioaccumulative contaminants of concern (BCCs) were retained as COPCs even if they did not exceed any of the screening levels. This reflects the fact that by definition,

Table 5. Bioaccumulative Chemicals of Concern

Name	USEPA	DMMP	OREGON DEQ
Arsenic	X	X	X
Cadmium			X
Lead	X	X	X
Mercury	X	X	X
PAHs	X		
Selenium		X	X

Sources:

USEPA. 2016d. Persistent Bioaccumulative Toxic (PBT) Chemicals Covered by the TRI Program. Update November 14, 2016. https://www.epa.gov/toxics-release-inventory-tri-program/persistent-bioaccumulative-toxic-pbt-chemicals-covered-tri

USACE. 2009. Dredged Material Management Program (DMMP) Clarification Paper Metals BCOC List. Final. June 1, 2009. http://www.nws.usace.army.mil/Portals/27/docs/civilworks/dredging/Updates/2009-METALS%20CLARIFICATION%20PAPER_final.pdf

Oregon DEQ. 2007. Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment. April 3, 2007. https://semspub.epa.gov/work/10/500011406.pdf

bioaccumulative contaminants can occur at low levels in environmental media yet be orders of magnitude higher in biological tissues. Five inorganics and the PAHs are considered by one or more agencies as BCCs for surface water or sediment (Table 5). These analytes are carried forward as COPCs for further evaluation.

4.2. Data Evaluation

The maximum detected value in surface water was compared to the chronic VA and chronic AWQC to determine potential effects on aquatic life, including plants, invertebrates, and fish (Table 6) by dividing the measured concentration (EPC) by the screening levels to obtain risk ratios. If the HQ is above 1, the data exceed the screening level. If all the data were non-detect for a given analyte, the maximum RL was used as the proxy for evaluation, as indicated by a “U” in Table 6. This allows determination that the reporting limits were adequate for nondetects. Where surface water criteria were lacking, screening levels were obtained as available from additional sources.

WQC from VDEQ or USEPA were lacking for 16 analytes. The RAIS Ecological Benchmark Tool (RAIS, 2016) was used to obtain additional surface water benchmarks (Table 6; Appendix A.4). It is standard practice to use these benchmarks as “To Be Considered Values” to determine whether further investigation is warranted for analytes lacking AWQC, even though the benchmarks may not be enforceable standards. The hardness used to obtain the criteria shown in Table 6 was the default value of 100 mg/L $CaCO_3$. Numerous analytes exceeded AWQC or other surface water criteria (Table 6).

The maximum value for each analyte for all the sediment data was used in this analysis (Table 7). The reporting limit was used for analytes that were not detected in the sample. Sediment data were compared to the sediment quality criteria (SQC), and also to soil SLs for wildlife and plants in order to evaluate contact with sediments during foraging or other activities by these types of receptors. Eight inorganic analytes and five organic analytes exceeded SQC for protection of benthic life. Seventeen analytes did not have SQC.

Nearly all inorganics exceeded screening levels for aquatic dependent or primarily terrestrial plants, invertebrates, birds, or mammals for sediment exposure. One organic analyte exceeded ecological screening values for these taxa (Table 7). Nine analytes had no sediment screening levels for wildlife or plants.

Hardness varies by sample, and for the hardness dependent metals, the WQC also will vary. The results from comparing the maxima in surface water to the VA WQC (Table 6) were compared to those that would be obtained if the WQC were compared to data for each sample (Table 8). A sample by sample comparison could differ for the hardness dependent metals in the event that increasing hardness resulted in a higher criterion for the analyte in the sample that provided the maximum.

For the existing data for which there were hardness-based Virginia chronic water quality criteria, the sample with the highest hardness (Sample 2 Red Cove) did not have any dissolved water concentration data. Sample 2 Red Cove had a hardness level of 924 mg/L $CaCO_3$ as calculated from measured magnesium and calcium concentrations. For the VA chronic standards, the minimum hardness allowed in the hardness dependent equations is 25 mg/L and the maximum hardness is 400 mg/L even when the actual ambient hardness is less than 25 or greater than 400. Therefore, where hardness fell above 400 mg/L, the existing value was replaced with 400 mg/L $CaCO_3$. There is no difference between results based on using the maximum relative to results based on evaluating each sample independently because the dissolved concentrations did not exceed the chronic VA WQS for any of the metals evaluated (Table 8).

Table 6. Comparison of Surface Water Exposure Point Concentrations to Ecological Screening Criteria.

Analyte	CAS	Surface Water EPC		Water Quality Criteria				Hazard Quotients		
		Maximum Value (mg/L)	Basis	VA Chronic Aquatic Life (mg/L)	EPA Chronic AWQC (mg/L)	Other Aquatic Life SW SL and Basis (mg/L)		VA Aquatic Life Chronic HQ	EPA Aquatic Life Chronic HQ	Other SW HQ
Aluminum, Dissolved	7429-90-5	0.0721		NV	0.087	NA	NA	NV	0.8	NA
Antimony	7440-36-0	0.002	U	NV	NV	0.03	Draft NAWQC Chronic	NV	NV	0.1
Arsenic, Dissolved	7440-38-2	0.0064		0.15	0.15	NA	NA	0.04	0.04	NA
Barium, Dissolved	7440-39-3	0.0877		NV	NV	0.0039	OSWER Tier II Secondary	NV	NV	22
Beryllium	7440-41-7	0.0011		NV	NV	0.00053	EPA R4 Chronic	NV	NV	2
Boron, Dissolved	7440-42-8	1.42		NV	NV	0.0016	SW EPA R6 FW	NV	NV	888
Cadmium, Dissolved	7440-43-9	0.00005	U	0.0011	0.00072	NA	NA	0.04	0.07	NA
Calcium	7440-70-2	217		NV	NV	NV	NV	NV	NV	NV
Chloride	16887-00-6	42.5		230	230	NA	NA	0.2	0.2	NA
Chromium, Dissolved	16065-83-1	0.00064		0.074	0.074	NA	NA	0.01	0.01	NA
Chromium, Hexavalent	18540-29-9	0.0046		0.011	0.011	NA	NA	0.42	0.42	NA
Cobalt, Dissolved	7440-48-4	0.016		NV	NV	0.003	OSWER Tier II Secondary	NV	NV	5
Copper, Dissolved	7440-50-8	0.00093	U	0.009	0.009	NA	NA	0.1	0.1	NA
Dissolved Solids	NA	1100		NV	1000	NA	NA	NV	1	NA
Iron, Dissolved	7439-89-6	67.7		NV	1	NA	NA	NV	68	NA
Lead, Dissolved	7439-92-1	0.0005	U	0.011	0.003	NA	NA	0.05	0.2	NA
Lithium, Dissolved	7439-93-2	0.25	U	NV	NV	0.014	SW EPA R6 FW	NV	NV	18
Magnesium	7439-95-4	44.2		NV	NV	0.647	SW EPA R6 FW	NV	NV	68
Manganese, Dissolved	7439-96-5	11		NV	NV	0.08	OSWER Tier II Secondary	NV	NV	138
Mercury	7487-94-7	0.0002	U	0.00077	0.00077	NA	NA	0.3	0.3	NA
Molybdenum, Dissolved	7439-98-7	0.0023		NV	NV	0.000034	Australian and New Zealand	NV	NV	68
Nickel, Dissolved	7440-02-0	0.0104		0.023	0.052	NA	NA	0.4	0.2	NA
Nitrate-Nitrite	NA	0.354		NV	0.009	NA	NA	NV	39	NA
Phosphorus,Total	7723-14-0	0.526		0.1	0.01	NA	NA	5.3	53	NA
Selenium	7782-49-2	0.0026		0.005	0.0015	NA	NA	0.5	2	NA
Silicon	7440-21-3	13		NV	NV	NV	NV	NV	NV	NV
Sodium	7440-23-5	23.1		NV	NV	680	LCV Daphnids	NV	NV	0.0
Strontium, Dissolved	7440-24-6	3.96		NV	NV	1.5	SW EPA R6 FW	NV	NV	3
Sulfate	14808-79-8	594		NV	NV	NV	NV	NV	NV	NV
Thallium	7440-28-0	0.001	U	NV	NV	0.00003	Australian and New Zealand	NV	NV	33
Vanadium, Dissolved	7440-62-2	0.0011		NV	NV	0.012	SW EPA R5 ESL	NV	NV	0.1
Zinc, Dissolved	7440-66-6	0.0036		0.12	0.12	NA	NA	0.03	0.03	NA

Notes:

AWQC results based on an EPC may differ from those on a sample by sample analysis because maximum concentrations are not always found where hardness is minimal

The dissolved solids criterion was derived from the narrative standard. It states that 10,000 mg/L are "survivable by a few species" of aquatic life. Divided by an uncertainty factor of 10 for "survivable by a few species" to a presumed no effect level for many species. Note that water with >500 mg/L may adversely affect crops if used

Red highlighted cells have HQs>1 and indicate the analyte is a contaminant of potential concern (COPC) for further evaluation

Blue highlighted cells represent hardness dependent criteria shown at 100 mg/L CaCO3.

Abbreviations:

AWQC - ambient water quality criteria for the protection of freshwater aquatic life and their uses
EPC - exposure point concentration
HQ - hazard quotient
mg/L - milligram per liter
NV - no value
U - nondetect

Source:

VWQC, PWS, Surface Water	9VAC25-260-140. Criteria for surface water. http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140
EPA AWQC	National Recommended Water Quality Criteria - Aquatic Life Criteria Table. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table
	If no AWQC, value is lowest output from RAIS Ecological Benchmark Tool The Risk Assessment Information System https://rais.ornl.gov/tools/eco_search.php
Other SW Criteria	RAIS. 2016. Ecological Benchmark Tool. Accessed November 18, 2016. https://rais.ornl.gov/tools/eco_search.php - See Appendix A.4 for references and information for the basis of the RAIS surface water benchmarks

Table 7. Comparison of Sediment Exposure Point Concentrations to Sediment Benchmarks.

					Benthic Life		Terrestrial Ecological Receptors							
Analyte Name	CAS No.	Units	Sediment EPC	Basis	Benthic Sediment Quality Criteria (mg/kg)	Benthic HQ	Plant SL (mg/kg)	Invertebrate SL (mg/kg)	Avian SL (mg/kg)	Mammalian SL (mg/kg)	Plant HQ	Invertebrate HQ	Avian HQ	Mammalian HQ
Inorganics														
Aluminum	7429-90-5	mg/kg	8380		58000	0.1	50	50	50	50	168	168	168	168
Antimony	7440-36-0	mg/kg	0.849		2	0.4	0.142	0.142	0.142	0.142	6	6	6	6
Arsenic	7440-38-2	mg/kg	292		5.9	49	5.7	5.7	5.7	5.7	51	51	51	51
Barium	7440-39-3	mg/kg	42.6		NV	NV	1.04	1.04	1.04	1.04	41	41	41	41
Beryllium	7440-41-7	mg/kg	0.527		NV	NV	1.06	1.06	1.06	1.06	0.5	0.5	0.5	0.5
Boron	7440-42-8	mg/kg	144	U	NV	NV	0.5	0.5	0.5	0.5	288	288	288	288
Cadmium	7440-43-9	mg/kg	6.7		0.596	11.2	0.00222	0.00222	0.00222	0.00222	3018	3018	3018	3018
Calcium	7440-70-2	mg/kg	7130		NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Chloride	16887-00-6	mg/kg	125		NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Chromium	16065-83-1	mg/kg	14.4	U	26	0.6	NV	0.4	0.4	0.4	NV	36	36	36
Chromium, Hexavalent	18540-29-9	mg/kg	3.66	U	NV	NV	1	0.4	NV	130	4	9	NV	0.03
Cobalt	7440-48-4	mg/kg	69.1		50	1.4	0.14	0.14	0.14	0.14	494	494	494	494
Copper	7440-50-8	mg/kg	56.3		16	4	5.4	5.4	5.4	5.4	10	10	10	10
Iron	7439-89-6	mg/kg	178000		20000	9	200	200	200	200	890	890	890	890
Lead	7439-92-1	mg/kg	28.9	U	30.2	1.0	0.0537	0.0537	0.0537	0.0537	538	538	538	538
Lithium	7439-93-2	mg/kg	7.21		NV	NV	2	2	2	2	4	4	4	4
Magnesium	7439-95-4	mg/kg	1440	U	NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Manganese	7439-96-5	mg/kg	807		460	2	100	100	100	100	8	8	8	8
Mercury	7439-97-6	mg/kg	0.0178		0.13	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Molybdenum	7439-98-7	mg/kg	98.6		NV	NV	2	2	2	2	49	49	49	49
Nickel	7440-02-0	mg/kg	60.2		15.9	4	13.6	13.6	13.6	13.6	4	4	4	4
Nitrate-Nitrite	NA	mg/kg	3.66	U	NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Phosphorus,Total	7723-14-0	mg/kg	1.83	U	600	0.003	NV	NV	NV	NV	NV	NV	NV	NV
Selenium	7782-49-2	mg/kg	43.3	U	2	22	0.0276	0.0276	0.0276	0.0276	1569	1569	1569	1569
Silicon	7440-21-3	mg/kg	11400		NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Sodium	7440-23-5	mg/kg	916	U	NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Strontium	7440-24-6	mg/kg	192		NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Sulfate	14808-79-8	mg/kg	616		NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Sulfur	7704-34-9	mg/kg	1740		NV	NV	2	2	2	2	870	870	870	870
Thallium	7440-28-0	mg/kg	0.352		NV	NV	0.0569	0.0569	0.0569	0.0569	6	6	6	6
Vanadium	7440-62-2	mg/kg	40.8		NV	NV	1.59	1.59	1.59	1.59	26	26	26	26
Zinc	7440-66-6	mg/kg	114		120	1.0	6.62	6.62	6.62	6.62	17	17	17	17
Organics														
1-Methylnaphthalene	90-12-0	mg/kg	0.0366	U	0.0202	2	NV	3.24	3.24	3.24	NV	0.0	0.0	0.0
2-Chloronaphthalene	91-58-7	mg/kg	0.0366	U	0.41723	0.1	0.0122	0.0122	0.0122	0.0122	3.0	3.0	3.0	3.0
2-Methylnaphthalene	91-57-6	mg/kg	0.0366	U	0.0202	2	3.24	3.24	3.24	3.24	0.0	0.0	0.0	0.0
Acenaphthene	83-32-9	mg/kg	0.011	U	0.0067	2	20	20	20	20	0.0	0.0	0.0	0.0
Acenaphthylene	208-96-8	mg/kg	0.011	U	0.00587	2	682	682	682	682	0.0	0.0	0.0	0.0
Anthracene	120-12-7	mg/kg	0.011	U	0.0469	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Benzo(a)Anthracene	56-55-3	mg/kg	0.00567		0.0317	0.2	5.21	5.21	5.21	5.21	0.0	0.0	0.0	0.0
Benzo(a)Pyrene	50-32-8	mg/kg	0.00594		0.0319	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Benzo(b)Fluoranthene	205-99-2	mg/kg	0.00864		0.0272	0.3	59.8	59.8	59.8	59.8	0.0	0.0	0.0	0.0
Benzo(g,h,i)Perylene	191-24-2	mg/kg	0.00493		0.17	0.03	119	119	119	119	0.0	0.0	0.0	0.0
Benzo(k)Fluoranthene	207-08-9	mg/kg	0.0022		0.0272	0.1	148	148	148	148	0.0	0.0	0.0	0.0
Chrysene	218-01-9	mg/kg	0.00553		0.0571	0.1	4.73	4.73	4.73	4.73	0.0	0.0	0.0	0.0
Dibenz(A,H)Anthracene	53-70-3	mg/kg	0.00114		0.00622	0.2	18.4	18.4	18.4	18.4	0.0	0.0	0.0	0.0
Fluoranthene	206-44-0	mg/kg	0.00817		0.111	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Fluorene	86-73-7	mg/kg	0.011	U	0.019	0.6	30	30	30	30	0.0	0.0	0.0	0.0
Indeno(1,2,3-Cd)Pyrene	193-39-5	mg/kg	0.00388		0.017	0.2	109	109	109	109	0.0	0.0	0.0	0.0
Naphthalene	91-20-3	mg/kg	0.0366	U	0.0346	1	0.0994	0.0994	0.0994	0.0994	0.4	0.4	0.4	0.4
Phenanthrene	85-01-8	mg/kg	0.00217		0.0419	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Pyrene	129-00-0	mg/kg	0.00848		0.053	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table 7. Comparison of Sediment Exposure Point Concentrations to Sediment Benchmarks cont.

Note: Highlighted cells indicate a risk ratio greater than 1

Abbreviations:

EPA - exposure point concentration
HQ - hazard quotient or risk ratio (EPC/SL)
mg/kg - milligram per kilogram
NV - no value
SL - screening level
U - not detected

Screening Level Source:

RAIS (2016). Risk Assessment Information System. Ecological Benchmark Tool. University of Tennessee.

Table 8. Sample by Sample Comparison to VA Chronic Hardness-Dependent Standards.

Name	July 6, 2016								November 30 - December 1, 2016							
	1 Sample By Bird House	VA WQC (ug/L)	Sample 2 Red Cove	VA WQC (ug/L)	Sample 3 Outfall 005	VA WQC (ug/L)	4 Osborne Landing	VA WQC (ug/L)	Sample 1- N. Swamp	VA WQC (ug/L)	Sample 2- Red Cove	VA WQC (ug/L)	Sample 3- Shipwreck Cove	VA WQC (ug/L)	Sample 4- Cove Across Triangle	VA WQC (ug/L)
Cadmium (ug/L)	0.262		1		1		1		0.11		0.077		0.36		0.31	
Cadmium, Dissolved (ug/L)		1		3		1		1	0.05	3	0.05	3	0.05	2	0.05	2
Chromium (ug/L)	15.4		1.48		1		1.04		4.9		1.5		13.3		10.4	
Chromium, Dissolved (ug/L)		67		231		52		75	0.64	217	0.5	231	0.5	100	0.5	138
Copper (ug/L)	23.7		3.03		1.71		1.6		6.7		4.5		22.4		24.9	
Copper, Dissolved (ug/L)		8		29		6		9	0.93	27	0.93	29	0.93	12	0.93	17
Lead (ug/L)	15.6		1.41		1		0.878		9		1.7		16.3		10.5	
Lead, Dissolved (ug/L)		12		79		8		14	0.5	72	0.5	79	0.5	22	0.5	36
Nickel (ug/L)	14		53.7		0.913		1.69		9.5		15.8		13.9		14.6	
Nickel, Dissolved (ug/L)		21		75		16		24	6.3	70	10.4	75	0.94	32	1	44
Zinc (ug/L)	94.7		10.8		6.98		540		23.4		11.6		209		103	
Zinc, Dissolved (ug/L)		106		382		81		120	3.6	359	2.7	382	2.5	162	2.7	225
Hardness, Total (mg/L)	88.2		400	[716]	64.3		102		371		400	[924]	145		214	

Notes:
VA WQC – Virginia chronic water quality criteria
ug/L – microgram per liter (ppb)
Red text – sample hardness exceeded 400 mg/L; 400 mg/L used in hardness-dependent equation, and measured sample hardness shown in parenthesis.

4.2.1. Surface Water

As presented in Table 6, the data suggest that impacts to aquatic life are occurring. The following analytes are COPCs for further evaluation in surface water for protection of aquatic life and their uses:

- Barium
- Beryllium
- Boron
- Cobalt
- Dissolved Solids
- Iron
- Lithium
- Magnesium
- Manganese
- Molybdenum
- Nitrate-Nitrite
- Phosphorus,Total
- Selenium
- Strontium
- Thallium

In addition, arsenic, mercury, and selenium would be retained as COPCs for surface water on the basis of bioaccumulation potential.

4.2.2. Sediment

As presented in Table 7, the data suggest that impacts to the benthic life are occurring. For example, the HQ for arsenic was 49, indicating that the sediment concentration is nearly 50 times higher than the benchmark. Seven other inorganics exceeded the SQC.

Many inorganics exceed screening levels for terrestrial plants or wildlife or aquatic-dependent plants or wildlife where acceptable concentrations for chronic contact are defined by use of the soil screening benchmarks. Concentrations of aluminum, boron, cadmium, cobalt, iron, lead, selenium, and sulfur were over 100 times higher than benchmarks (Table 7). This suggests that adverse effects to aquatic-dependent plants or wildlife could occur.

The COPCs for further evaluation in sediment for ecological risk assessment based on the data evaluation presented in Table 7 are as follows:

- Aluminum
- Antimony
- Arsenic
- Barium
- Boron
- Cadmium
- Chromium
- Chromium, Hexavalent
- Cobalt
- Copper
- Iron

- Lead
- Lithium
- Manganese
- Molybdenum
- Nickel
- Selenium
- Sulfur
- Thallium
- Vanadium
- Zinc
- 1-Methylnapthalene
- 2-Chloronaphthalene
- 2-Methylnapthalene
- Acenapthene
- Acenapthylene
- Napthalene

In addition, mercury and other PAHs are retained as COPCs in sediment on the basis of bioaccumulation potential.

5. Baseline Human Health Risk Assessment

The baseline HHRA explores potential risk in more depth for the COPCs identified in Sections 3.4 and 4.2 of this report. In particular, the bioaccumulation pathways are analyzed in more detail because these pathways are not a component of the screening level equations.

5.1. Exposure Assessment

5.1.1. Exposure Point Concentrations

The EPC is the same as used in the screening level evaluation due to the small sample size. Thus, the maximum detected value or the maximum reporting limit is used as the EPC. When there are at least 10 to 20 samples, statistical evaluation can be used to refine the EPCs. All of the analytes that exceeded one or more screening levels in Section 3.3 in surface water or sediments were carried forward for both media of potential concern. In addition, mercury and PAHs were also carried forward due to a propensity to bioaccumulate as indicated in Table 5 of this report. To obtain an EPC for Total PAHs for the baseline risk assessment, the concentrations were summed for each PAH; if not detected, the reporting limit was used as a proxy for estimating Total PAH concentration.

5.1.2. Receptor Identification

Receptors are the groups most likely to occur at, and be exposed to contaminants originating from, the site. There are receptors that currently occur at the site, and those that may occur at some point in the future, perhaps after facility closure. The most likely current and future receptor is the recreational visitor, which was evaluated in this report. Figure 4 presents a map distributed by the County for recreational purposes. A commercial/industrial worker and a construction worker are also a current receptor, and could be receptors in the future. A hypothetical future resident on the site is also possible, and is a receptor typically associated with predicting unrestricted use of a property.

The screening level risk assessment evaluated potential risks to future residents, and these estimated risks would not change drastically in the baseline risk assessment unless dietary ingestion was added as an exposure pathway. Only the recreational visitor was quantitatively assessed in the baseline risk assessment. The other receptors were not evaluated at this time. However, because of their higher exposure rates, workers and future residents would have even higher risk estimates than those predicted for a recreational visitor.

Figure 4. County Recreation Map

5.1.3. Potentially Complete Exposure Pathways

The following exposure pathways were identified as potentially complete for a recreational visitor and quantified in the baseline HHRA:

- Incidental ingestion of sediments/surface soils during watersports or other recreational activities
- Incidental ingestion of surface water during watersports or other recreational activities
- Inhalation of fugitive dusts generated from dried sediments
- Ingestion of wild plants (e.g., berries) or animals (i.e., fish) contaminated by uptake from surface water or sediments
- Dermal contact with sediments/surface soils during watersports or other recreational activities
- Dermal contact with surface water during watersports or other recreational activities

While this section of the report focuses on recreational visitor exposure to contaminated sediment and surface water, there is also significant, documented ground water contamination from the Ash Ponds. The ground water conditions are discussed in Section 6. There are no potable use or irrigation ground water wells at this time within site boundaries or in Dutch Gap Conservation areas, but discharging ground water presents potential exposure pathways, and ground water is statistically significantly impacted by site conditions based on comparison to background wells for the Lower Ash Pond (Dominion 2018a).

There are two potentially complete exposure pathways for ground water contact by recreational visitors: incidental dermal contact with ground water at or near seeps or springs during recreational use, and incidental ingestion of ground water at or near seeps or springs during recreational use. It is possible that some recreational visitors such as campers might use ground water from a spring for potable purposes, although this would be a less frequent exposure than residential use of a developed domestic well, and this is not evaluated in this analysis.

In addition, while dust from dried sediments within Dutch Gap Conservation Area was evaluated, fugitive dusts from the coal ash ponds and other activities occurring within Chesterfield Power Station property, were not evaluated. A visitor to Dutch Gap Conservation Area could encounter such fugitive dusts, also increasing risk.

5.1.4. Exposure Intakes

Exposure intake is the amount of each COPC that is estimated to reach a target organ in a receptor where the effect can occur. Exposure intakes are receptor, medium, and pathway specific, and estimated for each receptor with the equations presented below. For transparency, each exposure pathway identified as potentially complete is evaluated separately and then summed with other pathways to predict total intakes.

Table 9 presents the site receptor-specific exposure parameters used in the exposure intake equations of the baseline HHRA. These parameters were obtained from USEPA (2018a), unless they were site-specific. There are no established regulatory guidelines for the recreational visitor/trespasser as there are for residential or commercial/industrial receptors; thus, all exposure parameters for this receptor are site-specific. The exposure parameters are selected from professional judgment, knowledge of site activities, and understanding of site physical conditions (i.e., swimming occurs only during warmer months). The exposure parameters for which professional judgement was used to establish the value are:

- Exposure Frequency (EF) = EF was assumed to differ for adults and children. For children the EF was two days/week, 4 weeks per month, for 6 months. For adults, EF was assumed to be three days/week, 4 weeks per month, 6 months per year.

Table 9. Exposure Parameters for the Recreational Visitor

Parameter	Description	Units	Recreational Visitor (Child, 0-6 y)		Recreational Visitor (Adult)	
AT	Averaging Time	(days/yr)	365	nc:(ED*365) c:(70*365)	365	nc:(ED*365) c:(70*365)
BW	Body Weight	(kg)	15	a	80	a
AF	Sediment/Soil Adherence Factor	(mg/cm2)	0.2	a	0.07	a
DFSadj	Sediment/Soil Dermal Contact Factor - age adjusted	(mg/kg)	13675.2	a,d (twa; no 0-2)	NA	
DFSMadj	Sediment/Soil Mutagenic Dermal Contact Factor	(mg/kg)	33425.28	a,d (twa; no 0-2)	NA	
EDi	Exposure Duration	(yr)	4	No 0-2 component for ingestion, dermal.	20	a
EFi	Exposure Frequency	(d/yr)	48	d	72	d
ETi	Exposure Time	(hr/event)	3	d (2-6 only)	5	d
EVi	Events per Day	(event/d)	1	a,d (twa=0.667; no 0-2)	1	a,d
IFWadj	Water Ingestion Rate-age adjusted	(L/kg)	10.998	a,d (twa; no 0-2)	NA	
IFWMadj	Mutagenic Water Ingestion Rate-age adjusted	(L/kg)	26.604	a,d (twa; no 0-2)	NA	
DFWadj	Dermal Contact Factor Water-age adjusted	cm2-event/kg	435208	a,d (twa; no 0-2)	NA	
DFWMadj	Mutagenic Dermal Factor Water-age adjusted	cm2-event/kg	951888	a,d (twa; no 0-2)	NA	
IRWi	Incidental Water Ingestion Rate	(L/hr)	0.12	a	0.071	a
INFM	Mutagenic Inhalation Factor	(d)	672	a,d (twa; no 0-2)	NA	
IRF	Food Fish/Shellfish Ingestion Rate	(mg/day)	12225	b,d	30400	b,d
IRV	Food Fruit/Vegetables Ingestion Rate	(mg/day)	62775	b,d	69680	b,d
IFSadj	Sediment/Soil Ingestion Rate-age adjusted	(mg/kg)	4360	a,d (twa; no 0-2)	NA	
IFSMadj	Mutagenic Sediment/Soil Ingestion Rate-age adjusted	(mg/kg)	11280	a,d (twa; no 0-2)	NA	
IFSMadj	Mutagenic Sediment/Soil Ingestion Rate-age adjusted	(mg-yr/kg-day)	NA			
IRSi	Incidental Sediment/Soil Ingestion Rate	(mg/day)	200	a	100	a
	LifeTime	(yrs)	70	a		
SAi	Surface Area -Sediment/Soil	(cm2/d)	2373	a	6032	a
SAWi	Residential or Recreational Water Surface Area	(cm2)	6365	a	19652	a
tevent	Event duration (age adjusted, cancer, surface water exposure)	hr/event	4.667	d (2-6 only)	5	d
PEF	Particulate Emission Factor (site-specific) (Raleigh NC) 0.5 ac	(m3/kg)	59300000000	a		

Notes:

a - USEPA 2016a. RSL calculator

b - USEPA (2011). Exposure Factors Handbook

d - Professional judgement based on climate, site proximity to homes and parks

twa - time weighted average

- Exposure Time (ET) = ET was assumed to differ for adults and children. For children, ET was assumed to be 3 hours per event, and 1 event per day. For adults, it was assumed to be 5 hours per event, for 1 event per day.
- Exposure Duration (ED) = It was assumed children of the age newborn up to 2 would not be exposed. The recreational child was assumed to be 2 to 6 years old. Thus, ED was 24 years (4 years as a child, 20 years as an adult).
- These assumptions for the recreational visitor affected other exposure factors that incorporate ED, EF, or ET into their calculation, such as the age-adjustment or mutagenic-adjustment factors used in various exposure pathways as described below.

Unless otherwise stated, the equations below were obtained by rearranging standard soil screening-level equations from USEPA (2018a). The units for the exposure intake differ to maintain consistency with the units for the carcinogenic and noncarcinogenic toxicity values for different media. The units for daily intake are milligram per kilogram body weight per day (mg/kg-d) for ingestion and dermal contact. For inhalation, the units are milligram per cubic meter (mg/m^3) for noncancer intakes, and microgram per cubic meter (ug/m^3) for cancer intakes. The intake equations differ for cancer and noncancer also in the averaging time (AT) and in addressing cumulative exposure across age groups by use of the age adjustment factors and for mutagens by use of the mutagenic adjustment factors.

Inhalation of Fugitive Dust

Sediments in Dutch Gap Conservation Area contaminated by the coal ash sources may dry and release fugitive dust. The fugitive dust model (USEPA 2018a) utilizes the area of bare ground, which was assumed to be 0.5 ac of bare ground at any given time. Given the large amount of land within Dutch Gap Conservation Area that is immediately adjacent to the coal ash ponds, and where sediment samples were collected, assuming 0.5 ac of bare ground appears reasonable. The equation for the particulate emission factor (PEF) is as follows:

$$PEF = \frac{Q}{C} * \frac{3600\ s/h}{\left[0.036 * (1-V) * \left(\frac{Um}{Ut}\right)^3 * F(x)\right]}$$

Where:

PEF	=	Particulate emission factor ($5.93x10^{10}$ m^3/kg)
F(x)	=	Cowherd function dependent on Um/Ut (0.0086 unitless)
Q/C	=	Dispersion factor (inverse of the mean concentration at the center of a square source); site-specific (68.18 g/m^2-s per kg/m^3)
Um	=	Mean annual windspeed (3.44 m/s)
Ut	=	Equivalent threshold value of windspeed at 7 m (11.32 m/s)
V	=	Fraction of vegetative cover (0.5 (unitless))

The PEF values were estimated with the online USEPA calculator (USEPA, 2018a) and are presented in Table 9. The nearest city for which there are data to establish the climatic zone is Raleigh NC. It was assumed that percent vegetative cover was 50 percent.

Intake Equations

Inhalation of fugitive dust emitting from the contaminated sediment within Dutch Gap Conservation Area was estimated with the following equations, where the ***i*** indicates child- or adult-specific parameters are used:

Recreational Visitor Fugitive Dust – Noncancer – Adult and Child

$$CDI\ \left(\frac{mg}{m3}\right) = Csed * EFi * EDi * ETi * \frac{1\ d}{24\ h} * \frac{1}{PEF} / ATnci$$

Recreational Visitor Fugitive Dust – Cancer – Adult and Child

$$CDI\ \left(\frac{mg}{m3}\right) = Csed * EFi * EDi * ETi * \frac{1\ d}{24\ h} * \frac{1}{PEF} / ATc$$

Recreational Visitor Fugitive Dust –Mutagenic Adjustment –Child

$$CDI\ \left(\frac{mg}{m3}\right) = Csed * INFM * \frac{1}{PEF} / ATc$$

$$INFM = ED_{2-6} * EFc * ETc * \frac{1}{24} * 3 + ED_{6-16} * EFa * ETa * \frac{1}{24} * 3 + ED_{16-26} * EFa * ETa * \frac{1}{24} * 1$$

Where:

CDI	=	Chronic daily exposure air concentration; chemical-specific (mg/m^3)
C_{sed}	=	Sediment EPC; chemical-specific (mg/kg)
EFi	=	Exposure frequency; receptor-specific (d/y)
EDi	=	Exposure duration; receptor-specific (y)
ETi	=	Exposure time; receptor-specific (h/d)
ATnc	=	Averaging time for noncarcinogenic health effects; receptor-specific [ED*365 d/y] (d)
ATc	=	Averaging time for carcinogenic health effects; receptor-specific [70 y*365 d/y] (25550 d)
PEF	=	Particulate emission factor (kg/m^3)
INFM	=	Mutagenic inhalation factor (d)

Contaminant intake due to fugitive dust emissions is shown in Table 10. This is expressed in units of mg/m^3, which is consistent with the units used later in this report for the toxicity values. It is the combination of intake with toxicity information that results in an estimate of risk or hazard.

Dietary Ingestion

All analytes from Table 5 were evaluated for bioaccumulation potential. In addition, all of the sediment COPCs were evaluated for uptake by plants.

Vegetation

Plants may bioaccumulate COPCs from contaminated sediments. Root systems may access shallow ground water. Wetland or riparian plants may be exposed to surface water by root uptake or foliar uptake from water contacting leaves or deposition from air to leaves. People entering the area for recreation could gather and eat berries, mushrooms, or other plant materials. During a site visit, numerous edible berries were present along hiking trails and other park features, in close proximity to sampling locations.

Tables 4a and 4b of USEPA (2007) EcoSSL Attachment 4-1 present regression models for predicting plant tissue concentrations. These models were used in the HHRA to predict uptake from contaminated solid media (soils or sediments), where Cp refers to the predicted plant concentration and Cs is the sediment EPC.

There are no regression equations for chlorinated PAHs from USEPA (2005). The r^2 values for the linear regression for soil to rinsed plant foliage are 0.7846 for high molecular weight PAHs (all data combined), but only 0.1965 for low molecular weight PAHs (USEPA 2005). The regression for the high molecular weight PAHs was used to represent uptake of Total PAHs by plants. The concentrations of each PAH in the sediment sample were summed to obtain an estimate of Total PAHs.

Plant uptake equations are reported in Table 10. The equation is used with the sediment concentration to predict the plant concentration. If a single value or bioaccumulation factor (BAF) is shown in Table 10 under the heading "Plant BAF" (e.g., aluminum or arsenic), this value is multiplied by the sediment concentration (Table 10). Otherwise, the result of the equation shown in the column "Plant BAF" is shown as the plant concentration under C_{plant}.

The average ingestion rate (g/kg-d) for fruits for children and adults (Table 9) was obtained from the Exposure Factors Handbook (USEPA 2011). A mean of 95th percentile of fruit ingestion rates for ages 0 to 6 y was used (USEPA 2011; Table 9-4). Adult values were used to obtain ingestion rates of fruits for adults. Consumer only values were selected for the edible portion of uncooked fruit. The mean was multiplied by body weight to get ingestion rates in units of g/d, multiplied by 1000 to convert this to units of mg/d on a wet weight basis, and then converted to dry weight basis (dwb = wwb*[100-80%H_2O]/100), essentially multiplying by 0.2.

Table 10. Exposure Intakes for the Recreational Visitor

Noncarcinogenic Intake - Recreational Visitor - Child															
Analyte Name	CAS No.	Sediment EPC	Surface Water EPC	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways						Total Intake
				Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish BCF	Cfish	Fish Ingestion	Plant BAF	Cplant	Plant Ingestion	
		(mg/kg)	(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/m3)	(mg/kg-d)	(mg/kg-d)	(L/kg)	(mg/kg dwb)	(mg/kg-d)		(mg/kg dwb)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	8380	9.49	1.47E-02	No ABS	2.32E-09	3.00E-02	1.59E-03	231a	2.19E+03	2.35E-01	0.004a	3.35E+01	1.84E-02	3.00E-01
Antimony	7440-36-0	0.849	***0.002***	1.49E-06	No ABS	2.35E-13	6.31E-06	3.35E-07	1a	2.00E-03	2.14E-07	0.2a	1.70E-01	9.35E-05	1.02E-04
Arsenic	7440-38-2	292	0.0741	5.12E-04	3.64E-05	8.09E-11	2.34E-04	1.24E-05	17a	1.26E+00	1.35E-04	0.03752b	1.10E+01	6.03E-03	6.96E-03
Boron	7440-42-8	***144***	1.99	2.52E-04	No ABS	3.99E-11	6.28E-03	3.33E-04	No BCF	NV	NV	4a	5.76E+02	3.17E-01	3.24E-01
Cadmium	7440-43-9	6.7	***0.001***	1.17E-05	2.79E-08	1.86E-12	3.16E-06	1.67E-07	12400a	1.24E+01	1.33E-03	=EXP(0.546*LN(Csed)-0.475)b	1.76E+00	9.67E-04	2.31E-03
Cobalt	7440-48-4	69.1	0.024	1.21E-04	No ABS	1.92E-11	7.57E-05	1.61E-06	No BCF	NV	NV	0.0075b	5.18E-01	2.85E-04	4.84E-04
Chromium, Hexavalent	18540-29-9	***3.66***	0.0046	6.42E-06	No ABS	1.01E-12	1.45E-05	1.54E-06	3a	1.38E-02	1.48E-06	0.041b	1.50E-01	8.26E-05	1.07E-04
Iron	7439-89-6	178000	91.3	3.12E-01	No ABS	4.93E-08	2.88E-01	1.53E-02	No BCF	NV	NV	0.004a	7.12E+02	3.92E-01	1.01E+00
Lead	7439-92-1	***28.9***	0.0163	5.07E-05	No ABS	8.01E-12	5.14E-05	2.73E-07	45a	7.34E-01	7.86E-05	=EXP(0.561*LN(Csed)-1.328)b	1.75E+00	9.63E-04	1.14E-03
Lithium	7439-93-2	7.21	***0.25***	1.26E-05	No ABS	2.00E-12	7.89E-04	4.19E-05	No BCF	NV	NV	0.025a	1.80E-01	9.92E-05	9.43E-04
Manganese	7439-96-5	807	11	1.42E-03	No ABS	2.24E-10	3.47E-02	1.84E-03	No BCF	NV	NV	0.079b	6.38E+01	3.51E-02	7.31E-02
Mercury*	7487-94-7	0.0178	***0.0002***	3.12E-08	No ABS	4.93E-15	6.31E-07	3.35E-08	101658c	2.03E+01	2.18E-03	0.9a	1.60E-02	8.82E-06	2.19E-03
Molybdenum	7439-98-7	98.6	0.0431	1.73E-04	No ABS	2.73E-11	1.36E-04	7.22E-06	No BCF	NV	NV	0.25a	2.47E+01	1.36E-02	1.39E-02
Nickel	7440-02-0	60.2	0.0537	1.06E-04	No ABS	1.67E-11	1.69E-04	1.80E-06	106a	5.69E+00	6.10E-04	0.06a	3.61E+00	1.99E-03	2.87E-03
PAHs (Total)	PAH	0.247	No Data	4.33E-07	1.34E-07	6.85E-14	No Data	No Data	No Data	No Data	NA	=EXP(0.7912*LN(Csed)-1.1442)b	1.05E-01	5.80E-05	5.86E-05
Selenium	7782-49-2	***43.3***	0.0026	7.59E-05	No ABS	1.20E-11	8.21E-06	4.35E-07	No BCF	NV	NV	=EXP(1.104*LN(Csed)-0.677)b	3.26E+01	1.79E-02	1.80E-02
Strontium	7440-24-6	192	5.73	3.37E-04	No ABS	5.32E-11	1.81E-02	9.59E-04	No BCF	NV	NV	2.5a	4.80E+02	2.64E-01	2.84E-01
Sulfate	14808-79-8	616	594	1.08E-03	No ABS	1.71E-10	1.87E+00	0.00E+00	No BCF	NV	NV	1.5a	9.24E+02	5.09E-01	2.38E+00
Thallium	7440-28-0	0.352	***0.001***	6.17E-07	No ABS	9.76E-14	3.16E-06	1.67E-07	34a	3.40E-02	3.64E-06	0.004a	1.41E-03	7.75E-07	8.36E-06
Vanadium	7440-62-2	40.8	36.6	7.15E-05	No ABS	1.13E-11	1.16E-01	6.13E-03	27.9d	1.02E+03	1.09E-01	0.0055a	2.24E-01	1.23E-04	2.31E-01

Notes:

Bold italics - Maximum value is not detected; EPC is based on the reporting limit

EPC - Exposure point concentration

Csed - Sediment EPC

Cplant - Plant concentration

BAF - Bioaccumulation factor

BCF - Bioconcentration factor

mg/kg - milligrams per kilogram

mg/kg dwb - milligrams per kilogram on a dry weight basis

a - BAF from ORNL (Plants - Baes et al. 1984; Fish - Toxicological Benchmarksfor Wildlife:1996 Revision)

b- BAF from EcoSSL Attachment 4-1 (USEPA 2005)

** - Carried forward as a bioaccumulative contaminant of concern (BCC)*

c - Ecotox Database, Mercury,Goldfish, at 1789 days, reference 48. Striped bass, HgCl2 BCF 7600 at 1 d

d - Ecotox Database, Vanadium oxide, flagfish,at 96 days, reference 15775

Table 10. Exposure Intakes for the Recreational Visitor, cont.

Noncarcinogenic Intake - Recreational Visitor - Adult

Analyte Name	CAS No.	Sediment EPC	Surface Water EPC	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways						Total Intake
				Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish BCF	C_{fish}	Fish Ingestion	Plant BAF	C_{Plant}	Plant Ingestion	
		(mg/kg)	(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(L/kg)	(mg/kg dwb)	(mg/kg-d)		(mg/kg)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	8380	9.49	2.07E-03	No ABS	5.81E-09	8.31E-03	2.30E-03	231[a]	2.19E+03	1.64E-01	0.004[a]	3.35E+01	5.76E-03	1.83E-01
Antimony	7440-36-0	0.849	***0.002***	2.09E-07	No ABS	5.88E-13	1.75E-06	4.85E-07	1[a]	2.00E-03	1.50E-07	0.2[a]	1.70E-01	2.92E-05	3.18E-05
Arsenic	7440-38-2	292	0.0741	7.20E-05	9.12E-06	2.02E-10	6.49E-05	1.80E-05	17[a]	1.26E+00	9.44E-05	0.03752[b]	1.10E+01	1.88E-03	2.14E-03
Boron	7440-42-8	***144***	1.99	3.55E-05	No ABS	9.98E-11	1.74E-03	4.82E-04	No BCF	NV	NV	4[a]	5.76E+02	9.90E-02	1.01E-01
Cadmium	7440-43-9	6.7	***0.001***	1.65E-06	6.98E-09	4.64E-12	8.75E-07	2.42E-07	12400[a]	1.24E+01	9.29E-04	=EXP(0.546*LN(Csed)-0.475)[b]	1.76E+00	3.02E-04	1.23E-03
Cobalt	7440-48-4	69.1	0.024	1.70E-05	No ABS	4.79E-11	2.10E-05	2.33E-06	No BCF	NV	NV	0.0075[b]	5.18E-01	8.90E-05	1.29E-04
Hexavalent Chromium	18540-29-9	***3.66***	0.0046	9.02E-07	No ABS	2.54E-12	4.03E-06	2.23E-06	3[a]	1.38E-02	1.03E-06	0.041[b]	1.50E-01	2.58E-05	3.40E-05
Iron	7439-89-6	178000	91.3	4.39E-02	No ABS	1.23E-07	7.99E-02	2.21E-02	No BCF	NV	NV	0.004[a]	7.12E+02	1.22E-01	2.68E-01
Lead	7439-92-1	***28.9***	0.0163	NA	No ABS	2.00E-11	1.43E-05	3.95E-07	45[a]	7.34E-01	5.50E-05	=EXP(0.561*LN(Csed)-1.328)[b]	1.75E+00	3.01E-04	3.70E-04
Lithium	7439-93-2	7.21	***0.25***	1.78E-06	No ABS	5.00E-12	2.19E-04	6.06E-05	No BCF	NV	NV	0.025[a]	1.80E-01	3.10E-05	3.12E-04
Manganese	7439-96-5	807	11	1.99E-04	No ABS	5.59E-10	9.63E-03	2.67E-03	No BCF	NV	NV	0.079[b]	6.38E+01	1.10E-02	2.34E-02
Mercury*	7487-94-7	0.0178	***0.0002***	4.39E-09	No ABS	1.23E-14	1.75E-07	4.85E-08	101658[c]	2.03E+01	1.52E-03	0.9[a]	1.60E-02	2.75E-06	1.53E-03
Molybdenum	7439-98-7	98.6	0.0431	2.43E-05	No ABS	6.83E-11	3.77E-05	1.04E-05	No BCF	NV	NV	0.25[a]	2.47E+01	4.24E-03	4.31E-03
Nickel	7440-02-0	60.2	0.0537	1.48E-05	No ABS	4.17E-11	4.70E-05	2.60E-06	106[a]	5.69E+00	4.27E-04	0.06[a]	3.61E+00	6.21E-04	1.11E-03
PAHs (Total)*	PAH	0.247	No Data	6.09E-08	3.35E-08	1.71E-13	No Data	No Data	No Data	No Data	No Data	=EXP(0.7912*LN(Csed)-1.1442)[b]	1.05E-01	1.81E-05	1.82E-05
Selenium	7782-49-2	***43.3***	0.0026	1.07E-05	No ABS	3.00E-11	2.28E-06	6.30E-07	No BCF	NV	NV	=EXP(1.104*LN(Csed)-0.677)[b]	3.26E+01	5.59E-03	5.61E-03
Strontium	7440-24-6	192	5.73	4.73E-05	No ABS	1.33E-10	5.02E-03	1.39E-03	No BCF	NV	NV	2.5[a]	4.80E+02	8.25E-02	8.89E-02
Sulfate	14808-79-8	616	594	1.52E-04	No ABS	4.27E-10	5.20E-01	0.00E+00	No BCF	NV	NV	1.5[a]	9.24E+02	1.59E-01	6.79E-01
Thallium	7440-28-0	0.352	***0.001***	8.68E-08	No ABS	2.44E-13	8.75E-07	2.42E-07	34[a]	3.40E-02	2.55E-06	0.004[a]	1.41E-03	2.42E-07	3.99E-06
Vanadium	7440-62-2	40.8	36.6	1.01E-05	No ABS	2.83E-11	3.20E-02	8.87E-03	27.9[d]	1.02E+03	7.65E-02	0.0055[a]	2.24E-01	3.86E-05	1.17E-01

Notes:

Bold italics - Maximum value is not detected; EPC is based on the reporting limit
EPC - Exposure point concentration
Csed - Sediment EPC
Cplant - Plant concentration
BAF - Bioaccumulation factor
BCF - Bioconcentration factor
mg/kg - milligrams per kilogram
mg/kg dwb - milligrams per kilogram on a dry weight basis

a - BAF from ORNL (Plants - Baes et al. 1984; Fish - Toxicological Benchmarksfor Wildlife:1996 Revision)
b- BAF from EcoSSL Attachment 4-1 (USEPA 2005)
** - Carried forward as a bioaccumulative contaminant of concern (BCC)*
c - Ecotox Database, Mercury,Goldfish, at 1789 days, reference 48. Striped bass, HgCl2 BCF 7600 at 1 d
d - Ecotox Database, Vanadium oxide, flagfish,at 96 days, reference 15775

Table 10. Exposure Intakes for the Recreational Visitor, cont.

Carcinogenic Intake - Recreational Visitor - Child																
Analyte Name	CAS No.	Sediment EPC	Surface Water EPC	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways							Total Intake
				Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish BCF	C_{fish}	Fish Ingestion	Plant BAF	C_{plant}	Plant Ingestion		
		(mg/kg)	(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/m^3)	(mg/kg-d)	(mg/kg-d)	(L/kg)	(mg/kg dwb)	(mg/kg-d)		(mg/kg dwb)	(mg/kg-d)		(mg/kg-d)
Aluminum	7429-90-5	8380	9.49	1.43E-03	No ABS	1.33E-10	4.08E-03	7.54E-04	231[a]	2.19E+03	1.34E-02	0.004[a]	3.35E+01	1.05E-03		2.07E-02
Antimony	7440-36-0	0.849	***0.002***	1.45E-07	No ABS	1.34E-14	8.61E-07	1.59E-07	1[a]	2.00E-03	1.22E-08	0.2[a]	1.70E-01	5.34E-06		6.52E-06
Arsenic	7440-38-2	292	0.0741	4.98E-05	4.69E-06	4.63E-12	3.19E-05	5.89E-06	17[a]	1.26E+00	7.71E-06	0.03752[b]	1.10E+01	3.45E-04		4.45E-04
Boron	7440-42-8	***144***	1.99	2.46E-05	No ABS	2.28E-12	8.57E-04	1.58E-04	No BCF	NV	NV	4[a]	5.76E+02	1.81E-02		1.92E-02
Cadmium	7440-43-9	6.7	***0.001***	1.14E-06	3.59E-09	1.06E-13	4.30E-07	7.95E-08	12400[a]	1.24E+01	7.59E-05	=EXP(0.546*LN(Csed)-0.475)[b]	1.76E+00	5.53E-05		1.33E-04
Cobalt	7440-48-4	69.1	0.024	1.18E-05	No ABS	1.09E-12	1.03E-05	7.63E-07	No BCF	NV	NV	0.0075[b]	5.18E-01	1.63E-05		3.92E-05
Hexavalent Chromium	18540-29-9	***3.66***	0.0046	1.62E-06	No ABS	1.62E-12	4.79E-06	1.60E-06	3[a]	1.38E-02	8.45E-08	0.041[b]	1.50E-01	4.72E-06		1.28E-05
Iron	7439-89-6	178000	91.3	3.04E-02	No ABS	2.82E-09	3.93E-02	7.26E-03	No BCF	NV	NV	0.004[a]	7.12E+02	2.24E-02		9.93E-02
Lead	7439-92-1	***28.9***	0.0163	4.93E-06	No ABS	4.58E-13	7.02E-06	1.30E-07	45[a]	7.34E-01	4.49E-06	=EXP(0.561*LN(Csed)-1.328)[b]	1.75E+00	5.50E-05		7.16E-05
Lithium	7439-93-2	7.21	***0.25***	1.23E-06	No ABS	1.14E-13	1.08E-04	1.99E-05	No BCF	NV	NV	0.025[a]	1.80E-01	5.67E-06		1.34E-04
Manganese	7439-96-5	807	11	1.38E-04	No ABS	1.28E-11	4.73E-03	8.74E-04	No BCF	NV	NV	0.079[b]	6.38E+01	2.00E-03		7.75E-03
Mercury*	7487-94-7	0.0178	***0.0002***	3.04E-09	No ABS	2.82E-16	8.61E-08	1.59E-08	101658[c]	2.03E+01	1.25E-04	0.9[a]	1.60E-02	5.04E-07		1.25E-04
Molybdenum	7439-98-7	98.6	0.0431	1.68E-05	No ABS	1.56E-12	1.86E-05	3.43E-06	No BCF	NV	NV	0.25[a]	2.47E+01	7.75E-04		8.14E-04
Nickel	7440-02-0	60.2	0.0537	1.03E-05	No ABS	9.54E-13	2.31E-05	8.54E-07	106[a]	5.69E+00	3.49E-05	0.06[a]	3.61E+00	1.14E-04		1.83E-04
PAHs (Total)*	PAH	0.247	No Data	4.22E-08	1.72E-08	3.91E-15	No Data	No Data	No Data	No Data	No Data	=EXP(0.7912*LN(Csed)-1.1442)[b]	1.05E-01	3.31E-06		3.37E-06
Selenium	7782-49-2	***43.3***	0.0026	7.39E-06	No ABS	6.86E-13	1.12E-06	2.07E-07	No BCF	NV	NV	=EXP(1.104*LN(Csed)-0.677)[b]	3.26E+01	1.02E-03		1.03E-03
Strontium	7440-24-6	192	5.73	3.28E-05	No ABS	3.04E-12	2.47E-03	4.55E-04	No BCF	NV	NV	2.5[a]	4.80E+02	1.51E-02		1.81E-02
Sulfate	14808-79-8	616	594	1.05E-04	No ABS	9.76E-12	2.56E-01	0.00E+00	No BCF	NV	NV	1.5[a]	9.24E+02	2.91E-02		2.85E-01
Thallium	7440-28-0	0.352	***0.001***	6.01E-08	No ABS	5.58E-15	4.30E-07	7.95E-08	34[a]	3.40E-02	2.08E-07	0.004[a]	1.41E-03	4.43E-08		8.23E-07
Vanadium	7440-62-2	40.8	36.6	6.96E-06	No ABS	6.46E-13	1.58E-02	2.91E-03	27.9[d]	1.02E+03	6.25E-03	0.0055[a]	2.24E-01	7.06E-06		2.49E-02

Notes:

Bold italics - Maximum value is not detected; EPC is based on the reporting limit
EPC - Exposure point concentration
Csed - Sediment EPC
Cplant - Plant concentration
BAF - Bioaccumulation factor
BCF - Bioconcentration factor
mg/kg - milligrams per kilogram
mg/kg dwb - milligrams per kilogram on a dry weight basis

a - BAF from ORNL (Plants - Baes et al. 1984; Fish - Toxicological Benchmarksfor Wildlife:1996 Revision)
b- BAF from EcoSSL Attachment 4-1 (USEPA 2005)
** - Carried forward as a bioaccumulative contaminant of concern (BCC)*
c - Ecotox Database, Mercury,Goldfish, at 1789 days, reference 48. Striped bass, HgCl2 BCF 7600 at 1 d
d - Ecotox Database, Vanadium oxide, flagfish,at 96 days, reference 15775

Table 10. Exposure Intakes for the Recreational Visitor, cont.

Carcinogenic Intake - Recreational Visitor - Adult

Analyte Name	CAS No.	Sediment EPC	Surface Water EPC	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways						Total Intake
				Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish BCF	C_{fish}	Fish Ingestion	Plant BAF	C_{Plant}	Plant Ingestion	
		(mg/kg)	(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(L/kg)	(mg/kg dwb)	(mg/kg-d)		(mg/kg)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	8380	9.49	5.90E-04	No ABS	1.66E-09	2.37E-03	6.57E-04	231[a]	2.19E+03	4.69E-02	0.004[a]	3.35E+01	1.65E-03	5.22E-02
Antimony	7440-36-0	0.849	***0.002***	5.98E-08	No ABS	1.68E-13	5.00E-07	1.38E-07	1[a]	2.00E-03	4.28E-08	0.2[a]	1.70E-01	8.34E-06	9.08E-06
Arsenic	7440-38-2	292	0.0741	2.06E-05	2.61E-06	5.78E-11	1.85E-05	5.13E-06	17[a]	1.26E+00	2.70E-05	0.03752[b]	1.10E+01	5.38E-04	6.12E-04
Boron	7440-42-8	***144***	1.99	1.01E-05	No ABS	2.85E-11	4.98E-04	1.38E-04	No BCF	NV	NV	4[a]	5.76E+02	2.83E-02	2.89E-02
Cadmium	7440-43-9	6.7	***0.001***	4.72E-07	1.99E-09	1.33E-12	2.50E-07	6.92E-08	12400[a]	1.24E+01	2.66E-04	=EXP(0.546*LN(Csed)-0.475)[b]	1.76E+00	8.62E-05	3.53E-04
Cobalt	7440-48-4	69.1	0.024	4.87E-06	No ABS	1.37E-11	6.00E-06	6.65E-07	No BCF	NV	NV	0.0075[b]	5.18E-01	2.54E-05	3.70E-05
Hexavalent Chromium	18540-29-9	***3.66***	0.0046	2.58E-07	No ABS	7.25E-13	1.15E-06	6.37E-07	3[a]	1.38E-02	2.96E-07	0.041[b]	1.50E-01	7.37E-06	9.71E-06
Iron	7439-89-6	178000	91.3	1.25E-02	No ABS	3.52E-08	2.28E-02	6.32E-03	No BCF	NV	NV	0.004[a]	7.12E+02	3.50E-02	7.66E-02
Lead	7439-92-1	***28.9***	0.0163	2.04E-06	No ABS	5.72E-12	4.08E-06	1.13E-07	45[a]	7.34E-01	1.57E-05	=EXP(0.561*LN(Csed)-1.328)[b]	1.75E+00	8.59E-05	1.08E-04
Lithium	7439-93-2	7.21	***0.25***	5.08E-07	No ABS	1.43E-12	6.25E-05	1.73E-05	No BCF	NV	NV	0.025[a]	1.80E-01	8.85E-06	8.92E-05
Manganese	7439-96-5	807	11	5.69E-05	No ABS	1.60E-10	2.75E-03	7.61E-04	No BCF	NV	NV	0.079[b]	6.38E+01	3.13E-03	6.70E-03
Mercury*	7487-94-7	0.0178	***0.0002***	1.25E-09	No ABS	3.52E-15	5.00E-08	1.38E-08	101658[c]	2.03E+01	4.35E-04	0.9[a]	1.60E-02	7.86E-07	4.36E-04
Molybdenum	7439-98-7	98.6	0.0431	6.95E-06	No ABS	1.95E-11	1.08E-05	2.98E-06	No BCF	NV	NV	0.25[a]	2.47E+01	1.21E-03	1.23E-03
Nickel	7440-02-0	60.2	0.0537	4.24E-06	No ABS	1.19E-11	1.34E-05	7.43E-07	106[a]	5.69E+00	1.22E-04	0.06[a]	3.61E+00	1.77E-04	3.18E-04
PAHs (Total)*	PAH	0.247	No Data	1.74E-08	9.56E-09	4.89E-14	No Data	No Data	No Data	No Data	No Data	=EXP(0.7912*LN(Csed)-1.1442)[b]	1.05E-01	5.17E-06	5.20E-06
Selenium	7782-49-2	***43.3***	0.0026	3.05E-06	No ABS	8.57E-12	6.50E-07	1.80E-07	No BCF	NV	NV	=EXP(1.104*LN(Csed)-0.677)[b]	3.26E+01	1.60E-03	1.60E-03
Strontium	7440-24-6	192	5.73	1.35E-05	No ABS	3.80E-11	1.43E-03	3.97E-04	No BCF	NV	NV	2.5[a]	4.80E+02	2.36E-02	2.54E-02
Sulfate	14808-79-8	616	594	4.34E-05	No ABS	1.22E-10	1.49E-01	0.00E+00	No BCF	NV	NV	1.5[a]	9.24E+02	4.54E-02	1.94E-01
Thallium	7440-28-0	0.352	***0.001***	2.48E-08	No ABS	6.97E-14	2.50E-07	6.92E-08	34[a]	3.40E-02	7.28E-07	0.004[a]	1.41E-03	6.91E-08	1.14E-06
Vanadium	7440-62-2	40.8	36.6	2.87E-06	No ABS	8.08E-12	9.15E-03	2.53E-03	27.9[d]	1.02E+03	2.19E-02	0.0055[a]	2.24E-01	1.10E-05	3.36E-02

Notes:

Bold italics - Maximum value is not detected; EPC is based on the reporting limit
EPC - Exposure point concentration
Csed - Sediment EPC
Cplant - Plant concentration
BAF - Bioaccumulation factor
BCF - Bioconcentration factor
mg/kg - milligrams per kilogram
mg/kg dwb - milligrams per kilogram on a dry weight basis

a - BAF from ORNL (Plants - Baes et al. 1984; Fish - Toxicological Benchmarksfor Wildlife:1996 Revision)
b- BAF from EcoSSL Attachment 4-1 (USEPA 2005)
** - Carried forward as a bioaccumulative contaminant of concern (BCC)*
c - Ecotox Database, Mercury,Goldfish, at 1789 days, reference 48. Striped bass, HgCl2 BCF 7600 at 1 d
d - Ecotox Database, Vanadium oxide, flagfish,at 96 days, reference 15775

Fish

Fish may bioconcentrate contaminants from water, evaluated with a bioconcentration factor (BCF), which is the ratio of fish tissue concentration to water concentration. Regression equations also are used to estimate bioconcentration. Fish may also bioaccumulate contaminants from sediment. For this evaluation, only BCFs were used due to the difficulty in obtaining bioaccumulation factors (BAFs) relating fish tissue concentrations to sediment concentrations. Fish BCFs are reported in Table 10.

The ingestion rate for fish (for children and adults (Table 9) was obtained from the Exposure Factors Handbook (USEPA 2011). Values for fish, based on consumer only data, were used. The mean of the 95th percentiles for age birth to 6 year were used for children. The average of 95th percentile values for adults was used to obtain an ingestion rate for adults. This was multiplied by body weight to obtain an ingestion rate in g/d, multiplied by 1000 to convert to mg/d, and then converted to a dry weight basis (dwb) by multiplying by 0.2 from USEPA (2011; Table 10-125) assuming fish had an 80% moisture content.

Intake Equations

Ingestion of fish or plant material contaminated by source material from the ash ponds was estimated with the following equations, where Ci or IRi refers to plant or fish concentration, and indicates adult or child-specific values used for the other parameters (Table 9):

Recreational Visitor – Noncancer – Adult and Child

$$CDI\ \left(\frac{mg}{kg-d}\right) = \frac{Ci * EFi * EDi * IRi * 10^{-6}\ \frac{kg}{mg}}{(BWi * ATnci)}$$

Recreational Visitor – Cancer – Adult and Child

$$CDI\ \left(\frac{mg}{kg-d}\right) = \frac{Ci * EFi * EDi * IRi * 10^{-6}\ \frac{kg}{mg}}{(BWi * ATc)}$$

Where:

CDI	=	Chronic daily intake; chemical-specific (mg/kg-d)
Ci	=	Fish or plant tissue EPC; chemical-specific (mg/kg, dry weight basis)
IRi	=	Fish or plant ingestion rate; (c=child, a=adult); receptor-specific (mg/d)
EFi	=	Exposure frequency; (c=child, a=adult); receptor-specific (d/y)
EDi	=	Exposure duration; (c=child, a=adult); receptor-specific (y)
BWi	=	Body weight; (c=child, a=adult); receptor-specific (kg)
ATnc	=	Averaging time for noncarcinogenic health effects; (c=child, a=adult); receptor-specific [ED*365 d/y] (d)
ATc	=	Averaging time for carcinogenic health effects; [70 y*365 d/y] (25550 d)

Sediment/Surface Soil Ingestion

The following equations are used to estimate potential COPC intake due to incidental solid media (i.e., sediment/surficial soil) ingestion. For this medium, there are age adjustments for carcinogens, and mutagen adjustments for mutagens. Hexavalent chromium and high molecular weight PAHs are the only mutagens identified at the site at this time. For present purposes, it is assumed that children under the age of 2 are not expected to play in or next to the James River due to physical hazards associated with watersports for very young children. This is reflected in the exposure duration (ED), the IFS_{adj}, and the $IFSM_{adj}$. This may not be a conservative assumption since children under the age of 2 could be on docks or in boats with parents and get sediment up on their fingers and then ingest it. The EDi for sediment pathways is 4 years (for years 2-6), for a child aged 0-6 yr.

Intake Equations

Sediment/Surface Soil Ingestion -Noncancer Intake –Adult and Child

$$CDI = \frac{C_{Sed} \ * IRSi * EFi * EDi * 10^{-6} \ \frac{kg}{mg}}{BWi \ * ATnci}$$

Sediment/Surface Soil Ingestion - Age Adjusted Cancer Intake - Child

$$CDI = \frac{C_{Sed} * IFS_{adj} * 10^{-6} \ \frac{kg}{mg}}{ATc}$$

Where:

$$IFS_{adj} = \frac{IRSc * EFc * EDc}{BWc} + \frac{IRSa * EFa * EDa}{BWa}$$

Sediment/Surface Soil Ingestion - Cancer Intake for Mutagens

$$CDI = \frac{C_{Sed} * IFSM_{adj} * 10^{-6} \ \frac{kg}{mg}}{ATc}$$

Where the $IFSM_{adj}$ is calculated without the age 0-2 year component:

$$IFSM_{adj} = \frac{IRSc * EFc * ED_{2-6} * 3}{BWc} + \frac{IRSa * EFa * ED_{6-16} * 3}{BWa} \quad + \frac{IRSa * EFa * ED_{16-26} * 1}{BWa}$$

Sediment/Surface Soil Ingestion -Cancer Intake –Adult

$$CDI = \frac{C_{Sed} \ * IRSa * EFa * EDa * 10^{-6} \ \frac{kg}{mg}}{BWa \ * ATc}$$

Where:

CDI = Chronic daily intake; chemical-specific (mg/kg-d)
C_{Sed} = Exposure point concentration for sediment; chemical-specific (mg/kg)
IRSi = Ingestion rate for solid media; receptor-specific (a=adult; c=child) (mg/d)
IFS_{adj} = Ingestion adjustment factor for sediment; receptor-specific (mg/kg)
$IRSM_{adj}$ = Mutagen-adjusted ingestion rate for sediment/soil; receptor-specific (mg /kg)

ATc	=	Averaging time for carcinogenic health effects; [70 yr*365 d/y= 25,550 d] (d)
ATnc	=	Averaging time for noncarcinogenic health effects; receptor-specific [ED*365 d/y] (d)
EFi	=	Exposure frequency; receptor-specific (a=adult; c=child) (d/y)
EDi	=	Exposure duration; receptor-specific (a=adult; c=child) (y)
BWi	=	Body weight; receptor-specific (a=adult; c=child) (kg)

The mutagenic adjustment factor partitions exposure duration into several age-specific categories that are then weighted with a numerical factor to compensate for the higher toxicity for mutagenic activity in younger age groups. The weighting factors are as follows:

- $ED_{2\text{-}6}$ is 4 years, and has a factor of 3,
- $ED_{6\text{-}16}$ is 10 years, and has a factor of 3, and
- $ED_{16\text{-}26}$ is 10 years, with a factor of 1.

Sediment/Soil Dermal Contact

Dermal contact evaluates the contaminant exposure due to skin contact. It assumes that a thin layer of sediments adsorbs to skin, and that contaminants cross the skin to ultimately enter the body. For this medium and pathway, there are age adjustments for carcinogens, and mutagen adjustments for mutagens. Hexavalent chromium and high molecular weight PAHs are the only mutagens identified at the site at this time. For present purposes, it is assumed that children under the age of 2 are not expected to play in or next to the James River due to physical hazards associated with watersports for very young children. This is reflected in the exposure duration (ED), the DFS_{adj}, and the $DFSM_{adj}$. This may not be a conservative assumption since children under the age of 2 could be on docks or in boats with parents and get sediment up on their fingers and then ingest it. The EDi for sediment pathways is 4 years (for years 2-6), for a child aged 0-6 yr.

Intake Equations

The following equations are used to estimate potential intake due to dermal contact with sediment or surface soils, with parameters defined in Table 9. If the COPC is a mutagen, the mutagenic intake equation is used in Table 10 under carcinogenic intake for child, instead of the cancer intake equation.

Dermal Contact with Sediment/Surface Soil - Noncancer Intakes – Adult and Child

$$CDI = \frac{C_{Sed} * EFi * EDi * SAi * AFi * ABS * 10^{-6} \frac{kg}{mg}}{BWi * ATnci}$$

Dermal Contact with Sediment/Surface Soil - Child Age-Adjusted Cancer Intakes

$$CDI = \frac{Csed\ ) * DFS_{adj} * ABS * 10^{-6} \frac{kg}{mg}}{ATc}$$

Where:

$$DFS = \frac{EDc * EFc * SAc * AFc)}{BWc} + \frac{EDa * EFa * SAa * AFa)}{BWa}$$

Dermal Contact with Sediment/Surface Soil - Child Age – Adjusted Cancer Intakes for Mutagens

$$CDI = \frac{Csed * DFSM_{adj} * ABS * 10^{-6}\frac{kg}{mg}}{ATc}$$

$$DFSM = \frac{(ED_{2-6} * EFc * SAc * AFc)}{BWc} * 3 + \frac{(ED_{6-16} * EFa * SAa * AFa)}{BWa} * 3 + \frac{(ED_{16-26} * EFa * SAa * AFa)}{BWa} * 1$$

Dermal Contact with Sediment/Surface Soil - Cancer Intake - Adults

$$CDI = \frac{C_{Sed} * EFa * EDa * SAa * AFa * ABS * 10^{-6}\frac{kg}{mg}}{BWa * ATc}$$

Where:

CDI = Chronic daily intake; chemical-specific (mg/kg-d)
C_{sed} = Sediment EPC; chemical-specific (mg/kg)
DFS_{adj} = Dermal age-adjustment factor (mg/kg)
$DFSM_{adj}$ = Dermal age-adjustment factor for mutagens (mg/kg)
SAi = Surface area exposed to sediment; receptor-specific (cm^2/d)
ABS = Skin absorption factor for sediment contact; chemical specific (unitless)
AFi = Adherence factor for sediment contact (c=child, a=adult); receptor-specific (mg/cm^2)
EFi = Exposure frequency; (c=child, a=adult); receptor-specific (d/y)
EDi = Exposure duration; (c=child, a=adult); receptor-specific (y)
BWi = Body weight; (c=child, a=adult); receptor-specific (kg)
ATc = Averaging time for carcinogenic health effects; [70 yr*365 d/y= 25,550 d] (d)
ATnc = Averaging time for noncarcinogenic health effects; receptor-specific [ED*365 d/y] (d)

Surface Water Ingestion

The following equations are used to estimate potential intake due to incidental ingestion of surface water. For present purposes, it is assumed that very young children (0-2 yr) do not play in the James River. The intakes are shown in Table 10.

Intake Equations

If the COPC is a mutagen, the mutagenic intake equation is used in Table 10 under carcinogenic intake for child, instead of the cancer intake equation.

Incidental Ingestion of Surface Water - Noncancer Intakes – Adult and Child

$$CDI = \frac{Cw * IRWi * EFi * EDi * EV * tev}{BWi * ATnc}$$

Incidental Ingestion of Surface Water – Child Age Adjusted Cancer Intakes

$$CD = \frac{\text{Cw} * IFWadj}{ATc}$$

Where:

$$IFW_{adj} = \frac{(EDc * EFc * EVc * ETc * IRWc)}{BWc} + \frac{(EDa * EFa * EVa * ETa * IRWa)}{BWa}$$

Incidental Ingestion of Surface Water – Child Cancer Intake for Mutagens

$$CDI = \frac{\text{Cw} * IFWMadj}{ATc}$$

Where:

$$IFWM_{adj} = \frac{(ED_{2-6} * EFc * EVc * ETc * IRWc)}{BWc} * 3 + \frac{(ED_{6-16} * EFa * EVa * ETa * IRWa)}{BWa} * 3 + \frac{(ED_{16-26} * EFa * EVa * ETa * IRWa)}{BWa} * 1$$

Where:

CDI = Chronic daily intake; chemical-specific (mg/kg-d)
Cw = Exposure point concentration for surface water; chemical-specific (mg/L)
IRWi = Ingestion rate for surface water (c = child, a=adult); receptor-specific (L/hr)
IFW_{adj} = Age adjusted ingestion rate for surface water; receptor-specific (L/kg)
$IFWM_{adj}$= Mutagen-adjusted ingestion rate for surface water; receptor-specific (L/kg)
EFi = Exposure frequency for surface water; (c = child, a=adult); receptor-specific (d/y)
EDi = Exposure duration (c = child, a=adult); receptor-specific (y)
EV = Event per day (c = child, a=adult); set to 1 event per day (event/d)
ET = Exposure time (c = child, a=adult); receptor-specific (hr/event)
BWi = Body weight (c = child, a=adult); receptor-specific (kg)
ATnc = Averaging time for noncarcinogenic health effects; [EDa*365 d/y] (d)
ATc = Averaging time for carcinogenic health effects; [70 yr*365 d/y] (25550 d)

Surface Water Dermal Contact

The intake equations estimate intake due to the absorbed dose from water and are consistent with USEPA (2004). The intakes are referred to as the dermally absorbed dose (DAD), and are estimated using the predicted absorbed dose (DA_{event}), which differs depending on the COPC. There are separate equations used to estimate the absorbed dose for inorganic and organic COPCs (DA_{event}), but only the inorganic ones are used in this report because there are no organic COPCs in surface water known at this time. If the COPC is a mutagen, the mutagenic intake equation is used in Table 10 under carcinogenic intake for child, instead of the cancer intake equation.

Intake Equations

The DA_{event} for inorganics (USEPA 2007) was estimated for the following receptor and pathway combinations by using adult or child exposure parameters as follows, and is therefore receptor-specific:

Noncancer DA_{event} – Adult and Child

$$DA_{event}\left(\frac{mg}{cm^2 - event}\right) = Kp\,(\frac{cm}{h}) * Cw(\frac{mg}{L}) * ETi(\frac{h}{event}) * \frac{1\,L}{1000\,cm^3}$$

Cancer DA_{event} – Adult

$$DA_{event}\left(\frac{mg}{cm^2 - event}\right) = Kp\,(\frac{cm}{h}) * Cw(\frac{mg}{L}) * ETa(\frac{h}{event}) * \frac{1\,L}{1000\,cm^3}$$

Cancer DA_{event} – Age Adjusted, Child

$$DA_{event}\left(\frac{mg}{cm^2 - event}\right) = Kp\,(\frac{cm}{h}) * Cw(\frac{mg}{L}) * t_{event}(\frac{h}{event}) * \frac{1\,L}{1000\,cm^3}$$

Where:

$$t_{event} = \frac{ETc * EDc + ETa * EDa}{EDc + EDa}$$

Cancer DA_{event} –Mutagen Adjusted, Child

$$DA_{event}\left(\frac{mg}{cm^2 - event}\right) = Kp\,(\frac{cm}{h}) * Cw(\frac{mg}{L}) * t_{event}(\frac{h}{event}) * \frac{1\,L}{1000\,cm^3}$$

Where the exposure time is broken out further by age group. The age groups evaluated in this report were 2 to 6 years, 6 to 16 years, and 16 to 26 years by USEPA, but it results in the same numerical value as the t_{event} for cancer above:

$$t_{event} = \frac{(ET * ED)_{2-6} + (ET * ED)_{6-16} + (ET * ED)_{16-26}}{ED_{2-6} + ED_{6-16} + ED_{16-26}}$$

Surface Water Dermal Contact - Noncancer Intake- Adult and Child

$$DAD(\frac{mg}{kg - d}) = \frac{DAevent\left(\frac{mg}{cm^2 - event}\right) * EV\left(\frac{event}{d}\right) * EFi\left(\frac{d}{yr}\right) * EDi(yr) * SAWi(cm^2)}{BWi\,(kg) * ATnc\,(d)}$$

Surface Water Dermal Contact – Child Age-Adjusted Cancer Intake

$$DADadj(\frac{mg}{kg-\ d}) = \frac{DAevent\left(\frac{mg}{cm^2 - event}\right) * DFWadj\left(\frac{event - cm^2}{kg}\right)}{ATc\ (d)}$$

Where:

$$DFW_{adj}\left(\frac{ev - cm2}{kg}\right) = \frac{EVc\left(\frac{event}{d}\right) * EFc\left(\frac{d}{yr}\right) * EDc(yr) * SAWc(cm^2)}{BWc\ (kg)} + \frac{EVa\left(\frac{event}{d}\right) * EFa\left(\frac{d}{yr}\right) * EDa(yr) * SAWa(cm^2)}{BWa\ (kg)}$$

Surface Water Dermal Contact – Child Age-Adjusted Cancer Intake for Mutagens

$$DADM_{adj}(\frac{mg}{kg-\ d}) = \frac{DAevent\left(\frac{mg}{cm^2 - event}\right) * DFWMadj\left(\frac{event - cm^2}{kg}\right)}{ATc\ (d)}$$

Where:

$$DFWM_{adj}\left(\frac{ev - cm^2}{kg}\right) = \frac{ED_{2-6} * EVc * EFc * SAWc}{BWc} * 3 + \frac{ED_{6-16} * EVa * EFa * SAWa}{BWa} * 3 + \frac{ED_{16-26} * EVa * EFa * SAWa}{BWa} * 1$$

Surface Water Dermal Contact - Cancer Intake- Adult

$$DAD(\frac{mg}{kg-\ d}) = \frac{DAevent\left(\frac{mg}{cm^2 - event}\right) * SAWa(cm^2) * EVa\left(\frac{event}{d}\right) * EFa\left(\frac{d}{yr}\right) * EDa(yr)}{BWa\ (kg) * ATca\ (d)}$$

Where:

DA_{event} = Absorbed dose per event (mg/cm^2-event)
Kp = Dermal permeability coefficient of compound in water (cm/hr); chemical-specific
Cw = Concentration in water (mg/L)
ETi = Event duration; receptor-specific (hr/event)
t_{event} = Event duration, age adjusted (hr/event)
DAD = Dermally absorbed dose; chemical-specific (mg/kg-d)
DAD_{adj} = Dermally absorbed dose, age-adjusted; chemical-specific (mg/kg-d)
$DADM_{adj}$= Dermally absorbed dose, mutagen adjusted; chemical specific (mg/kg-d)
DFW_{adj} = Dermal age adjustment factor for surface water (event-cm^2/kg)
$DFWM_{adj}$= Dermal mutagen adjustment factor for surface water (event-cm^2/kg)
SAWi = Surface area (c=child, a=adult); receptor-specific (cm^2)
EV = Events per day (1)
EFi = Exposure frequency (c=child, a=adult); receptor-specific (d/y)
EDi = Exposure duration (c=child, a=adult), receptor-specific) (y)
BWi = Body weight (c=child, a=adult); receptor-specific (kg)

ATc = Averaging time for carcinogenic health effects; [70 yr*365 d/y= 25,550 d] (d)

ATnc = Averaging time for noncarcinogenic health effects; receptor-specific [ED*365 d/y] (d)

5.2. Toxicity Assessment

The Toxicity Assessment presents the toxicity values that link exposure to health effects. The toxicity values (Table 11) are used in the Risk Characterization (Section 6) to determine if exposure to COPCs (Section 4) exceeds acceptable levels for limited to no effects on human health. There are separate toxicity values for cancer and noncancer health effects. Inhalation exposure is addressed with different toxicity values than those used in evaluating ingestion or dermal exposure.

The toxicity values used to predict the potential for noncarcinogenic risk are the oral reference dose (RfDo) values for dermal and ingestion exposure and the reference concentrations (RfCi) for inhalation exposure. The toxicity values used to predict the potential for carcinogenic risk are the cancer slope factors (CSFs) for dermal and ingestion exposure and the unit risk factors (IUR) for inhalation exposure.

The toxicity values used in the baseline HHRA are presented in this section. The following hierarchy is used for selection of toxicity values (USEPA 2018a):

- Tier 1 – USEPA IRIS
- Tier 2 – USEPA's Provisional Peer Reviewed Toxicity Values (PPRTVs) – The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center develops PPRTVs on a chemical-specific basis when requested by USEPA's Superfund program.
- Tier 3 – Other Toxicity Values – Tier 3 includes additional USEPA and non-USEPA sources of toxicity information, where priority is given to the most current, transparent, and publically available peer reviewed data.

In the event that toxicity values are unavailable for any of the COPCs on the USEPA (2016) RSL website, an alternative toxicity value is proposed if available. If toxicity information is not available, it indicates that no information is available in IRIS, the PPRTV, or the Health Effects Assessment Summary Tables (HEAST). This requires an in-depth review of the available scientific literature, which is outside the scope of this report at this time.

5.2.1. Lead

There are no established toxicity values for lead. Lead risks protective of residential uses are determined by comparing site-specific lead concentrations to acceptable soil concentrations developed with the USEPA Integrated Exposure Uptake Biokinetic (IEUBK) model. This model predicts blood lead concentrations associated with environmental exposures. The level of concern for lead in blood is 10 micrograms per deciliter (ug/dl) (USEPA 1998b). The established screening-level lead soil concentration for the residential use scenario is 400 mg/kg (USEPA 2018a). The lead tapwater and MCL value are 15 ug/L. Using the detected sediment EPC, the surface water EPC, the incidental surface water ingestion rates, and the dietary intake for children, the IEUBK model indicated blood lead concentrations would be below 10 ug/dl.

5.2.1. Toxicity Adjustment Factors for the Sediment Ingestion Exposure Pathway

The sediment ingestion pathway is adjusted with a relative bioavailability (RBA) factor for arsenic of 0.6. All other metals have an RBA of 1. The adjustment is as follows:

$$Noncancer\ Health\ Effects = \frac{RBA}{RfD\ \left(\frac{mg}{kg-d}\right)}$$

$$Cancer\ Health\ Effects = CSF\ \left(\frac{kg-d}{mg}\right) * RBA$$

5.2.2. Toxicity Adjustment Factors for the Dermal Exposure Pathway

Oral and inhalation toxicity factors represent an administered or external dose, whereas dermal toxicity is evaluated as an absorbed dose (i.e., molecules of contaminant crossing the skin to circulate in the bloodstream). When gastrointestinal absorption of a compound in the critical study from which the toxicity value (i.e., RfD or CSF) was derived is high (i.e., 100%), the absorbed dose is equivalent to the administered dose. Therefore, no adjustment of the toxicity values is necessary. For chemicals for which gastrointestinal absorption is low (e.g., less than 50 percent), the absorbed dose is much smaller than the administered dose. An adjustment is made (ABS_{GI}) to the toxicity factors to account for the difference in the absorbed dose relative to the administered dose (USEPA 2004). These adjustments only apply to the dermal exposure pathways, but they apply to dermal uptake from both sediment and surface water.

For the derivation of the cancer slope factor for an absorbed dose (CSF_{ABS}) from the oral administered dose (CSFo), the following equation is used:

$$CSF_{ABS} = \frac{CSF}{GIABS}$$

Where:

CSF_{ABS} - Absorbed cancer slope factor; chemical-specific, inverse of milligram per kilogram per body weight per day $(mg/kg\text{-}d)^{-1}$;

CSF - Oral cancer slope factor; chemical-specific $(mg/kg\text{-}d)^{-1}$;

GIABS - Gastrointestinal absorption factor; the fraction of contaminant absorbed in the gastrointestinal tract in the critical toxicity study (dimensionless); chemical-specific

For the derivation of the absorbed reference dose (RfD_{ABS}) from the oral administered reference dose (RfDo), the following equation is used:

$$RfD_{ABS} = RFD_O * GIABS$$

Where:

RfD_{ABS} - Absorbed reference dose; chemical-specific (mg/kg-d)

RfD - Oral reference dose; chemical-specific (mg/kg-d)

GIABS - Fraction of contaminant absorbed in the gastrointestinal tract in the critical toxicity study (dimensionless); chemical-specific

In general, organic compounds (e.g., PAHs) are well absorbed in toxicity tests (USEPA 2004). Therefore, organic compounds typically do not require adjustment to reflect the actual absorbed dose. Some inorganics do require adjustment (e.g., barium). If a value is lacking, USEPA (2004) recommends assuming that absorption is 100 percent (i.e., a value of 1 is used for GIABS). The adjustment factors for the COPCs are shown in Table 11.

5.3. Risk Characterization

Risks to the recreational receptor were calculated with a HQ for noncancer hazard, and a cancer risk (CR) for carcinogens, as follows:

Sediment or Surface Water Ingestion

$$Hazard\ Quotient = \frac{CDI\ (\frac{mg}{kg-d})}{RfD\ (\frac{mg}{kg-d})}$$

$$Cancer\ Risk = \ CDI(\frac{mg}{kg-d}) * CSF\ (\frac{kg-d)}{mg}$$

Sediment of Surface Water Dermal Contact

$$Hazard\ Quotient = \frac{CDI\ (\frac{mg}{kg-d})}{RfDabs\ (\frac{mg}{kg-d})}$$

$$Cancer\ Risk = \ CDI(\frac{mg}{kg-d}) * CSFabs\ (\frac{kg-d)}{mg}$$

Sediment Inhalation of Fugitive Dust Pathway

$$Hazard\ Quotient = \frac{CDI\ (\frac{mg}{m^3})}{RfC\ (\frac{mg}{m^3})}$$

$$Cancer\ Risk = \ CDI\left(\frac{mg}{m^3}\right) * IUR\ (\frac{m^3}{ug}) * 1000\frac{ug}{mg}$$

Summing the HQs across all exposure pathways results in a Total HQ for the analyte. Summing the HQs across all analytes produces a noncancer hazard index (HI). Summing the cancer risks across all exposure pathways produces a total cancer risk, whereas summing the cancer risks across all carcinogenic analytes results in a cumulative cancer risk. HQs above 1 indicate an unacceptable level of noncancer hazard. A CR above $1x10^{-4}$, the upper bound of the cancer risk management range, indicates an unacceptable level of cancer risk.

5.3.1. Risk Description

Table 12 presents the noncancer and cancer risk estimates for child and adult recreational visitors. As shown in the table, HQs above 1 and CRs above $1x10^{-4}$ are present at the Site. The noncancer HI indicates that hazard due to site-related contaminant intakes by children is 140 times higher than intakes identified as having no adverse health effects. The HI for adults indicates that site-related contaminant intakes by adults are 110 times higher than those identified as having no adverse health effects. The target HI is a value of 1.

Table 11. Toxicity Information Used in the Baseline Risk Assessment

Contaminant		Toxicity and Chemical-specific Information											
Analyte	CAS No.	CSF (mg/kg-day)-1	key	IUR (ug/m3)-1	key	RfDo (mg/kg-day)	key	RfCi (mg/m3)	key	mutagen	GIABS	ABS	Csat (mg/kg)
Aluminum	7429-90-5					1	P	0.005	P		1		
Antimony	7440-36-0					0.0004	I				0.15		
Arsenic	7440-38-2	1.5	I	0.0043	I	0.0003	I	0.000015	C		1	0.03	
Barium	7440-39-3					0.2	I	0.0005	H		0.07		
Beryllium	7440-41-7			0.0024	I	0.002	I	0.00002	I		0.007		
Boron	7440-42-8					0.2	I	0.02	H		1		
Cadmium (diet)	7440-43-9			0.0018	I	0.001	I	0.00001	A		0.025	0.001	
Cadmium (water)	7440-43-9			0.0018	I	0.0005	I	0.00001	A		0.05	0.001	
Chromium, III	16065-83-1					1.5	I				0.013		
Chromium, hexavalent	18540-29-9	0.5	J	0.084	S	0.003	I	0.0001	I	M	0.025		
Cobalt	7440-48-4			0.009	P	0.0003	P	0.000006	P		1		
Copper	7440-50-8					0.04	H				1		
Iron	7439-89-6					0.7	P				1		
Lead	7439-92-1										1		
Lithium	7439-93-2					0.002	P				1		
Manganese (Diet)	7439-96-5					0.14	I	0.00005	I		1		
Manganese	7439-96-5					0.024	S	0.00005	I		0.04		
Mercury	7487-94-7					0.0003	I	0.0003	S		0.07		
Methyl Mercury	22967-92-6					0.0001	I				1		
Molybdenum	7439-98-7					0.005	I				1		
Nickel	7440-02-0			0.00026	C	0.02	I	0.00009	A		0.04		
Nitrate	14797-55-8					1.6	I				1		
Nitrate-Nitrite	NA										1		
Nitrite	14797-65-0					0.1	I				1		
Phosphates, Inorganic													
Acenaphthene	83-32-9					0.06	I				1	0.13	
Benz(a)anthracene	56-55-3	0.73	E	0.00011	C					M	1	0.13	
Benzo(j)fluoranthene	205-82-3	1.2	C	0.00011	C						1	0.13	
Benzo(a)pyrene	50-32-8	7.3	I	0.0011	C					M	1	0.13	
Benzo(b)fluoranthene	205-99-2	0.73	E	0.00011	C					M	1	0.13	
Benzo(k)fluoranthene	207-08-9	0.073	E	0.00011	C					M	1	0.13	
2-Chloronaphthalene	91-58-7					0.08	I				1	0.13	
Chrysene	218-01-9	0.0073	E	0.000011	C					M	1	0.13	
Dibenz(a,h)anthracene	53-70-3	7.3	E	0.0012	C					M	1	0.13	
Fluoranthene	206-44-0					0.04	I				1	0.13	
Fluorene	86-73-7					0.04	I				1	0.13	
Indeno(1,2,3-cd)pyrene	193-39-5	0.73	E	0.00011	C					M	1	0.13	
1-Methylnaphthalene	90-12-0	0.029	P			0.07	A				1	0.13	394
2-Methylnaphthalene	91-57-6					0.004	I				1	0.13	
Naphthalene	91-20-3			0.000034	C	0.02	I	0.003	I		1	0.13	
Pyrene	129-00-0					0.03	I				1	0.13	
Total PAHs	PAH	7.3		0.0011		0.03		0.003			1	0.13	
Selenium	7782-49-2					0.005	I	0.02	C		1		
Strontium	7440-24-6					0.6	I				1		
Thallium	7440-28-0					0.00001	X				1		
Vanadium	7440-62-2					0.005	S	0.0001	A		0.026		
Zinc	7440-66-6					0.3	I				1		

Notes:
Source: USEPA (2018a)

Abbreviations:
ABS – dermal absorption factor for soil uptake
Csat – soil saturation concentration
CSF – cancer slope factor
GIABS – gastrointestinal absorption factor
IUR – inhalation unit risk
RfD – noncancer reference dose
RfC – noncancer reference concentration

USEPA (2018a) Key Codes:
A – Agency for Toxic Substances and Disease Registry (ATSDR)
C – California EPA
I – Integrated Risk Information System (IRIS)
E – PAHs addressed with relative potency factors
H – Health Effects Summary Tables (HEAST)
P - PPRTV
S – refers to metal-specific information used to calculate toxicity value
X – thallium RfDs based on molecular weight; (USEPA (2018a), User's Guide, Section 5

Table 12. Noncancer Hazard and Cancer Risk for Recreational Visitors, All Data

Hazard Quotients - Recreational Visitor - Child									
Analyte Name	CAS No.	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways		Total HQ
		Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish Ingestion	Plant Ingestion	
Aluminum	7429-90-5	1.5E-02	No ABS	4.6E-07	3.00E-02	1.59E-03	2.3E-01	1.8E-02	3.0E-01
Antimony	7440-36-0	3.7E-03	No ABS	No RfC	1.58E-02	5.58E-03	5.4E-04	2.3E-01	2.6E-01
Arsenic	7440-38-2	1.02E+00	1.2E-01	5.4E-06	7.80E-01	4.13E-02	4.5E-01	2.0E+01	2.3E+01
Boron	7440-42-8	1.3E-03	No ABS	2.0E-09	3.14E-02	1.67E-03	NV	1.6E+00	1.6E+00
Cadmium	7440-43-9	1.17E-02	1.1E-03	1.9E-07	6.31E-03	6.70E-03	1.3E+00	9.7E-01	2.3E+00
Cobalt	7440-48-4	4.0E-01	No ABS	3.2E-06	2.52E-01	5.36E-03	NV	9.5E-01	1.6E+00
Hexavalent Chromium	18540-29-9	2.14E-03	No ABS	1.0E-08	4.84E-03	2.05E-02	4.9E-04	2.8E-02	5.6E-02
Iron	7439-89-6	4.5E-01	No ABS	No RfC	4.12E-01	2.18E-02	NV	5.6E-01	1.4E+00
Lead	7439-92-1	No RfD	No ABS	No RfC	No RfD	No RfD	No RfD	No RfD	0.0E+00
Lithium	7439-93-2	6.3E-03	No ABS	No RfC	3.95E-01	2.09E-02	NV	5.0E-02	4.7E-01
Manganese	7439-96-5	1.0E-02	No ABS	4.5E-06	2.48E-01	1.32E-02	NV	2.5E-01	5.2E-01
Mercury*	7487-94-7	1.0E-04	No ABS	1.6E-11	2.10E-03	1.59E-03	7.3E+00	2.9E-02	7.3E+00
Molybdenum	7439-98-7	3.5E-02	No ABS	No RfC	2.72E-02	1.44E-03	NV	2.7E+00	2.8E+00
Nickel	7440-02-0	5.3E-03	No ABS	1.9E-07	8.47E-03	2.25E-03	3.1E-02	9.9E-02	1.5E-01
PAHs (Total)*	PAH	1.4E-05	4.5E-06	2.3E-11	No Data	No Data	NA	1.9E-03	2.0E-03
Selenium	7782-49-2	1.5E-02	No ABS	6.0E-10	1.64E-03	8.71E-05	NV	3.6E+00	3.6E+00
Strontium	7440-24-6	5.6E-04	No ABS	No RfC	3.01E-02	1.60E-03	NV	4.4E-01	4.7E-01
Sulfate	14808-79-8	No RfD	No ABS	No RfC	No RfD	No RfD	No RfD	No RfD	0.0E+00
Thallium	7440-28-0	6.2E-02	No ABS	No RfC	3.16E-01	1.67E-02	3.6E-01	7.7E-02	8.4E-01
Vanadium	7440-62-2	1.4E-02	No ABS	1.1E-07	2.29E+01	4.68E+01	2.2E+01	2.5E-02	9.1E+01
Total HI									1.4E+02

Hazard Quotients - Recreational Visitor - Adult									
Analyte Name	CAS No.	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways		Total HQ
		Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish Ingestion	Plant Ingestion	
		(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	2.07E-03	No ABS	1.2E-06	8.31E-03	2.30E-03	1.6E-01	5.8E-03	1.8E-01
Antimony	7440-36-0	5.23E-04	No ABS	No RfC	4.38E-03	8.08E-03	3.7E-04	7.3E-02	8.6E-02
Arsenic	7440-38-2	1.44E-01	3.04E-02	1.35E-05	2.16E-01	5.98E-02	3.1E-01	6.3E+00	7.0E+00
Boron	7440-42-8	1.78E-04	No ABS	5.0E-09	8.71E-03	2.41E-03	NV	4.9E-01	5.1E-01
Cadmium	7440-43-9	1.65E-03	2.79E-04	4.64E-07	1.75E-03	9.69E-03	9.3E-01	3.0E-01	1.2E+00
Cobalt	7440-48-4	5.68E-02	No ABS	8.0E-06	7.00E-02	7.75E-03	NV	3.0E-01	4.3E-01
Hexavalent Chromium	18540-29-9	3.01E-04	No ABS	2.5E-08	1.34E-03	2.97E-02	3.4E-04	8.6E-03	4.0E-02
Iron	7439-89-6	6.27E-02	No ABS	No RfC	1.14E-01	3.16E-02	NV	1.7E-01	3.8E-01
Lead	7439-92-1	No RfD	No ABS	No RfC	No RfD	NA	No RfD	No RfD	0.0E+00
Lithium	7439-93-2	8.89E-04	No ABS	No RfC	1.09E-01	3.03E-02	NV	1.5E-02	1.6E-01
Manganese	7439-96-5	1.42E-03	No ABS	1.1E-05	6.88E-02	1.90E-02	NV	7.8E-02	1.7E-01
Mercury*	7487-94-7	1.46E-05	No ABS	4.1E-11	5.84E-04	2.31E-03	5.1E+00	9.2E-03	5.1E+00
Molybdenum	7439-98-7	4.86E-03	No ABS	No RfC	7.55E-03	2.09E-03	NV	8.5E-01	8.6E-01
Nickel	7440-02-0	7.42E-04	No ABS	4.6E-07	2.35E-03	3.25E-03	2.1E-02	3.1E-02	5.9E-02
PAHs (Total)*	PAH	2.03E-06	1.1E-06	5.7E-11	No Data	No Data	No Data	6.0E-04	6.1E-04
Selenium	7782-49-2	2.14E-03	No ABS	1.5E-09	4.55E-04	1.26E-04	NV	1.1E+00	1.1E+00
Strontium	7440-24-6	7.89E-05	No ABS	No RfC	8.36E-03	2.31E-03	NV	1.4E-01	1.5E-01
Sulfate	14808-79-8	No RfD	No ABS	No RfC	No RfD	No RfD	No RfD	No RfD	0.0E+00
Thallium	7440-28-0	8.68E-03	No ABS	No RfC	8.75E-02	2.42E-02	2.5E-01	2.4E-02	4.0E-01
Vanadium	7440-62-2	2.00E-03	No ABS	2.8E-07	6.36E+00	6.77E+01	1.5E+01	7.6E-03	8.9E+01
Total HI									1.1E+02

Notes
** - Carried forward as a bioaccumulative contaminant of concern (BCC)*
No ABS – Dermal absorption factor unavailable
No Data – Analytical data unavailable
No RfD – Noncancer reference dose unavailable
No RfC – Noncancer reference concentration is unavailable
NV – No value because a bioconcentration factor is unavailable

Table 12. Noncancer Hazard and Cancer Risk for Recreational Visitors, All Data, cont.

Cancer Risk - Recreational Visitor - Child									
Analyte Name	CAS No.	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways		Total Cancer Risk
		Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish Ingestion	Plant Ingestion	
Aluminum	7429-90-5	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Antimony	7440-36-0	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Arsenic	7440-38-2	4.48E-05	7.03E-06	1.99E-11	4.78E-05	8.84E-06	1.2E-05	5.2E-04	6.4E-04
Boron	7440-42-8	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Cadmium	7440-43-9	No CSF	No CSF	1.9E-13	No CSF	No CSF	No CSF	No CSF	1.9E-13
Cobalt	7440-48-4	No CSF	No CSF	9.9E-12	No CSF	No CSF	No CSF	No CSF	9.9E-12
Hexavalent Chromium	18540-29-9	8.1E-07	No ABS	1.4E-10	2.39E-06	3.20E-05	4.2E-08	2.4E-06	3.8E-05
Iron	7439-89-6	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Lead	7439-92-1	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Lithium	7439-93-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Manganese	7439-96-5	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Mercury*	7487-94-7	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Molybdenum	7439-98-7	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Nickel	7440-02-0	No CSF	No CSF	2.5E-13	No CSF	No CSF	No CSF	No CSF	2.5E-13
PAHs (Total)*	PAH	3.1E-07	1.3E-07	4.3E-15	No Data	No Data	No Data	2.4E-05	2.5E-05
Selenium	7782-49-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Strontium	7440-24-6	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Sulfate	14808-79-8	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Thallium	7440-28-0	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Vanadium	7440-62-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Cumulative Cancer Risk									7.0E-04

Cancer Risk - Recreational Visitor - Adult									
Analyte Name	CAS No.	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways		Total Cancer Risk
		Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish Ingestion	Plant Ingestion	
Aluminum	7429-90-5	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Antimony	7440-36-0	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Arsenic	7440-38-2	1.9E-05	3.9E-06	2.5E-10	2.78E-05	7.69E-06	4.0E-05	8.1E-04	9.1E-04
Boron	7440-42-8	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Cadmium	7440-43-9	No CSF	No CSF	2.4E-12	No CSF	No CSF	No CSF	No CSF	2.4E-12
Cobalt	7440-48-4	No CSF	No CSF	1.2E-10	No CSF	No CSF	No CSF	No CSF	1.2E-10
Hexavalent Chromium	18540-29-9	1.3E-07	No ABS	6.1E-11	5.75E-07	1.27E-05	1.5E-07	3.7E-06	1.7E-05
Iron	7439-89-6	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Lead	7439-92-1	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Lithium	7439-93-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Manganese	7439-96-5	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Mercury*	7487-94-7	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Molybdenum	7439-98-7	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Nickel	7440-02-0	No CSF	No CSF	3.1E-12	No CSF	No CSF	No CSF	No CSF	3.1E-12
PAHs (Total)*	PAH	1.3E-07	7.0E-08	5.4E-14	No Data	No Data	No Data	3.8E-05	3.8E-05
Selenium	7782-49-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Strontium	7440-24-6	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Sulfate	14808-79-8	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Thallium	7440-28-0	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Vanadium	7440-62-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Cumulative Cancer Risk									9.6E-04

Notes:
** - Carried forward as a bioaccumulative contaminant of concern (BCC)*
No ABS – Dermal absorption factor unavailable
No CSF – Cancer slope factor unavailable
No IUR – Cancer inhalation unit risk factor is unavailable
No Data – Analytical data unavailable

The cancer risk indicates that there are more excess cancers predicted to occur due to exposure to site-related contaminants. The target cancer risk is 1 excess cancer per 1 million people. The risk management range EPA uses for Superfund projects is $1x10^{-6}$ to $1x10^{-4}$ (i.e., 1 excess cancer per 1 million people up to 1 excess cancer per 10,000 people). The cancer risks here of $7x10^{-4}$ to $9.6x10^{-4}$ (i.e., 7 to nearly 10 excess cancers per 10,000 people) exceed the target of 1 excess cancer per 1 million people, and also exceed the upper-bound of the risk management range for Superfund projects.

These risks suggest that the coal ash ponds at Chesterfield need remediation to stop the flow of coal ash contamination offsite into the Dutch Gap Conservation Area.

The EPCs used in the risk assessment were the maximum detected value or maximum reporting limit, whichever was higher. This was considered conservative given the small data set available. The noncancer hazard and cancer risks can also be presented on the basis of detected values only. This would result in changes to the EPCs for boron, hexavalent chromium, lead, and selenium in sediment, and to the EPCs for antimony, cadmium, lithium, mercury, and thallium for surface water. Making these changes reduces predicted noncancer hazard or cancer risk for these contaminants. Table 13 presents the noncancer hazard and the cancer intakes on the basis of detected data only. The noncancer hazard and cancer risks based on detected data only are presented in Table 14.

Noncancer Hazard

The highest total HQ was 91 for the child recreational visitor for vanadium for exposure to surface water and for fish ingestion. The total HQ for arsenic was 23 based primarily on sediment and plant ingestion. The HQs for boron, molybdenum, and selenium exceeded 1 for ingestion of plants contaminated by uptake from sediments. Cadmium and mercury HQs exceeded 1 for fish ingestion. Total HQs for cobalt and iron exceeded 1 although none of the pathway-specific HQs exceeded 1. The HI for the child was **140** (Table 12). When only detected data were used (Table 14), the HI was slightly lower at 120.

The highest total HQ was 89 for the adult recreational visitor for vanadium for exposure to surface water and ingestion of fish contaminated by uptake from surface water. The HQ for arsenic was 7 based primarily on plant ingestion. The total HQ for cadmium exceeded 1 although pathway-specific HQs did not exceed 1. The total HQs for mercury and selenium exceeded 1 for ingestion of fish and plants, respectively. The HI was **110** (Table 12). When only detected data were used (Table 14), the HI was slightly lower at 100.

Noncancer hazard was elevated for arsenic, boron, molybdenum, and selenium for exposure pathways associated with sediment. Arsenic and molybdenum EPCs were based on detected values, but although boron and selenium were detected in sediment samples, the maximum values used as the EPCs were reporting limits (nondetected values). Cadmium, mercury, and vanadium were detected in surface water, but EPCs for cadmium and mercury were based on reporting limits in Table 12 since these were the maxima. The EPCs for cobalt and iron were based on detected values in Table 12. All results in Table 14 were based on detected values, although this eliminated evaluation of some contaminants with reporting limits in excess of screening levels.

Cancer Risk

The highest total CR was $6x10^{-4}$ for the child recreational visitor for arsenic based on ingestion of plants contaminated by uptake from sediments. However, all exposure pathways had CRs for arsenic above the target level of $1x10^{-6}$. The CRs for hexavalent chromium exceeded $1x10^{-6}$ for surface water ingestion and dermal contact and ingestion of plants, and the CRs for PAHs exceeded $1x10^{-6}$ for ingestion of plants. The cumulative cancer risk was $\mathbf{7x10^{-4}}$ (Table 12). Plants were modeled as contaminated by uptake from sediments. When only detected data were used (Table 14), the cumulative cancer risk was the same ($\mathbf{7x10^{-4}}$, Table 14).

The highest total CR was $9.6x10^{-4}$ for the adult recreational visitor for arsenic based on ingestion of plants contaminated by uptake from sediments. However, all exposure pathways had CRs for arsenic above the

Table 13. Noncancer and Cancer Intakes, Detected Data Only

Noncarcinogenic Intake - Recreational Visitor - Child

Analyte Name	CAS No.	Sediment EPC	Surface Water EPC	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways						Total Intake
				Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish BCF	Cfish	Fish Ingestion	Plant BAF	Cplant	Plant Ingestion	
		(mg/kg)	(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/m^3)	(mg/kg-d)	(mg/kg-d)	(L/kg)	(mg/kg dwb)	(mg/kg-d)		(mg/kg dwb)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	8380	9.49	1.47E-02	No ABS	2.32E-09	3.00E-02	1.59E-03	231a	2.19E+03	2.35E-01	0.004a	3.35E+01	1.84E-02	3.00E-01
Antimony	7440-36-0	0.849	*0.000851*	1.49E-06	No ABS	2.35E-13	2.69E-06	1.42E-07	1a	8.51E-04	9.12E-08	0.2a	1.70E-01	9.35E-05	9.79E-05
Arsenic	7440-38-2	292	0.0741	5.12E-04	3.64E-05	8.09E-11	2.34E-04	1.24E-05	17a	1.26E+00	1.35E-04	0.03752b	1.10E+01	6.03E-03	6.96E-03
Boron	7440-42-8	*46.2*	1.99	8.10E-05	No ABS	1.28E-11	6.28E-03	3.33E-04	No BCF	NV	NV	4a	1.85E+02	1.02E-01	1.08E-01
Cadmium	7440-43-9	6.7	*0.00036*	1.17E-05	2.79E-08	1.86E-12	1.14E-06	6.03E-08	12400a	4.46E+00	4.78E-04	=EXP(0.546*LN(Csed)-0.475)b	1.76E+00	9.67E-04	1.46E-03
Cobalt	7440-48-4	69.1	0.024	1.21E-04	No ABS	1.92E-11	7.57E-05	1.61E-06	No BCF	NV	NV	0.0075b	5.18E-01	2.85E-04	4.84E-04
Chromium, Hexavalent	18540-29-9	*0.00*	0.0046	0.00E+00	No ABS	0.00E+00	1.45E-05	1.54E-06	3a	1.38E-02	1.48E-06	0.041b	0.00E+00	0.00E+00	1.75E-05
Iron	7439-89-6	178000	91.3	3.12E-01	No ABS	4.93E-08	2.88E-01	1.53E-02	No BCF	NV	NV	0.004a	7.12E+02	3.92E-01	1.01E+00
Lead	7439-92-1	*15.9*	0.0163	2.79E-05	No ABS	4.41E-12	5.14E-05	2.73E-07	45a	7.34E-01	7.86E-05	=EXP(0.561*LN(Csed)-1.328)b	1.25E+00	6.88E-04	8.47E-04
Lithium	7439-93-2	7.21	*0.22*	1.26E-05	No ABS	2.00E-12	6.94E-04	3.68E-05	No BCF	NV	NV	0.025a	1.80E-01	9.92E-05	8.43E-04
Manganese	7439-96-5	807	11	1.42E-03	No ABS	2.24E-10	3.47E-02	1.84E-03	No BCF	NV	NV	0.079b	6.38E+01	3.51E-02	7.31E-02
Mercury*	7487-94-7	0.0178	*0*	3.12E-08	No ABS	4.93E-15	0.00E+00	0.00E+00	101658c	0.00E+00	0.00E+00	0.9a	1.60E-02	8.82E-06	8.85E-06
Molybdenum	7439-98-7	98.6	0.0431	1.73E-04	No ABS	2.73E-11	1.36E-04	7.22E-06	No BCF	NV	NV	0.25a	2.47E+01	1.36E-02	1.39E-02
Nickel	7440-02-0	60.2	0.0537	1.06E-04	No ABS	1.67E-11	1.69E-04	1.80E-06	106a	5.69E+00	6.10E-04	0.06a	3.61E+00	1.99E-03	2.87E-03
PAHs (Total)	PAH	0.247	No Data	4.33E-07	1.34E-07	6.85E-14	No Data	No Data	No Data	No Data	NA	=EXP(0.7912*LN(Csed)-1.1442)b	1.05E-01	5.80E-05	5.86E-05
Selenium	7782-49-2	*3.8*	0.0026	6.66E-06	No ABS	1.05E-12	8.21E-06	4.35E-07	No BCF	NV	NV	=EXP(1.104*LN(Csed)-0.677)b	2.22E+00	1.22E-03	1.24E-03
Strontium	7440-24-6	192	5.73	3.37E-04	No ABS	5.32E-11	1.81E-02	9.59E-04	No BCF	NV	NV	2.5a	4.80E+02	2.64E-01	2.84E-01
Sulfate	14808-79-8	616	594	1.08E-03	No ABS	1.71E-10	1.87E+00	0.00E+00	No BCF	NV	NV	1.5a	9.24E+02	5.09E-01	2.38E+00
Thallium	7440-28-0	0.352	*0*	6.17E-07	No ABS	9.76E-14	0.00E+00	0.00E+00	34a	0.00E+00	0.00E+00	0.004a	1.41E-03	7.75E-07	1.39E-06
Vanadium	7440-62-2	40.8	36.6	7.15E-05	No ABS	1.13E-11	1.16E-01	6.13E-03	27.9d	1.02E+03	1.09E-01	0.0055a	2.24E-01	1.23E-04	2.31E-01

Noncarcinogenic Intake - Recreational Visitor - Adult

Analyte Name	CAS No.	Sediment EPC	Surface Water EPC	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways						Total Intake
				Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish BCF	C_{fish}	Fish Ingestion	Plant BAF	C_{Plant}	Plant Ingestion	
		(mg/kg)	(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(L/kg)	(mg/kg dwb)	(mg/kg-d)		(mg/kg)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	8380	9.49	2.07E-03	No ABS	5.81E-09	8.31E-03	2.30E-03	231[a]	2.19E+03	1.64E-01	0.004[a]	3.35E+01	5.76E-03	1.83E-01
Antimony	7440-36-0	0.849	*0.000851*	2.09E-07	No ABS	5.88E-13	7.45E-07	2.06E-07	1[a]	8.51E-04	6.38E-08	0.2[a]	1.70E-01	2.92E-05	3.04E-05
Arsenic	7440-38-2	292	0.0741	7.20E-05	9.12E-06	2.02E-10	6.49E-05	1.80E-05	17[a]	1.26E+00	9.44E-05	0.03752[b]	1.10E+01	1.88E-03	2.14E-03
Boron	7440-42-8	*46.2*	1.99	1.14E-05	No ABS	3.20E-11	1.74E-03	4.82E-04	No BCF	NV	NV	4[a]	1.85E+02	3.18E-02	3.40E-02
Cadmium	7440-43-9	6.7	*0.00036*	1.65E-06	6.98E-09	4.64E-12	3.15E-07	8.72E-08	12400[a]	4.46E+00	3.35E-04	=EXP(0.546*LN(Csed)-0.475)[b]	1.76E+00	3.02E-04	6.39E-04
Cobalt	7440-48-4	69.1	0.024	1.70E-05	No ABS	4.79E-11	2.10E-05	2.33E-06	No BCF	NV	NV	0.0075[b]	5.18E-01	8.90E-05	1.29E-04
Hexavalent Chromium	18540-29-9	*0*	0.0046	0.00E+00	No ABS	0.00E+00	4.03E-06	2.23E-06	3[a]	1.38E-02	1.03E-06	0.041[b]	0.00E+00	0.00E+00	7.29E-06
Iron	7439-89-6	178000	91.3	4.39E-02	No ABS	1.23E-07	7.99E-02	2.21E-02	No BCF	NV	NV	0.004[a]	7.12E+02	1.22E-01	2.68E-01
Lead	7439-92-1	*15.9*	0.0163	NA	No ABS	1.10E-11	1.43E-05	3.95E-07	45[a]	7.34E-01	5.50E-05	=EXP(0.561*LN(Csed)-1.328)[b]	1.25E+00	2.15E-04	2.85E-04
Lithium	7439-93-2	7.21	*0.22*	1.78E-06	No ABS	5.00E-12	1.93E-04	5.33E-05	No BCF	NV	NV	0.025[a]	1.80E-01	3.10E-05	2.79E-04
Manganese	7439-96-5	807	11	1.99E-04	No ABS	5.59E-10	9.63E-03	2.67E-03	No BCF	NV	NV	0.079[b]	6.38E+01	1.10E-02	2.34E-02
Mercury*	7487-94-7	0.0178	*0*	4.39E-09	No ABS	1.23E-14	0.00E+00	0.00E+00	101658[c]	0.00E+00	0.00E+00	0.9[a]	1.60E-02	2.75E-06	2.76E-06
Molybdenum	7439-98-7	98.6	0.0431	2.43E-05	No ABS	6.83E-11	3.77E-05	1.04E-05	No BCF	NV	NV	0.25[a]	2.47E+01	4.24E-03	4.31E-03
Nickel	7440-02-0	60.2	0.0537	1.48E-05	No ABS	4.17E-11	4.70E-05	2.60E-06	106[a]	5.69E+00	4.27E-04	0.06[a]	3.61E+00	6.21E-04	1.11E-03
PAHs (Total)*	PAH	0.247	No Data	6.09E-08	3.35E-08	1.71E-13	No Data	No Data	No Data	No Data	No Data	=EXP(0.7912*LN(Csed)-1.1442)[b]	1.05E-01	1.81E-05	1.82E-05
Selenium	7782-49-2	*3.8*	0.0026	9.37E-07	No ABS	2.63E-12	2.28E-06	6.30E-07	No BCF	NV	NV	=EXP(1.104*LN(Csed)-0.677)[b]	2.22E+00	3.81E-04	3.85E-04
Strontium	7440-24-6	192	5.73	4.73E-05	No ABS	1.33E-10	5.02E-03	1.39E-03	No BCF	NV	NV	2.5[a]	4.80E+02	8.25E-02	8.89E-02
Sulfate	14808-79-8	616	594	1.52E-04	No ABS	4.27E-10	5.20E-01	0.00E+00	No BCF	NV	NV	1.5[a]	9.24E+02	1.59E-01	6.79E-01
Thallium	7440-28-0	0.352	*0*	8.68E-08	No ABS	2.44E-13	0.00E+00	0.00E+00	34[a]	0.00E+00	0.00E+00	0.004[a]	1.41E-03	2.42E-07	3.29E-07
Vanadium	7440-62-2	40.8	36.6	1.01E-05	No ABS	2.83E-11	3.20E-02	8.87E-03	27.9[d]	1.02E+03	7.65E-02	0.0055[a]	2.24E-01	3.86E-05	1.17E-01

Table 13. Noncancer and Cancer Intakes, Detected Data Only, Cont.

Carcinogenic Intake - Recreational Visitor - Child															
Analyte Name	CAS No.	Sediment EPC	Surface Water EPC	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways						Total Intake
				Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish BCF	C_{fish}	Fish Ingestion	Plant BAF	C_{plant}	Plant Ingestion	
		(mg/kg)	(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/m^3)	(mg/kg-d)	(mg/kg-d)	(L/kg)	(mg/kg dwb)	(mg/kg-d)		(mg/kg dwb)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	8380	9.49	1.43E-03	No ABS	1.33E-10	4.08E-03	7.54E-04	231[a]	2.19E+03	1.34E-02	0.004[a]	3.35E+01	1.05E-03	2.07E-02
Antimony	7440-36-0	0.849	***0.000851***	1.45E-07	No ABS	1.34E-14	3.66E-07	6.76E-08	1[a]	8.51E-04	5.21E-09	0.2[a]	1.70E-01	5.34E-06	5.92E-06
Arsenic	7440-38-2	292	0.0741	4.98E-05	4.69E-06	4.63E-12	3.19E-05	5.89E-06	17[a]	1.26E+00	7.71E-06	0.03752[b]	1.10E+01	3.45E-04	4.45E-04
Boron	7440-42-8	***46.2***	1.99	7.88E-06	No ABS	7.32E-13	8.57E-04	1.58E-04	No BCF	NV	NV	4[a]	1.85E+02	5.81E-03	6.83E-03
Cadmium	7440-43-9	6.7	***0.00036***	1.14E-06	3.59E-09	1.06E-13	1.55E-07	2.86E-08	12400[a]	4.46E+00	2.73E-05	=EXP(0.546*LN(Csed)-0.475)[b]	1.76E+00	5.53E-05	8.39E-05
Cobalt	7440-48-4	69.1	0.024	1.18E-05	No ABS	1.09E-12	1.03E-05	7.63E-07	No BCF	NV	NV	0.0075[b]	5.18E-01	1.63E-05	3.92E-05
Hexavalent Chromium	18540-29-9	***0***	0.0046	0.00E+00	No ABS	0.00E+00	4.79E-06	1.60E-06	3[a]	1.38E-02	8.45E-08	0.041[b]	0.00E+00	0.00E+00	6.47E-06
Iron	7439-89-6	178000	91.3	3.04E-02	No ABS	2.82E-09	3.93E-02	7.26E-03	No BCF	NV	NV	0.004[a]	7.12E+02	2.24E-02	9.93E-02
Lead	7439-92-1	***15.9***	0.0163	2.71E-06	No ABS	2.52E-13	7.02E-06	1.30E-07	45[a]	7.34E-01	4.49E-06	=EXP(0.561*LN(Csed)-1.328)[b]	1.25E+00	3.93E-05	5.37E-05
Lithium	7439-93-2	7.21	***0.22***	1.23E-06	No ABS	1.14E-13	9.47E-05	1.75E-05	No BCF	NV	NV	0.025[a]	1.80E-01	5.67E-06	1.19E-04
Manganese	7439-96-5	807	11	1.38E-04	No ABS	1.28E-11	4.73E-03	8.74E-04	No BCF	NV	NV	0.079[b]	6.38E+01	2.00E-03	7.75E-03
Mercury*	7487-94-7	0.0178	***0***	3.04E-09	No ABS	2.82E-16	0.00E+00	0.00E+00	101658[c]	0.00E+00	0.00E+00	0.9[a]	1.60E-02	5.04E-07	5.07E-07
Molybdenum	7439-98-7	98.6	0.0431	1.68E-05	No ABS	1.56E-12	1.86E-05	3.43E-06	No BCF	NV	NV	0.25[a]	2.47E+01	7.75E-04	8.14E-04
Nickel	7440-02-0	60.2	0.0537	1.03E-05	No ABS	9.54E-13	2.31E-05	8.54E-07	106[a]	5.69E+00	3.49E-05	0.06[a]	3.61E+00	1.14E-04	1.83E-04
PAHs (Total)*	PAH	0.247	No Data	4.22E-08	1.72E-08	3.91E-15	No Data	No Data	No Data	No Data	No Data	=EXP(0.7912*LN(Csed)-1.1442)[b]	1.05E-01	3.31E-06	3.37E-06
Selenium	7782-49-2	***3.8***	0.0026	6.48E-07	No ABS	6.02E-14	1.12E-06	2.07E-07	No BCF	NV	NV	=EXP(1.104*LN(Csed)-0.677)[b]	2.22E+00	6.98E-05	7.17E-05
Strontium	7440-24-6	192	5.73	3.28E-05	No ABS	3.04E-12	2.47E-03	4.55E-04	No BCF	NV	NV	2.5[a]	4.80E+02	1.51E-02	1.81E-02
Sulfate	14808-79-8	616	594	1.05E-04	No ABS	9.76E-12	2.56E-01	0.00E+00	No BCF	NV	NV	1.5[a]	9.24E+02	2.91E-02	2.85E-01
Thallium	7440-28-0	0.352	***0***	6.01E-08	No ABS	5.58E-15	0.00E+00	0.00E+00	34[a]	0.00E+00	0.00E+00	0.004[a]	1.41E-03	4.43E-08	1.04E-07
Vanadium	7440-62-2	40.8	36.6	6.96E-06	No ABS	6.46E-13	1.58E-02	2.91E-03	27.9[d]	1.02E+03	6.25E-03	0.0055[a]	2.24E-01	7.06E-06	2.49E-02

Carcinogenic Intake - Recreational Visitor - Adult															
Analyte Name	CAS No.	Sediment EPC	Surface Water EPC	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways						Total Intake
				Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish BCF	C_{fish}	Fish Ingestion	Plant BAF	C_{Plant}	Plant Ingestion	
		(mg/kg)	(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(L/kg)	(mg/kg dwb)	(mg/kg-d)		(mg/kg)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	8380	9.49	5.90E-04	No ABS	1.66E-09	2.37E-03	6.57E-04	231[a]	2.19E+03	4.69E-02	0.004[a]	3.35E+01	1.65E-03	5.22E-02
Antimony	7440-36-0	0.849	***0.000851***	5.98E-08	No ABS	1.68E-13	2.13E-07	5.89E-08	1[a]	8.51E-04	1.82E-08	0.2[a]	1.70E-01	8.34E-06	8.69E-06
Arsenic	7440-38-2	292	0.0741	2.06E-05	2.61E-06	5.78E-11	1.85E-05	5.13E-06	17[a]	1.26E+00	2.70E-05	0.03752[b]	1.10E+01	5.38E-04	6.12E-04
Boron	7440-42-8	***46.2***	1.99	3.25E-06	No ABS	9.15E-12	4.98E-04	1.38E-04	No BCF	NV	NV	4[a]	1.85E+02	9.07E-03	9.71E-03
Cadmium	7440-43-9	6.7	***0.00036***	4.72E-07	1.99E-09	1.33E-12	9.00E-08	2.49E-08	12400[a]	4.46E+00	9.56E-05	=EXP(0.546*LN(Csed)-0.475)[b]	1.76E+00	8.62E-05	1.82E-04
Cobalt	7440-48-4	69.1	0.024	4.87E-06	No ABS	1.37E-11	6.00E-06	6.65E-07	No BCF	NV	NV	0.0075[b]	5.18E-01	2.54E-05	3.70E-05
Hexavalent Chromium	18540-29-9	***0***	0.0046	0.00E+00	No ABS	0.00E+00	1.15E-06	6.37E-07	3[a]	1.38E-02	2.96E-07	0.041[b]	0.00E+00	0.00E+00	2.08E-06
Iron	7439-89-6	178000	91.3	1.25E-02	No ABS	3.52E-08	2.28E-02	6.32E-03	No BCF	NV	NV	0.004[a]	7.12E+02	3.50E-02	7.66E-02
Lead	7439-92-1	***15.9***	0.0163	1.12E-06	No ABS	3.15E-12	4.08E-06	1.13E-07	45[a]	7.34E-01	1.57E-05	=EXP(0.561*LN(Csed)-1.328)[b]	1.25E+00	6.14E-05	8.24E-05
Lithium	7439-93-2	7.21	***0.22***	5.08E-07	No ABS	1.43E-12	5.50E-05	1.52E-05	No BCF	NV	NV	0.025[a]	1.80E-01	8.85E-06	7.96E-05
Manganese	7439-96-5	807	11	5.69E-05	No ABS	1.60E-10	2.75E-03	7.61E-04	No BCF	NV	NV	0.079[b]	6.38E+01	3.13E-03	6.70E-03
Mercury*	7487-94-7	0.0178	***0***	1.25E-09	No ABS	3.52E-15	0.00E+00	0.00E+00	101658[c]	0.00E+00	0.00E+00	0.9[a]	1.60E-02	7.86E-07	7.88E-07
Molybdenum	7439-98-7	98.6	0.0431	6.95E-06	No ABS	1.95E-11	1.08E-05	2.98E-06	No BCF	NV	NV	0.25[a]	2.47E+01	1.21E-03	1.23E-03
Nickel	7440-02-0	60.2	0.0537	4.24E-06	No ABS	1.19E-11	1.34E-05	7.43E-07	106[a]	5.69E+00	1.22E-04	0.06[a]	3.61E+00	1.77E-04	3.18E-04
PAHs (Total)*	PAH	0.247	No Data	1.74E-08	9.56E-09	4.89E-14	No Data	No Data	No Data	No Data	No Data	=EXP(0.7912*LN(Csed)-1.1442)[b]	1.05E-01	5.17E-06	5.20E-06
Selenium	7782-49-2	***3.8***	0.0026	2.68E-07	No ABS	7.52E-13	6.50E-07	1.80E-07	No BCF	NV	NV	=EXP(1.104*LN(Csed)-0.677)[b]	2.22E+00	1.09E-04	1.10E-04
Strontium	7440-24-6	192	5.73	1.35E-05	No ABS	3.80E-11	1.43E-03	3.97E-04	No BCF	NV	NV	2.5[a]	4.80E+02	2.36E-02	2.54E-02
Sulfate	14808-79-8	616	594	4.34E-05	No ABS	1.22E-10	1.49E-01	0.00E+00	No BCF	NV	NV	1.5[a]	9.24E+02	4.54E-02	1.94E-01
Thallium	7440-28-0	0.352	***0***	2.48E-08	No ABS	6.97E-14	0.00E+00	0.00E+00	34[a]	0.00E+00	0.00E+00	0.004[a]	1.41E-03	6.91E-08	9.39E-08
Vanadium	7440-62-2	40.8	36.6	2.87E-06	No ABS	8.08E-12	9.15E-03	2.53E-03	27.9[d]	1.02E+03	2.19E-02	0.0055[a]	2.24E-01	1.10E-05	3.36E-02

Notes:

Red Bold italics - EPC is the maximum detected value, or zero where no detections occurred
EPC - Exposure point concentration
Csed - Sediment EPC
Cplant - Plant concentration
BAF - Bioaccumulation factor
BCF - Bioconcentration factor

a - BAF from ORNL (Plants - Baes et al. 1984; Fish - Toxicological Benchmarksfor Wildlife:1996 Revision)
b- BAF from EcoSSL Attachment 4-1 (USEPA 2005)
** - Carried forward as a bioaccumulative contaminant of concern (BCC)*
c - Ecotox Database, Mercury,Goldfish, at 1789 days, reference 48. Striped bass, HgCl2 BCF 7600 at 1 d
d - Ecotox Database, Vanadium oxide, flagfish,at 96 days, reference 15775

Table 14. Hazard Quotients and Cancer Risks for Recreational Visitors, Detected Data Only

Hazard Quotients - Recreational Visitor - Child									
Analyte Name	CAS No.	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways		Total HQ
		Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish Ingestion	Plant Ingestion	
Aluminum	7429-90-5	1.5E-02	No ABS	4.6E-07	3.00E-02	1.59E-03	2.3E-01	1.8E-02	3.0E-01
Antimony	7440-36-0	3.7E-03	No ABS	No RfC	6.71E-03	2.37E-03	2.3E-04	2.3E-01	2.5E-01
Arsenic	7440-38-2	1.02E+00	1.2E-01	5.4E-06	7.80E-01	4.13E-02	4.5E-01	2.0E+01	2.3E+01
Boron	7440-42-8	4.1E-04	No ABS	6.4E-10	3.14E-02	1.67E-03	NV	5.1E-01	5.4E-01
Cadmium	7440-43-9	1.17E-02	1.1E-03	1.9E-07	2.27E-03	2.41E-03	4.8E-01	9.7E-01	1.5E+00
Cobalt	7440-48-4	4.0E-01	No ABS	3.2E-06	2.52E-01	5.36E-03	NV	9.5E-01	1.6E+00
Hexavalent Chromium	18540-29-9	0.00E+00	No ABS	0.0E+00	4.84E-03	2.05E-02	4.9E-04	0.0E+00	2.6E-02
Iron	7439-89-6	4.5E-01	No ABS	No RfC	4.12E-01	2.18E-02	NV	5.6E-01	1.4E+00
Lead	7439-92-1	No RfD	No ABS	No RfC	No RfD	No RfD	No RfD	No RfD	0.0E+00
Lithium	7439-93-2	6.3E-03	No ABS	No RfC	3.47E-01	1.84E-02	NV	5.0E-02	4.2E-01
Manganese	7439-96-5	1.0E-02	No ABS	4.5E-06	2.48E-01	1.32E-02	NV	2.5E-01	5.2E-01
Mercury*	7487-94-7	1.0E-04	No ABS	1.6E-11	0.00E+00	0.00E+00	0.0E+00	2.9E-02	2.9E-02
Molybdenum	7439-98-7	3.5E-02	No ABS	No RfC	2.72E-02	1.44E-03	NV	2.7E+00	2.8E+00
Nickel	7440-02-0	5.3E-03	No ABS	1.9E-07	8.47E-03	2.25E-03	3.1E-02	9.9E-02	1.5E-01
PAHs (Total)*	PAH	1.4E-05	4.5E-06	2.3E-11	No Data	No Data	NA	1.9E-03	2.0E-03
Selenium	7782-49-2	1.3E-03	No ABS	5.3E-11	1.64E-03	8.71E-05	NV	2.4E-01	2.5E-01
Strontium	7440-24-6	5.6E-04	No ABS	No RfC	3.01E-02	1.60E-03	NV	4.4E-01	4.7E-01
Sulfate	14808-79-8	No RfD	No ABS	No RfC	No RfD	No RfD	No RfD	No RfD	0.0E+00
Thallium	7440-28-0	6.2E-02	No ABS	No RfC	0.00E+00	0.00E+00	0.0E+00	7.7E-02	1.4E-01
Vanadium	7440-62-2	1.4E-02	No ABS	1.1E-07	2.29E+01	4.68E+01	2.2E+01	2.5E-02	9.1E+01
Total HI									1.2E+02

Table 14. Hazard Quotients and Cancer Risks for Recreational Visitors, Detected Data Only, Cont.

Hazard Quotients - Recreational Visitor - Adult									
Analyte Name	CAS No.	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways		Total HQ
		Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish Ingestion	Plant Ingestion	
		(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Aluminum	7429-90-5	2.07E-03	No ABS	1.2E-06	8.31E-03	2.30E-03	1.6E-01	5.8E-03	1.8E-01
Antimony	7440-36-0	5.23E-04	No ABS	No RfC	1.86E-03	3.44E-03	1.6E-04	7.3E-02	7.9E-02
Arsenic	7440-38-2	1.44E-01	3.04E-02	1.35E-05	2.16E-01	5.98E-02	3.1E-01	6.3E+00	7.0E+00
Boron	7440-42-8	5.70E-05	No ABS	1.6E-09	8.71E-03	2.41E-03	NV	1.6E-01	1.7E-01
Cadmium	7440-43-9	1.65E-03	2.79E-04	4.64E-07	6.30E-04	3.49E-03	3.3E-01	3.0E-01	6.4E-01
Cobalt	7440-48-4	5.68E-02	No ABS	8.0E-06	7.00E-02	7.75E-03	NV	3.0E-01	4.3E-01
Hexavalent Chromium	18540-29-9	0.00E+00	No ABS	0.0E+00	1.34E-03	2.97E-02	3.4E-04	0.0E+00	3.1E-02
Iron	7439-89-6	6.27E-02	No ABS	No RfC	1.14E-01	3.16E-02	NV	1.7E-01	3.8E-01
Lead	7439-92-1	No RfD	No ABS	No RfC	No RfD	NA	No RfD	No RfD	0.0E+00
Lithium	7439-93-2	8.89E-04	No ABS	No RfC	9.63E-02	2.67E-02	NV	1.5E-02	1.4E-01
Manganese	7439-96-5	1.42E-03	No ABS	1.1E-05	6.88E-02	1.90E-02	NV	7.8E-02	1.7E-01
Mercury*	7487-94-7	1.46E-05	No ABS	4.1E-11	0.00E+00	0.00E+00	0.0E+00	9.2E-03	9.2E-03
Molybdenum	7439-98-7	4.86E-03	No ABS	No RfC	7.55E-03	2.09E-03	NV	8.5E-01	8.6E-01
Nickel	7440-02-0	7.42E-04	No ABS	4.6E-07	2.35E-03	3.25E-03	2.1E-02	3.1E-02	5.9E-02
PAHs (Total)*	PAH	2.03E-06	1.1E-06	5.7E-11	No Data	No Data	No Data	6.0E-04	6.1E-04
Selenium	7782-49-2	1.87E-04	No ABS	1.3E-10	4.55E-04	1.26E-04	NV	7.6E-02	7.7E-02
Strontium	7440-24-6	7.89E-05	No ABS	No RfC	8.36E-03	2.31E-03	NV	1.4E-01	1.5E-01
Sulfate	14808-79-8	No RfD	No ABS	No RfC	No RfD	No RfD	No RfD	No RfD	0.0E+00
Thallium	7440-28-0	8.68E-03	No ABS	No RfC	0.00E+00	0.00E+00	0.0E+00	2.4E-02	3.3E-02
Vanadium	7440-62-2	2.00E-03	No ABS	2.8E-07	6.36E+00	6.77E+01	1.5E+01	7.6E-03	8.9E+01
Total HI									1.0E+02

Notes
** - Carried forward as a bioaccumulative contaminant of concern (BCC)*
No ABS – Dermal absorption factor unavailable
No Data – Analytical data unavailable
No RfD – Noncancer reference dose unavailable
No RfC – Noncancer reference concentration is unavailable
NV – No value because a bioconcentration factor is unavailable

Table 14. Hazard Quotients and Cancer Risks for Recreational Visitors, Detected Data Only, Cont.

Cancer Risk - Recreational Visitor - Child									
Analyte Name	CAS No.	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways		Total Cancer Risk
		Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish Ingestion	Plant Ingestion	
Aluminum	7429-90-5	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Antimony	7440-36-0	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Arsenic	7440-38-2	4.48E-05	7.03E-06	1.99E-11	4.78E-05	8.84E-06	1.2E-05	5.2E-04	6.4E-04
Boron	7440-42-8	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Cadmium	7440-43-9	No CSF	No CSF	1.9E-13	No CSF	No CSF	No CSF	No CSF	1.9E-13
Cobalt	7440-48-4	No CSF	No CSF	9.9E-12	No CSF	No CSF	No CSF	No CSF	9.9E-12
Hexavalent Chromium	18540-29-9	0.0E+00	No ABS	0.0E+00	2.39E-06	3.20E-05	4.2E-08	0.0E+00	3.4E-05
Iron	7439-89-6	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Lead	7439-92-1	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Lithium	7439-93-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Manganese	7439-96-5	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Mercury*	7487-94-7	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Molybdenum	7439-98-7	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Nickel	7440-02-0	No CSF	No CSF	2.5E-13	No CSF	No CSF	No CSF	No CSF	2.5E-13
PAHs (Total)*	PAH	3.1E-07	1.3E-07	4.3E-15	No Data	No Data	No Data	2.4E-05	2.5E-05
Selenium	7782-49-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Strontium	7440-24-6	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Sulfate	14808-79-8	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Thallium	7440-28-0	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Vanadium	7440-62-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Cumulative Cancer Risk									7.0E-04

Table 14. Hazard Quotients and Cancer Risks for Recreational Visitors, Detected Data Only, Cont.

Cancer Risk - Recreational Visitor - Adult									
Analyte Name	CAS No.	Sediment Exposure Pathways			Surface Water Exposure Pathways		Dietary Exposure Pathways		Total Cancer Risk
		Ingestion	Dermal Contact	Inhalation	Ingestion	Dermal Contact	Fish Ingestion	Plant Ingestion	
Aluminum	7429-90-5	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Antimony	7440-36-0	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Arsenic	7440-38-2	1.9E-05	3.9E-06	2.5E-10	2.78E-05	7.69E-06	4.0E-05	8.1E-04	9.1E-04
Boron	7440-42-8	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Cadmium	7440-43-9	No CSF	No CSF	2.4E-12	No CSF	No CSF	No CSF	No CSF	2.4E-12
Cobalt	7440-48-4	No CSF	No CSF	1.2E-10	No CSF	No CSF	No CSF	No CSF	1.2E-10
Hexavalent Chromium	18540-29-9	0.0E+00	No ABS	0.0E+00	5.75E-07	1.27E-05	1.5E-07	0.0E+00	1.3E-05
Iron	7439-89-6	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Lead	7439-92-1	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Lithium	7439-93-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Manganese	7439-96-5	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Mercury*	7487-94-7	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Molybdenum	7439-98-7	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Nickel	7440-02-0	No CSF	No CSF	3.1E-12	No CSF	No CSF	No CSF	No CSF	3.1E-12
PAHs (Total)*	PAH	1.3E-07	7.0E-08	5.4E-14	No Data	No Data	No Data	3.8E-05	3.8E-05
Selenium	7782-49-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Strontium	7440-24-6	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Sulfate	14808-79-8	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Thallium	7440-28-0	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Vanadium	7440-62-2	No CSF	No CSF	No IUR	No CSF	No CSF	No CSF	No CSF	0.0E+00
Cumulative Cancer Risk									9.6E-04

Notes:
** - Carried forward as a bioaccumulative contaminant of concern (BCC)*
No ABS – Dermal absorption factor unavailable
No CSF – Cancer slope factor unavailable
No IUR – Cancer inhalation unit risk factor is unavailable
No Data – Analytical data unavailable

target level of $1x10^{-6}$. The CRs for hexavalent chromium exceeded $1x10^{-6}$ for surface water and plant ingestion, and the CRs for PAHs exceeded $1x10^{-6}$ for ingestion of plants. The cumulative cancer risk was **$9.6\ x10^{-4}$** (Table 12). When only detected data were used (Table 14), the cumulative cancer risk was the same (Table 14).

Cancer risks were above the target threshold of $1x10^{-6}$ for arsenic and hexavalent chromium for exposure pathways associated with surface water, and for PAHs for exposure pathways associated with sediment. Arsenic and hexavalent chromium were detected in surface water samples, and numerous PAHs were detected in sediment.

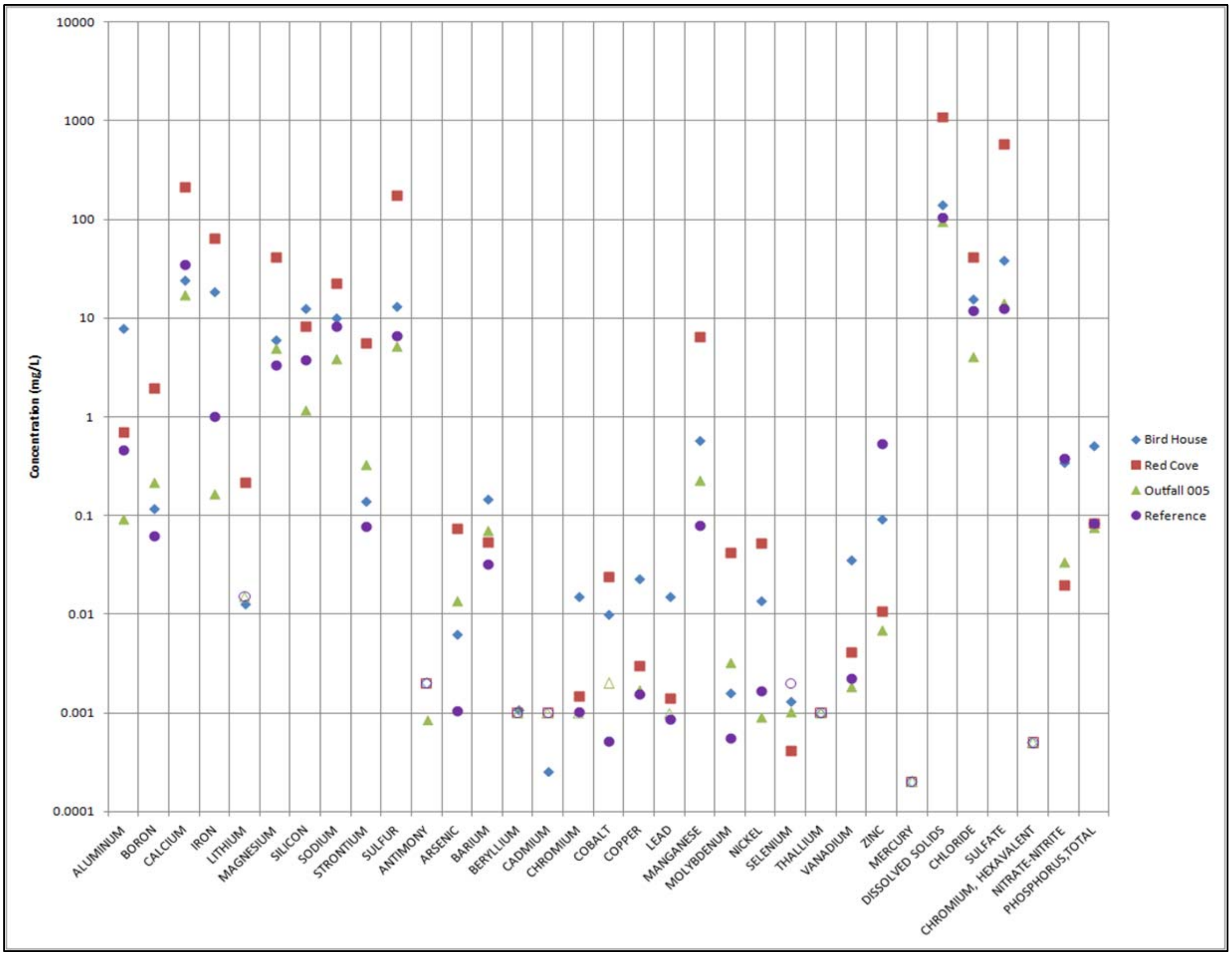
5.3.2. Comparison to Background

The three surface water samples collected in July 2016 were compared to the reference sample from Osborne Landing collected at the same time (Figure 5). Many of the concentrations of analytes from the site exceeded concentrations in the background sample in at least two of the site samples. The analytes that exceeded background in all three site samples are:

- Boron
- Magnesium
- Strontium
- Arsenic
- Barium
- Cobalt
- Copper
- Lead
- Manganese
- Molybdenum
- Sulfate

In Figure 5 the data are presented on a log scale to fit all analytes and samples together. Note that the Bird House sample is sometimes nearly two orders of magnitude (a factor of 100) higher than the reference area background sample (e.g., strontium, boron, arsenic, cobalt, manganese, molybdenum). Higher concentrations of hexavalent chromium (by nearly a factor of 10) were detected in site surface water samples in the winter sampling event. These are not shown in Figure 5 because they weren't collected at the same time. This information strongly indicates the coal ash ponds are impacting surrounding surface waters.

Figure 5. Comparison of July 2016 Surface Water Samples From the Site to the Reference Area



Note: Clear markers indicate analyte was not detected in sample

5.3.3. Uncertainty Analysis

The purpose of the uncertainty analysis is to identify and evaluate uncertainties that could influence or bias the risk assessment results.

Data Uncertainties

There are several uncertainties associated with the available data.

- Limited number of samples – this could bias the results high or low. A higher number of samples tends to reduce the magnitude of the EPC because as sample size increases, data statistics tend to decrease as a result. Additional sampling could be performed in similar areas of suspected off-site contamination, and additional sampling could be performed around the entire Dutch Gap Conservation Area, as part of a more comprehensive risk assessment applicable to the entire park.
- One background sample for one medium – this could bias the results high or low. Background for sediments is unknown. Additional background sampling could be performed.
- The ground water potentiometric surface indicates that ground water at the Site is likely discharging from the Ash Ponds to surface water and ultimately the James River, according to a January 15 (2018) memorandum from Aquilogic, Inc. Ground water concentrations of at least seven constituents exceeded the MCL or preliminary background values (Aquilogic 2018) in one or more samples. These are boron, arsenic, calcium, chloride, cobalt, nickel, and sulfate. Given these conditions, the surface water samples utilized in this analysis are likely influenced by the Site's contaminated ground water. Moreover, there are two potentially complete ground water pathways to recreational visitors. These are dermal contact and ingestion of ground water from seeps and springs, which are evaluated in Section 6.
- Risks based on detected analytes as opposed to reporting limits – this is not likely to bias risk estimates. However, measured concentrations are less uncertain than concentrations below reporting limits. Overall, uncertainty is lower for risk estimates for which detected data were used for the EPC. If the maximum RL exceeded all detected values, it was used because the true value could be just under the RL. Risks for boron and selenium for sediment exposure or plant ingestion, and cadmium and mercury for fish ingestion, are more uncertain.
- Fish data – because fish are mobile in the environment, the VDEQ fish data for an offsite location were not used. Fish tissue concentrations were modeled from surface water data and BCFs. Recent fish data for the James River near the site suggests arsenic concentrations may be elevated. Measured fish concentrations in catfish and carp are similar to that predicted for the site. Modeled mercury concentrations in fish produced an excess risk, suggesting that fish and shellfish near the site should be monitored for mercury. Mercury was not detected in surface water, but due to its propensity to bioaccumulate it may be present at hazardous levels in aquatic biota.

Exposure Parameters

Exposure parameters used in the analysis were standard default values used by USEPA (2018a) where possible. For site-specific parameters, professional judgment and knowledge of site conditions was used to predict exposure. This is not expected to bias the results high or low.

Toxicity Values

The values used as the toxicity component of the analysis were standard values applied by USEPA (2018a). This is not expected to bias the results high or low. The USEPA defines an RfD as an estimated value with uncertainty of about a factor of 10 that is likely to have no deleterious effects throughout a lifetime, inclusive of consideration of sensitive subgroups. The cancer slope factor approximates the 95% confidence limit of increased cancer risk from lifetime exposure.

6. Dominion Ground Water Data

The quantitative assessment presented in Section 5 focuses on the human health and environmental risks posed by surface water and sediment in the Dutch Gap Conservation Area, immediately adjacent to the Ash Ponds at Chesterfield Power Station. This section provides a similar quantitative assessment utilizing ground water data collected by Dominion. Ground water data from monitoring wells located around the perimeter of both ash ponds were collected by Dominion and reported in the "2017 CCR Annual Ground water Monitoring and Corrective Action Report, Chesterfield Power Station Lower Ash Pond (January 31, 2018; Revised February 28, 2018)" (Dominion 2018a) and "2017 CCR Annual Ground water Monitoring and Corrective Action Report, Chesterfield Power Station, Upper Ash Pond" (January 31, 2018, Revised February 28, 2018) (Dominion 2018b).

The Ash Ponds, which are unlined, have been in operation for decades and currently hold approximately 15 million tons of coal ash. These conditions have resulted in measureable and statistically significantly elevated levels of ground water contamination. According to a January (2018) memorandum from Aquilogic, Inc., ground water concentrations of at least seven constituents exceeded the MCL or preliminary background values (Aquilogic 2018). These are boron, arsenic, calcium, chloride, cobalt, nickel, and sulfate. Dominion acknowledges ground water impacts from the Ash Ponds (Dominion 2018a).

This section seeks to understand whether there is excess risk even if limiting the analysis only to Dominion's ground water data. Importantly, however, the ground water data reinforce the quantitative analysis set forth in Section 5, as the data confirm the mechanism by which the Ash Ponds are contaminating the sediment and surface water. The data strongly refute the notion that contaminated ground water is being confined to Dominion's property. Instead, the ground water potentiometric surface at both Ash Ponds indicates that ground water is likely discharging the short distance from the Ash Ponds to the adjacent surface water, and ultimately the James River (Aquilogic 2018, Dominion 2018a, Dominion 2018b). Thus the quantitative risk estimates set forth in Section 5, based on the surface water and sediment sampling, remain an appropriate measure of risk to recreational visitors to contaminated areas of Dutch Gap.

6.1. Comparison of Site to Background Well Data

The "background wells" used in both Dominion ground water reports raise several significant concerns and may not represent background conditions. True background wells would be located outside the zone of influence of the source. Due to the proximity to other areas of disturbance on Dominions' property, it is questionable if these four wells are truly background wells. MW-29U and MW-30U are next to an inlet emptying into the James River which receives ground water discharge from the Lower Ash Pond (Dominion 2018). These two wells could be influenced by source-related contaminants. MW-35S and MW-35D are in the northwest corner of the Upper Ash Pond boundary and are located next to railroad tracks and the main operating area of the Chesterfield facility. These wells describe conditions which are potentially influenced by fate and transport mechanisms of overland flow or fugitive dusts, leaching, and ground water migration. They do not meet a standard definition of a background well as they are not upgradient of potential source-related contamination. Well MW-29U appears quite different from the other three "background" wells in that concentrations of inorganics are higher, and so is conductivity, turbidity, and temperature, and it is also downgradient of a ground water flow from a metal-contaminated pond.

Nonetheless, Dominion (2018a) provides an appendix with output from statistical tests to derive background threshold values (BTVs) from the two wells identified as background for the Lower Ash Pond, acknowledging that boron, calcium, chloride, fluoride, pH, sulfate, and total dissolved solids were significantly elevated above background. However, Dominion does not provide adequate explanation for how the statistical analysis was performed, or provide a thorough discussion of the results.

Figure 6 shows box and whisker plots of several of the Lower Ash Pond contaminants from the Dominion (2018a; Table 2) report plotted against the presumed site background. In this figure, the narrow "waist" represents the median or middle of the data set for all sampling events and wells combined. The data are segregated by location: the site and background wells. The lines or "whiskers" represent the minimum and maximum concentrations, apart from outliers. The boundaries of the solid box represents the upper and lower quartiles, where 25% of the data are greater or less than this value. Skewness in the data is shown by a larger or smaller box above or below the median. Outliers should not be discarded in small data sets simply because they are statistical outliers, unless it's verified that they do not represent inherent heterogeneity, seasonal or other fluctuation in concentration, or in the case of the background wells, contamination. For each of these contaminants in Figure 6, concentrations were elevated in impacted site wells as compared to background, and there were numerous high outliers relative to concentrations observed in background wells. This figure suggests these, and possibly other elements, may be statistically elevated in site wells versus background were the data evaluated.

Figure 7 shows data for Lower Ash Pond September (2017) CCR Appendix III test results from the Dominion (2018a; Table 3) report. These data are plotted by well and represent one point in time. Many of the site wells had concentrations of one or more CCR analytes higher than concentrations measured in the background wells. Note that due to the physical location of the background wells near or adjacent to the presence of other site-related source areas, and the fact that ground water was identified as moving radially from the ash ponds, the background wells may be contaminated by site-related activities and have higher than true background concentrations of CCR analytes.

Initial review of the Dominion data for the Upper Ash Pond (Dominion 2018b) indicates numerous parameters at levels significantly above background or in excess of relevant screening levels or MCLs for the Upper Ash Pond. Figure 8 compares site data to data from the four background wells at the Upper Ash Pond (Dominion 2018b) in box plots. The data used in Figure 8 were originally reported by well in Table 2 of Dominion (2018b). As shown in Figure 8, many of these parameters appear at concentrations significantly above levels found in the designated background wells, such as arsenic, boron, cobalt, fluoride, and radium. Statistical evaluation details and analysis were not provided in Dominion (2018b).

Data for inorganics collected in the September 2017 sampling event from Table 3 of the Upper Ash Pond report (Dominion 2018b) were plotted by well (Figure 9). The data for some wells exceed secondary drinking water standards and for many analytes concentrations in the impacted wells are much higher than in background wells.

Maps of the locations of the Dominion background ground water wells indicate that they may be influenced by site-related activities. This introduces a major uncertainty to the data and any results or decisions made with these data. If these wells are impacted, even slightly, by site-related conditions, then the concentrations used as established background are elevated. This would decrease the relative amount by which the downgradient wells exceed background, artificially decreasing apparent risk. The comparison to background wells shown in Figures 8 and 9 could be skewed because of this. Well concentrations may be much higher than presumed background values if background is artificially inflated due to site-related contamination either from the ash ponds or other sources. To adequately assess background, only wells that are upgradient of the main power plant, and upgradient of any waste or storage ponds or areas, as well as laydown areas, railroad tracks, or loading docks should be used to represent background. Only by doing this would it be possible to verify that the wells chosen as background are truly representative of naturally occurring ambient conditions.

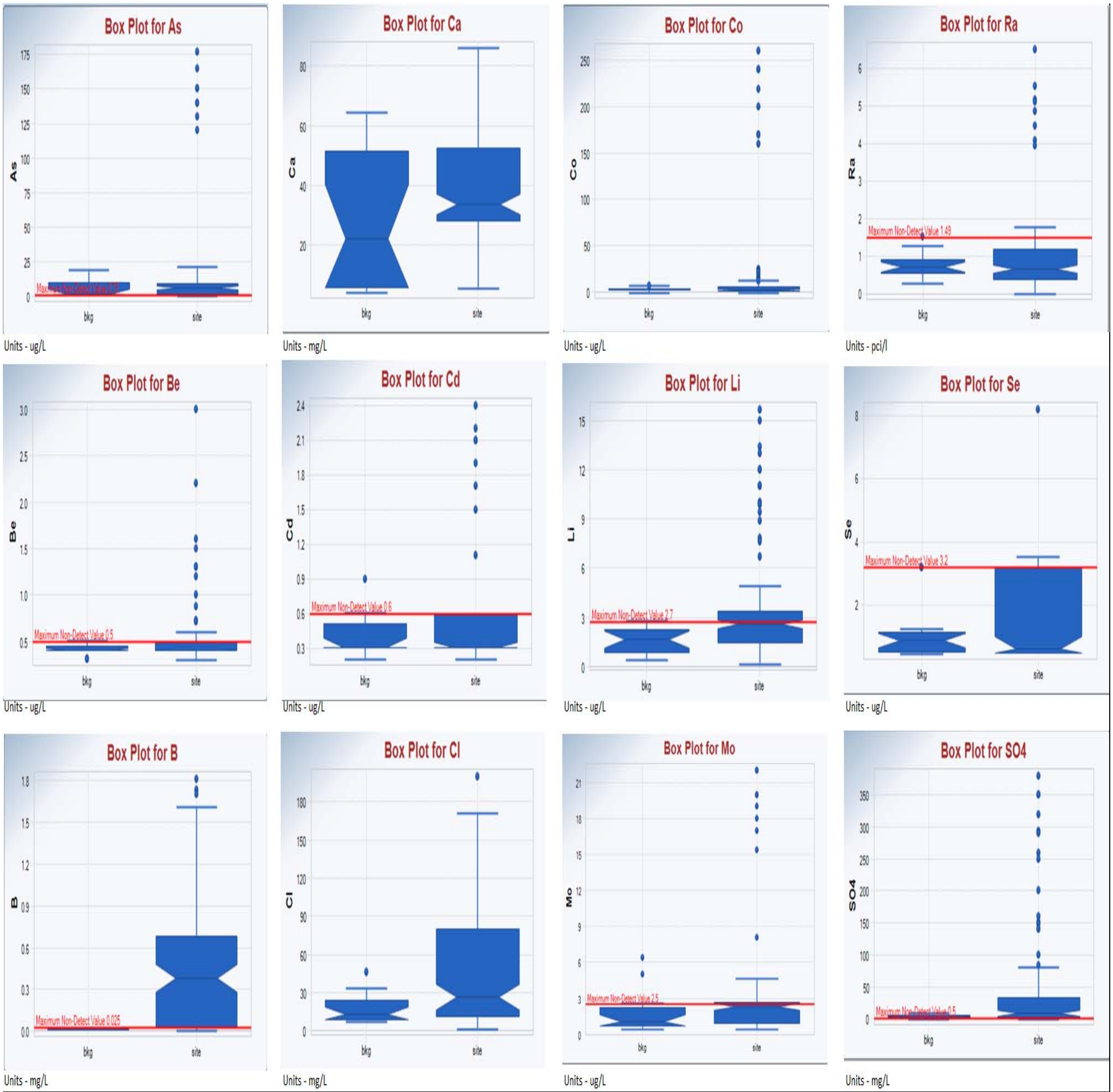
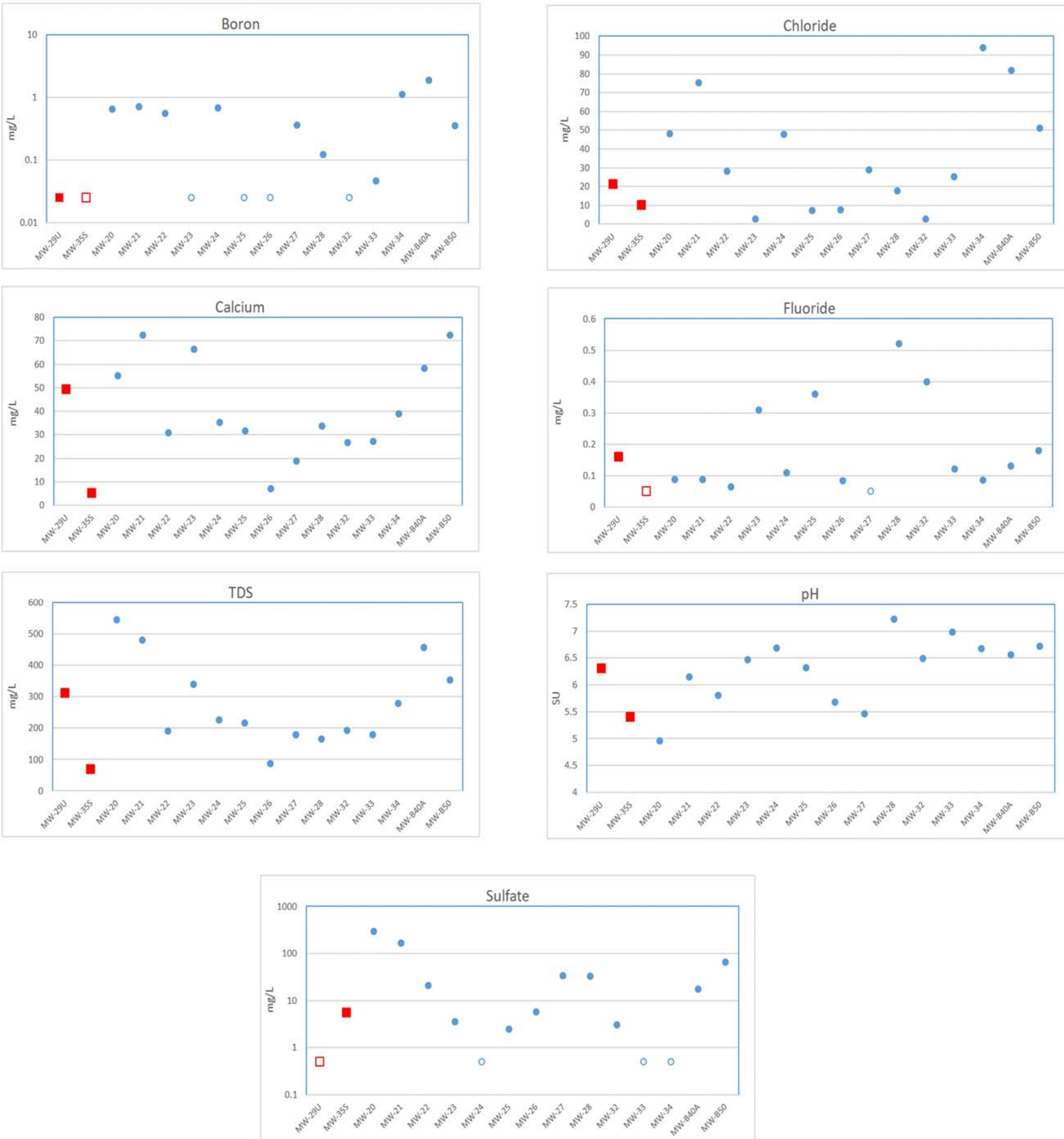


Figure 6. Box and Whisker Plots of Lower Ash Pond Analytes



Notes: mg/L = milligrams per liter; SU = Standard Units
Solid marker - detected value
Clear marker - nondetected value
Red Markers - Wells 29U and 35S were considered "background" although they may be impacted by site conditions

Figure 7. Dominion Lower Ash Pond Compliance Monitoring Data Presented by Well and Analyte

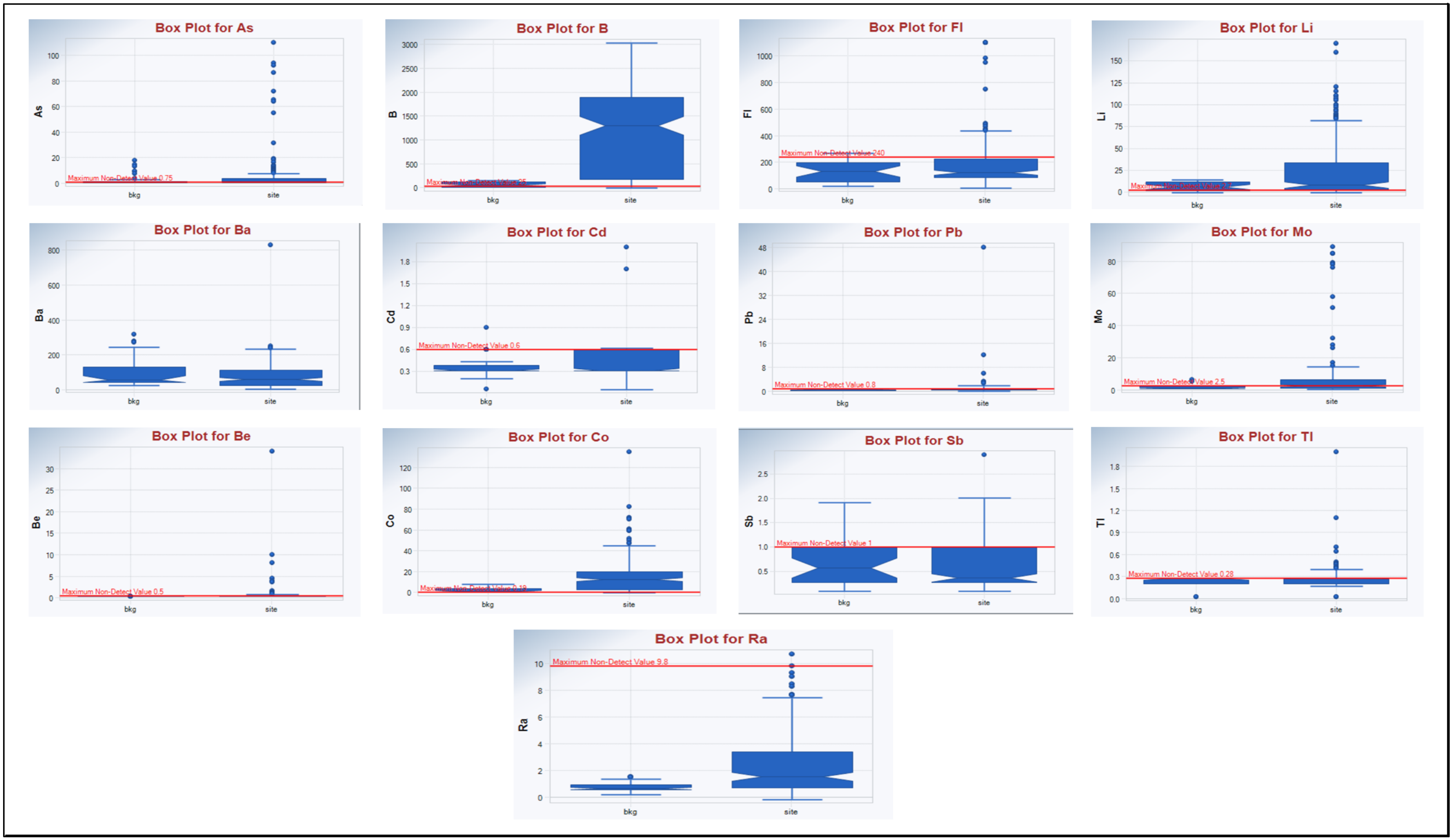
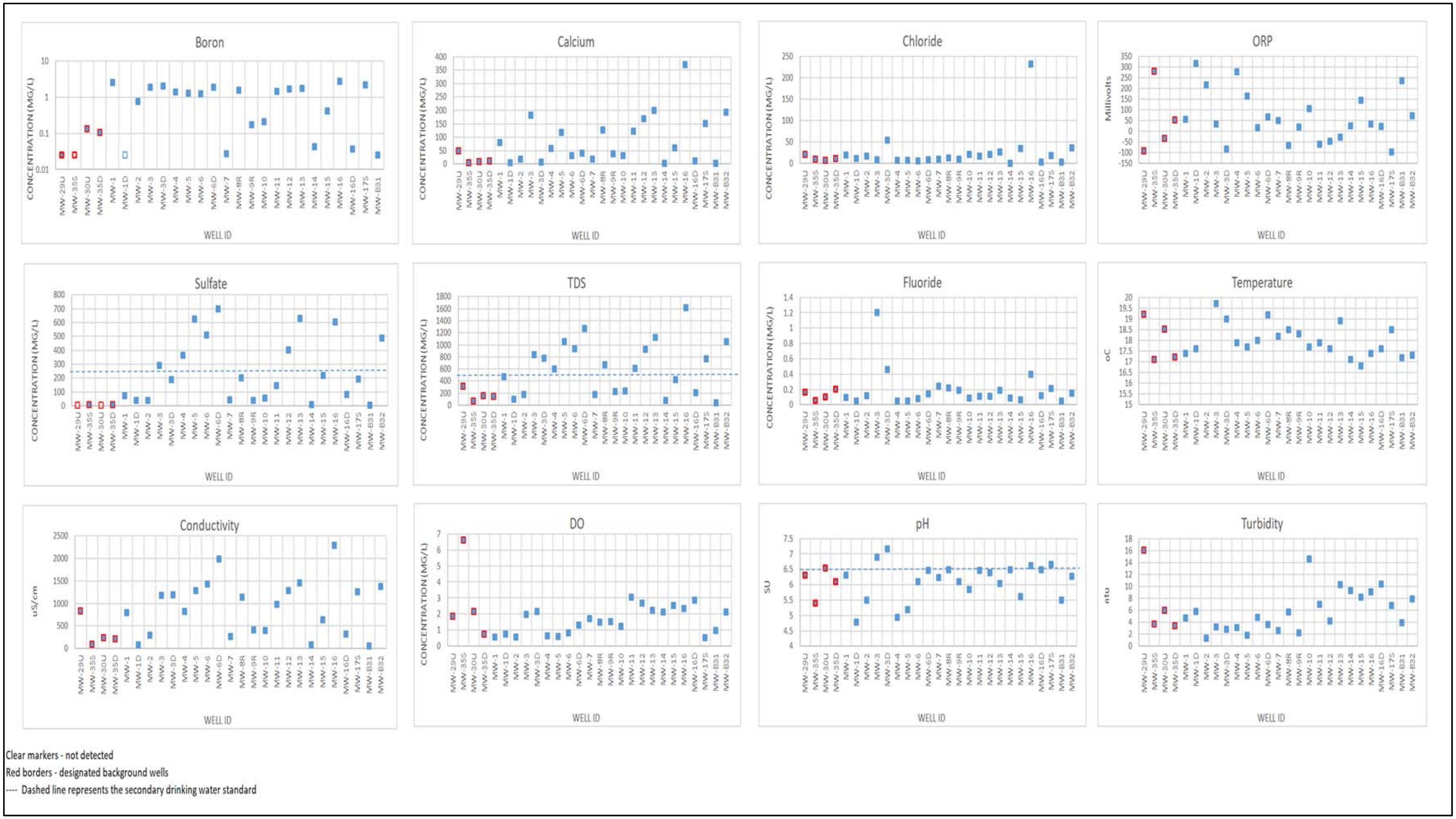


Figure 8. Box Plots Comparing Background to Site Ground Water Data for the Upper Ash Pond.



Note: Wells 29U, MW35S, MW-30U, and MW-35D were identified as background wells by Dominion. These wells are not necessarily upgradient of site-related impacts given ground water flow patterns and site disturbance..

Data points represent detected values or reporting limits for nondetects.

Figure 9. Dominion Upper Ash Pond Compliance Monitoring Data Presented By Well and Analyte

6.1. Risk Assessment for Ground Water Data

Dominion's reports conclude that there is no impact to public health. This conclusion must be based on an assumption that the only exposure scenario is use of ground water as a public water supply. The data shows, however, that ground water is discharging into nearby recreational areas, and may be contacted by recreational visitors. Dominion also concludes that there is no environmental risk, but that also fails to account for discharging ground water into surface water or wetlands. The ground water data were compared to human health and ecological screening levels to determine hazard or risk to likely receptors under potentially occurring exposure scenarios. Any analytes that exceeded screening levels were considered to be COPCs for baseline risk evaluation. Analytes that had HQs greater than 1 or cancer risks greater than $1x10^{-6}$ were identified as COCs for further evaluation or risk management.

6.1.1. Human Health Risk Assessment for Ground Water

Maximum detected concentrations of analytes in ground water were compared to human health screening levels as described in Section 3. Table 15 presents the summary statistics for the background and impacted (Site) wells, and Table 16 the screening level results for the Site wells for the Lower Ash Pond, based on combining all the ground water data over time. Similarly, Table 17 presents the summary statistics for the background and Site wells, and Table 18 the screening level results for the Site wells for the Upper Ash Pond. Every analyte was detected in at least one sample from the impacted wells. Numerous analytes exceeded human health screening levels for both ash ponds. This indicates that for many analytes, ground water concentrations exceed drinking water standards. Potable use as the only drinking water source may not be a viable scenario at this time for Chesterfield, but the data show that ground water is impacted. Because concentrations exceed background for many constituents, the data suggest ground water impacts are related to the unlined Ash Ponds. Analytes that exceeded screening levels were carried forward and evaluated with equations for a recreational visitor scenario as presented in Section 5.1.4.

Total Radium

The equations for calculating radium exposure are slightly different than those for chemical constituents, and were derived by rearranging equations presented in the EPA Preliminary Remediation Goals for Radionuclides (PRG) website (https://epa-prgs.ornl.gov/radionuclides/ (USEPA 2018b).

Total Radium Ground Water Ingestion

$$CDI\ (pCi) = C_{GW}\left(\frac{pCi}{L}\right) * EF\left(\frac{d}{yr}\right) * ED(yr) * ET\left(\frac{hr}{ev}\right) * EV\left(\frac{ev}{d}\right) * IRW\left(\frac{L}{hr}\right)$$

Total Radium Ground Water Immersion

$$CDI\ \left(\frac{pCi-yr}{L}\right) = C_{GW}\left(\frac{pCi}{L}\right) * \left[EF\left(\frac{d}{yr}\right) * ED(yr) * ET\left(\frac{hr}{ev}\right) * EV\left(\frac{ev}{d}\right)\right] * \left(\frac{1\ yr}{8760\ hr}\right)$$

Different parameter values are used for adults and children, where the water intake rate (IRW) is replaced by an age adjustment factor for ingestion ($IFW_{rec-adj}$) by the child, and the parameters within brackets are replaced with an age adjustment for immersion ($DFA_{rec-adj}$) term when evaluating childhood exposure. Secular equilibrium was assumed, where the ratio of the activity of the parent radionuclide and the activity of its daughter product(s) remains constant because the half-life of the parent is much longer than the daughter

Table 15. Summary Statistics for the Lower Ash Pond Ground Water Data

Summary Statistics and Risk Ratios for Lower Ash Pond Background Well Data							
Analyte	Units	Nondetected Data			Detected Data		
		Number of Nondetects	Minimum Nondetect	Maximum Nondetect	Number of Detects	Minimum Detect	Maximum Detect
Antimony	ug/L	11	0.27	1	5	0.13	1.7
Arsenic	ug/L	6	0.35	0.75	10	0.41	17.8
Barium	ug/L				16	28	318
Beryllium	ug/L	16	0.31	0.5			
Boron	ug/L	10	8.1	25	6	9.2	18
Cadmium	ug/L	12	0.21	0.6	4	0.33	0.9
Calcium	ug/L				16	4200	63900
Chloride	ug/L				16	8200	46000
Chromium	ug/L	5	0.26	1	11	0.34	2
Cobalt	ug/L				16	0.82	6.9
Conductivity	uS/cm				16	9.8	906
DO	ug/L				16	370	6460
Fluoride	ug/L	6	24	50	26	24	230
Lead	ug/L	7	0.08	0.8	9	0.18	0.79
Lithium	ug/L	4	0.7	2.7	12	0.41	2.4
Mercury	ug/L	16	0.09	0.13			
Molybdenum	ug/L	6	0.51	2.5	10	0.58	6.4
ORP	millivolts				16	-145.7	232.5
pH	SU				16	5.16	6.34
Selenium	ug/L	7	0.48	3.2	9	0.5	1.2
Sulfate	ug/L	2	500	500	14	1400	7700
TDS	ug/L				16	66000	450000
Temperature	C				16	12.71	22.2
Thallium	ug/L	16	0.02	0.28			
Total Radium	pCi/L	4	0.282	0.934	12	0.358	1.53
Turbidity	ntu				16	-1.5	145.4

Summary Statistics and Risk Ratios for Lower Ash Pond Impacted Well Data Five Plume Wells 20, 21, 27, 28, B40A							
Analyte	Units	Nondetected Data			Detected Data		
		Number of Nondetects	Minimum Nondetect	Maximum Nondetect	Number of Detects	Minimum Detect	Maximum Detect
Antimony	ug/L	35	0.27	1	5	0.34	2.2
Arsenic	ug/L	9	0.35	0.75	31	0.4	177
Barium	ug/L				40	27	340
Beryllium	ug/L	28	0.31	0.5	12	0.58	3
Boron	ug/L				40	116	1810
Cadmium	ug/L	30	0.21	0.6	10	0.36	2.4
Calcium	ug/L				40	16000	85800
Chloride	ug/L				40	1900	200000
Chromium	ug/L	34	0.26	1	6	0.32	21.1
Cobalt	ug/L				40	0.11	260
Conductivity	uS/cm				40	246	1025
DO	ug/L				40	250	1590
Fluoride	ug/L	6	50	120	74	37	720
Lead	ug/L	22	0.16	0.8	18	0.18	0.79
Lithium	ug/L	9	0.16	2.7	31	1	15.7
Mercury	ug/L	39	0.09	0.13	1	0.11	0.11
Molybdenum	ug/L	26	0.51	2.5	14	0.52	22
ORP	millivolts				40	-156	199.6
pH	SU				40	4.54	7.23
Selenium	ug/L	30	0.48	3.2	10	0.51	3.3
Sulfate	ug/L				40	660	380000
TDS	ug/L				40	150000	720000
Temperature	C				40	13.3	23.9
Thallium	ug/L	33	0.2	0.28	7	0.35	0.61
Total Radium	pCi/L	10	0.0113	1.4	30	0.0739	6.52
Turbidity	ntu				40	0	95.6

Notes:
Metals and inorganics in ug/L; field parameters in standard units
NA - Not applicable

Table 16. Screening Level Risk Analysis for the Lower Ash Pond 2016-2017 Five Plume Wells (MW-20, 21, 27, 28, B40A)

Analyte	Ground Water EPC		Water Quality Criteria				Hazard Quotients			
	Maximum Detected Value	Units	VA PWS (mg/L)	VA Surface Water (mg/L)	EPA Tapwater RSL (mg/L)	EPA WQS (mg/L)	VA PWS HQ	VA Surface Water HQ	USEPA Tapwater RSL HQ	USEPA WQS HQ
Antimony	0.0022	mg/L	0.006	0.64	0.00078 n	0.006	0.4	0.003	3	0.4
Arsenic	0.177	mg/L	0.01	NV	0.000052 c*	0.01	18	NV	3404	18
Barium	0.34	mg/L	2.00	NV	0.38 n	2	0.2	NV	0.9	0.17
Beryllium	0.003	mg/L	NV	NV	0.0025 n	0.004	NV	NV	1	0.75
Boron	1.81	mg/L	NV	NV	0.4 n	NV	NV	NV	5	NV
Cadmium	0.0024	mg/L	0.005	NV	0.00092 n	0.005	0.5	NV	3	0.5
Calcium	85.8	mg/L	NV	NV	NV	NV	NV	NV	NV	NV
Chloride	200	mg/L	250	NV	NV	250 2	0.8	NV	NV	0.80
Chromium	0.0211	mg/L	0.10	NV	2.2 n	0.1	0.2	NV	0.010	0.2
Cobalt	0.26	mg/L	NV	NV	0.0006 n	NV	NV	NV	433	NV
Fluoride	0.72	mg/L	NV	NV	0.0800 n	4	NV	NV	9	0.18
Lead	0.00079	mg/L	0.015	NV	0.015 L	0.015	0	NV	0	0
Lithium	0.0157	mg/L	NV	NV	0.004 n	NV	NV	NV	4	NV
Mercury	0.00011	mg/L	NV	NV	0.00057 n	0.002	NV	NV	0.2	0.1
Molybdenum	0.022	mg/L	NV	NV	0.010 n	NV	NV	NV	2	NV
Selenium	0.0033	mg/L	0.17	4.2	0.01 n	0.05	0.02	0.0008	0.3	0.07
Sulfate	380	mg/L	250	NV	NV	250 2	2	NV	NV	2
TDS	720	mg/L	500	NV	NV	500 2	1	NV	NV	1
Thallium	0.00061	mg/L	0.00024	0.00047	0.00002 n	0.002	3	1	31	0.3
Total Radium	6.52	pCi/L	5	NV	0.000397 c	NV	1.3	NV	16423	NV

Notes:

Radium units for criteria are in pCi/L

Red highlighted cells have HQs>1 and indicate the analyte is a contaminant of potential concern (COPC) for further evaluation

Abbreviations:

* = n screening level < 100 times the cancer screening level
** - n screening level < 10 time the cancer screening level
2 - secondary water quality standard (SMCL)
c - cancer effect
EPC - exposure point concentration
HQ - hazard quotient
MCL - maximum contaminant level
mg/L - milligram per liter
n - noncancer effect
NV - no value
PWS - public water supply
RSL - regional screening level
WQS - water quality standard is the MCL unless noted 2, and then it is the secondary standard

Source:

VWQC, PWS, Surface Water	9VAC25-260-140. Criteria for surface water. Commonwealth of Virginia, 2018 https://law.lis.virginia.gov/admincode/title9/agency25/chapter260/section140/
EPA RSLs, MCLs	EPA RSLs May 2018; Target HQ of 0.1

Table 17. Summary Statistics for the Upper Ash Pond Ground Water Data

Summary Statistics and Risk Ratios for Upper Ash Pond Background Well Data							
Analyte	Units	Nondetected Data			Detected Data		
		Number of Nondetects	Minimum Nondetect	Maximum Nondetect	Number of Detects	Minimum Detect	Maximum Detect
Antimony	ug/L	22	0.10	1.00	10	0.13	1.90
Arsenic	ug/L	14	0.35	0.75	18	0.22	17.80
Barium	ug/L				32	28.00	318.00
Beryllium	ug/L	32	0.31	0.50			
Boron	ug/L	10	8.10	25.00	22	9.20	130.00
Cadmium	ug/L	28	0.06	0.60	4	0.33	0.90
Calcium	ug/L				32	4200.00	63900.00
Chloride	ug/L				32	7900.00	46000.00
Chromium	ug/L	15	0.26	1.00	17	0.24	2.00
Cobalt	ug/L	4	0.10	0.19	28	0.04	6.90
Conductivity	uS/cm				32	9.80	906.00
DO	ug/L				32	370.00	6460.00
Fluoride	ug/L	6	24.00	50.00	58	24.00	260.00
Lead	ug/L	14	0.08	0.80	18	0.09	0.79
Lithium	ug/L	4	0.70	2.70	28	0.41	13.00
Mercury	ug/L	32	0.09	0.13			
Molybdenum	ug/L	14	0.51	2.50	18	0.58	6.40
ORP	millivolts				32	-198.00	232.50
pH	SU				32	5.16	6.92
Selenium	ug/L	20	0.32	3.20	12	0.50	1.20
Sulfate	ug/L	6	130.00	500.00	26	400.00	7700.00
TDS	ug/L				32	66000.00	450000.00
Temperature	C				32	12.71	22.20
Thallium	ug/L	32	0.02	0.28			
Total Radium	pCi/L	10	0.25	1.26	22	0.36	1.53
Turbidity	ntu				32	-1.50	145.40

Summary Statistics for Upper Ash Pond 2016-2017 Impacted Well Data Six Plume Wells [MW-13, 16, 1, 3, 4, 6]							
Analyte	Units	Nondetected Data			Detected Data		
		Number of Nondetects	Minimum Nondetect	Maximum Nondetect	Number of Detects	Minimum Detect	Maximum Detect
Antimony	ug/L	61	0.10	1.00	19	0.27	2.90
Arsenic	ug/L	21	0.50	0.75	59	0.36	110.00
Barium	ug/L				80	11.00	830.00
Beryllium	ug/L	54	0.31	0.50	26	0.32	34.00
Boron	ug/L	1	25.00	25.00	79	10.00	3020.00
Cadmium	ug/L	69	0.21	0.60	11	0.24	2.00
Calcium	ug/L				80	3100.00	397000.00
Chloride	ug/L				80	1700.00	219000.00
Chromium	ug/L	51	0.26	1.00	29	0.26	190.00
Cobalt	ug/L	4	0.10	0.19	76	0.13	135.00
Conductivity	uS/cm				80	115.80	2202.00
DO	ug/L				78	340.00	16000.00
Fluoride	ug/L	18	50.00	240.00	142	25.00	1100.00
Lead	ug/L	35	0.08	0.80	45	0.16	48.00
Lithium	ug/L	3	0.70	2.70	77	0.69	170.00
Mercury	ug/L	72	0.09	0.13	8	0.09	0.12
Molybdenum	ug/L	25	0.51	2.50	55	0.53	89.10
ORP	millivolts				78	-140.40	293.00
pH	SU				80	3.53	11.63
Selenium	ug/L	50	0.32	3.20	30	0.49	13.10
Sulfate	ug/L				80	9000.00	820000.00
TDS	ug/L				80	110000.00	1600000.00
Temperature	C				80	6.10	22.50
Thallium	ug/L	58	0.20	0.28	22	0.17	2.00
Total Radium	pCi/L	13	0.31	9.80	67	0.28	10.70
Turbidity	ntu				79	0.00	432.00

Notes:
NA - Not applicable
For Wells MW-1, 16, 3, 6 - includes shallow and deep aquifers

Table 18. Screening Level Risk Analysis for the Upper Ash Pond 2016-2017 Site Six Plume Wells (MW 13, 16, 1, 3, 4, 6)

Analyte	Ground Water EPC		Water Quality Criteria				Hazard Quotients			
	Maximum Detected Value	Units	VA PWS (mg/L)	VA Surface Water (mg/L)	EPA Tapwater RSL (mg/L)	EPA WQS (mg/L)	VA PWS HQ	VA Surface Water HQ	USEPA Tapwater RSL HQ	USEPA WQS HQ
Antimony	0.0029	mg/L	0.006	0.64	0.00078 n	0.006	0.5	0.005	4	0.5
Arsenic	0.11	mg/L	0.01	NV	0.000052 c*	0.01	11	NV	2115	11
Barium	0.83	mg/L	2.00	NV	0.38 n	2	0.4	NV	2.2	0.42
Beryllium	0.034	mg/L	NV	NV	0.0025 n	0.004	NV	NV	14	8.50
Boron	3.02	mg/L	NV	NV	0.4 n	NV	NV	NV	8	NV
Cadmium	0.002	mg/L	0.005	NV	0.00092 n	0.005	0.4	NV	2	0.4
Calcium	397	mg/L	NV	NV	NV	NV	NV	NV	NV	NV
Chloride	219	mg/L	250	NV	NV	250 2	0.9	NV	NV	0.88
Chromium	0.19	mg/L	0.10	NV	2.2 n	0.1	1.9	NV	0.086	1.9
Cobalt	0.135	mg/L	NV	NV	0.0006 n	NV	NV	NV	225	NV
Fluoride	1.1	mg/L	NV	NV	0.0800 n	4	NV	NV	14	0.28
Lead	0.048	mg/L	0.015	NV	0.015 L	0.015	3	NV	3	3
Lithium	0.17	mg/L	NV	NV	0.004 n	NV	NV	NV	43	NV
Mercury	0.00012	mg/L	NV	NV	0.00057 n	0.002	NV	NV	0.2	0.1
Molybdenum	0.0891	mg/L	NV	NV	0.010 n	NV	NV	NV	9	NV
Selenium	0.0131	mg/L	0.17	4.2	0.01 n	0.05	0.08	0.0031	1.3	0.26
Sulfate	820	mg/L	250	NV	NV	250 2	3	NV	NV	3
TDS	1600	mg/L	500	NV	NV	500 2	3	NV	NV	3
Thallium	0.002	mg/L	0.00024	0.00047	0.00002 n	0.002	8	4	100	1.0
Total Radium	10.7	pCi/L	5	NV	0.000397 c	NV	2.1	NV	26952	NV

Notes:

Radium units for criteria are in pCi/L

Red highlighted cells have HQs>1 and indicate the analyte is a contaminant of potential concern (COPC) for further evaluation

Abbreviations:

* = n screening level < 100 times the cancer screening level
** - n screening level < 10 time the cancer screening level
2 - secondary water quality standard (SMCL)
c - cancer effect
EPC - exposure point concentration
HQ - hazard quotient
MCL - maximum contaminant level
mg/L - milligram per liter
n - noncancer effect
NV - no value
PWS - public water supply
RSL - regional screening level
WQS - water quality standard is the MCL unless noted 2, and then it is the secondary standard

Source:

VWQC, PWS, Surface Water	9VAC25-260-140. Criteria for surface water. Commonwealth of Virginia, 2018 https://law.lis.virginia.gov/admincode/title9/agency25/chapter260/section140/
EPA RSLs, MCLs	EPA RSLs May 2018; Target HQ of 0.1

product. The EPA Radionuclide Calculator was used to generate risk estimates for childhood exposure, and to generate slope factors to apply to recreational adult-only exposure. The values used for the parameters for the radionuclide exposure equations are generally consistent with those for chemical exposure, and are presented in Table 19.

Ground Water Intakes, Hazard, and Risk Estimates

EPCs were calculated for ground water (Table 20) using recommended values from ProUCL. If more than one UCL was recommended, the higher was chosen as the EPC. These EPCs were used to develop risk and hazard estimates, assuming incidental ingestion and dermal contact with ground water would occur at seeps and springs. The point of exposure is assumed to be along the facility boundary; however, because radial flow was identified by Dominion, because ground water samples do not meet the statistical assumptions of independence over a short time span, and because of high levels of variability in concentrations, determining an appropriate EPC at the point of exposure is not as straight forward as using all the site data from all monitoring wells averaged across 2016-2017.

Guidance from USEPA (2014) indicates that only wells within the core of the plume should be used to estimate the EPC. Dominion, however, has not developed a contaminant plume. Thus, as an initial step, wells were selected that appear likely to be within the plume. The core was tentatively identified by reviewing the concentrations and evaluating where the highest concentrations occurred. USEPA (2014) indicates that using a minimum of three wells in the plume core is recommended. The EPC is then the 95% UCL of the mean concentration for each contaminant. Note that potential seasonal changes or aquifer depth effects were not addressed in this data review, but these could influence ground water EPCs. For wells with multiple aquifer depths, both depths were used. This applied to the UAP MW-1, 3, 6, and 16. Differences due to aquifer depths were not further addressed because it appeared there were fewer deep wells.

For the Upper Ash Pond, six wells along the southern boundary, MW-13, 16, 1, 3, 4, and 6, were identified as having higher levels of contaminants than others, suggesting these could be used to initially define a potential plume related to discharge from the Upper Ash Pond. Each of these wells also had moderate to high levels of CCR constituents, such as boron and TDS (Figure 9). In addition, wells along the southern boundary more accurately represent exposure point conditions for recreational visitors, who frequent this area.

For the Lower Ash Pond, five wells were identified as having the highest concentrations than others, suggesting they could be used to initially define a plume for this area. These are MW-27, 28, B40A, 20 and 21. Of these, receptors are most likely to contact constituents migrating from MW-27 into the slough and moving offsite, or constituents from MW-B40A. Fewer receptors are expected to use the area east of the Lower Ash Pond, but because there are trails in the area and the James River and wetlands are nearby, it was deemed appropriate to include these wells in calculating the EPC.

There were only a limited number of background wells. There were two background wells for the LAP, and three identified for the UAP. These wells may be impacted by the site and the ponds given potentiometric surface maps provided by Dominion and potential sources observed within Dominions' boundaries, and background concentrations may therefore be artificially high. Additional background wells located outside of any zone of influence should be proposed for this site. UCLs for nearly all constituents at both the LAP and UAP exceeded UCLs for background. Hypothesis testing was not performed for the risk assessment to determine that background concentrations were statistically significantly exceeded by site concentrations, but it appears likely given the difference between the background and site UCLs.

Table 19. Receptor-Specific Exposure Parameters for Total Radium

Variable	Value
TR (target cancer risk) unitless	0.000001
EF_{rec-c} (exposure frequency - recreator child) day/yr	48
EF_{rec-a} (exposure frequency - recreator adult) day/yr	72
ED_{rec} (exposure duration - recreator) yr	24
ED_{rec-c} (exposure duration - recreator child) yr	4
ED_{rec-a} (exposure duration - recreator adult) yr	20
$ET_{event-rec-c}$ (exposure time - recreator child) hr/event	3
$ET_{event-rec-a}$ (exposure time - recreator adult) hr/event	5
EV_{rec-c} (number of bathing events per day - recreator child) event/day	1
EV_{rec-a} (number of bathing events per day - recreator adult) event/day	1
$DFA_{rec-adj}$ (age-adjusted immersion factor - recreator) hr	7776
$IFW_{rec-adj}$ (age-adjusted water intake rate - recreator) L	580.32
IRW_{rec-c} (water intake rate - recreator child) L/hr	0.12
IRW_{rec-a} (water intake rate - recreator adult) L/hr	0.071

Table 20. EPCs for Ground Water Contaminants of Potential Concern

Lower Ash Pond EPCs for Background and Site Wells MW-20, 21, 27, 28, and B40A					
Analyte	Units	Background		Site	
		UCL	Type	UCL	Type
Antimony	ug/L	0.587	95% KM (t) UCL	0.503	95% KM (t) UCL
Arsenic	ug/L	7.681	95% KM (t) UCL	89.27	97.5% KM (Chebyshev) UCL
Boron	ug/L	11.5	95% KM (t) UCL	984	95% Chebyshev (Mean, Sd) UCL
Cadmium	ug/L	0.379	95% KM (t) UCL	0.752	95% KM (t) UCL
Cobalt	ug/L	4.06	95% Student's-t UCL	129.7	97.5% Chebyshev (Mean, Sd) UCL
Fluoride	ug/L	127.3	95% KM (t) UCL	356.5	95% KM (Chebyshev) UCL
Lithium	ug/L	1.702	95% KM (t) UCL	8.629	95% KM (Chebyshev) UCL
Molybdenum	ug/L	2.141	KM H-UCL	9.672	95% KM (Chebyshev) UCL
Radium (total)	pCi/L	0.865	95% KM (t) UCL	6.084	KM H-UCL
Sulfate	ug/L	5035	95% Student's-t UCL	184719	95% Chebyshev (Mean, Sd) UCL
Thallium	ug/L	0.28	All ND; Use Max	0.288	95% KM (t) UCL

Upper Ash Pond EPCs for Background and Site Wells MW-13, 16, 1, 3, 4, and 6					
Analyte	Units	Background		Site	
		UCL	Type	UCL	Type
Antimony	ug/L	0.611	95% KM (t) UCL	0.447	95% KM (t) UCL
Arsenic	ug/L	6.436	95% KM (Chebyshev) UCL	20.73	95% KM (Chebyshev) UCL
Barium	ug/L	169.7	95% Chebyshev (Mean, Sd) UCL	123.3	95% Chebyshev (Mean, Sd) UCL
Beryllium	ug/L	0.5	All ND; Max RL	3.141	95% KM (Chebyshev) UCL
Boron	ug/L	105.1	95% KM (Chebyshev) UCL	1933	95% KM (Chebyshev) UCL
Cadmium	ug/L	0.184	95% KM (t) UCL	0.424	95% KM (Chebyshev) UCL
Cobalt	ug/L	2.605	Gamma Adjusted KM-UCL	32.36	95% KM (Chebyshev) UCL
Fluoride	ug/L	150.2	95% KM (t) UCL	393.4	KM H-UCL
Lead	ug/L	0.379	95% KM (t) UCL	3.944	95% KM (Chebyshev) UCL
Lithium	ug/L	10.31	95% KM (Chebyshev) UCL	68.77	95% KM (Chebyshev) UCL
Molybdenum	ug/L	1.402	KM H-UCL	28.41	KM H-UCL
Radium (total)	pCi/L	0.809	95% KM Adjusted Gamma UCL	3.856	KM H-UCL
Sulfate	ug/L	5076	95% Chebyshev (Mean, Sd) UCL	485908	95% Chebyshev (Mean, Sd) UCL
Thallium	ug/L	0.28	All ND; Use Max RL	0.363	95% KM (Chebyshev) UCL

Notes:

Recommended UCLs were obtained from ProUCL 5.1.002

Shaded cells represent site UCLs higher than background well UCLs

Abbreviations

BTV - Background threshold value
EPC - Exposure point concentration
KM - Kaplan-Meier
Max - Maximum
ND - Not detected
pCi/L - Picocuries per liter
RL - Reporting limit
Sd - Standard deviation
UCL - Upper confidence limit
ug/L - Micrograms per liter

The toxicity values presented in Table 11 (i.e., noncancer oral RfDs and CSFs) were applied to the ground water evaluation. Total radium was addressed with the higher of the two CSFs for radium-226 and radium-228. These are considered to be two common isotopes of radium, and the CSFs for these two radionuclides are used because there was no total radium SF in the EPA Radionuclide PRG calculator. The most appropriate available cancer CSFs from USEPA (2018b) are based on exposure to tapwater as follows:

Tapwater Ingestion Slope Factors $(pCi)^{-1}$	RA-226	3.85×10^{-10}
	RA-228	***1.04×10^{-9}***
Tapwater Immersion Slope Factors (L/pCi-yr)	RA-226	***1.68×10^{-11}***
	RA-228	8.16×10^{-12}

The bold italic CSFs were used for adult risk calculations. The highest risk estimate produced by USEPA (2018b) for childhood exposure was used for the age and time adjusted childhood-lifetime risk estimate.

Table 21 presents the noncancer hazard and cancer risk estimates for the Lower Ash Pond for the recreational visitor scenario adult and child. Table 22 presents the noncancer hazard and cancer risk estimates for the Upper Ash Pond.

There was no RfD or CSF for sulfate or lead. These two analytes were compared to drinking water standards. Sulfate was compared to its secondary maximum contaminant level (SMCL), and lead was compared to the maximum contaminant level (MCL).

- Maximum concentrations of lead were below screening levels at the LAP, and lead did not carry forward into the baseline evaluation. The baseline EPC for lead at the UAP was below drinking water standards, and lead was not evaluated further. Lead concentrations were not evaluated with the Integrated Exposure Uptake Biokinetic (IEUBK) model since the baseline lead EPCs were below drinking water standards.
- Maximum concentrations of sulfate exceeded screening levels at the LAP and UAP. The baseline EPC for sulfate was below the SMCL at the LAP, and exceeded the SMCL at the UAP.

Table 21. Intakes, Hazard and Risk for Lower Ash Pond Ground Water Contaminants of Potential Concern

Noncarcinogenic Intake - Recreational Visitor - Child

Analyte Name	CAS No.	Ground Water EPC	Ground Water/Seep Exposure Pathways		Total Intake
			Ingestion	Dermal Contact	
		(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	0.0005	1.59E-06	8.42E-08	1.67E-06
Arsenic	7440-38-2	0.08927	2.82E-04	1.49E-05	2.97E-04
Boron	7440-42-8	0.984	3.11E-03	1.65E-04	3.27E-03
Cadmium	7440-43-9	0.000752	2.37E-06	1.26E-07	2.50E-06
Cobalt	7440-48-4	0.1297	4.09E-04	8.69E-06	4.18E-04
Fluoride	16984-48-8	0.3565	1.13E-03	5.97E-05	1.18E-03
Lithium	7439-93-2	0.008629	2.72E-05	1.44E-06	2.87E-05
Molybdenum	7439-98-7	0.009672	3.05E-05	1.62E-06	3.21E-05
Total Radium	7440-14-4	6.084	4.21E+02	4.00E-01	4.21E+02
Sulfate	14808-79-8	185	5.83E-01	No Kp	5.83E-01
Thallium	7440-28-0	0.000288	9.09E-07	4.82E-08	9.57E-07

Notes:

EPC - Exposure point concentration
No Kp - No dermal water uptake factor

Radium units are pCi/L for concentration, pCi for ingestion, and pCi-yr/L for immersion (dermal column)

Hazard Quotients - Recreational Visitor - Child

Analyte Name	CAS No.	Ground Water Exposure Pathways		Total HQ
		Ingestion	Dermal Contact	
		(mg/kg-d)	(mg/kg-d)	
Antimony	7440-36-0	4E-03	1E-03	5E-03
Arsenic	7440-38-2	9E-01	5E-02	1E+00
Boron	7440-42-8	2E-02	8E-04	2E-02
Cadmium	7440-43-9	5E-03	5E-03	1E-02
Cobalt	7440-48-4	1E+00	3E-02	1E+00
Fluoride	16984-48-8	3E-02	1E-03	3E-02
Lithium	7439-93-2	1E-02	7E-04	1E-02
Molybdenum	7439-98-7	6E-03	3E-04	6E-03
Total Radium	7440-14-4	No RfD	No RfD	0E+00
Sulfate	14808-79-8	No RfD	No RfD	EPC <SMCL
Thallium	7440-28-0	9E-02	5E-03	1E-01
Total HI				3E+00

Notes:

RfD - Reference dose

SMCL - secondary drinking water standard for SO4=250 mg/L

Noncarcinogenic Intake - Recreational Visitor - Adult

Analyte Name	CAS No.	Ground Water EPC	Ground Water/Seep Exposure Pathways		Total Intake
			Ingestion	Dermal Contact	
		(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	0.00050	4.40E-07	1.22E-07	5.62E-07
Arsenic	7440-38-2	0.08927	7.81E-05	2.16E-05	9.98E-05
Boron	7440-42-8	0.984	8.61E-04	2.38E-04	1.10E-03
Cadmium	7440-43-9	0.000752	6.58E-07	1.82E-07	8.40E-07
Cobalt	7440-48-4	0.1297	1.14E-04	1.26E-05	1.26E-04
Fluoride	16984-48-8	0.36	3.12E-04	8.64E-05	3.98E-04
Lithium	7439-93-2	0.0086	7.55E-06	2.09E-06	9.64E-06
Molybdenum	7439-98-7	0.009672	8.47E-06	2.34E-06	1.08E-05
Total Radium	7440-14-4	6.084	3.11E+03	5.00E+00	3.12E+03
Sulfate	14808-79-8	185	1.62E-01	No Kp	1.62E-01
Thallium	7440-28-0	0.00029	2.52E-07	6.98E-08	3.22E-07

Notes:

EPC - Exposure point concentration
No Kp - No dermal water uptake factor

Radium units are pCi/L for concentration, pCi for ingestion, and pCi-yr/L for immersion (dermal column)

Hazard Quotients - Recreational Visitor - Adult

Analyte Name	CAS No.	Ground Water Exposure Pathways		Total HQ
		Ingestion	Dermal Contact	
		(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	1E-03	2E-03	3E-03
Arsenic	7440-38-2	3E-01	7E-02	3E-01
Boron	7440-42-8	4E-03	1E-03	5E-03
Cadmium	7440-43-9	1E-03	7E-03	9E-03
Cobalt	7440-48-4	4E-01	4E-02	4E-01
Fluoride	16984-48-8	8E-03	2E-03	1E-02
Lithium	7439-93-2	4E-03	1E-03	5E-03
Molybdenum	7439-98-7	2E-03	5E-04	2E-03
Total Radium	7440-14-4	No RfD	No RfD	0E+00
Sulfate	14808-79-8	No RfD	No RfD	EPC <SMCL
Thallium	7440-28-0	3E-02	7E-03	3E-02
Total HI				8E-01

Notes:

RfD - Reference dose

SMCL - secondary drinking water standard for SO4=250 mg/L

Table 21. Intakes, Hazard and Risk for Lower Ash Pond Ground Water Contaminants of Potential Concern, Cont.

Carcinogenic Intake - Recreational Visitor - Child					
Analyte Name	CAS No.	Ground Water EPC	Ground Water/Seep Exposure Pathways		Total Intake
			Ingestion	Dermal Contact	
		(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	0.0005	2.17E-07	4.00E-08	2.56E-07
Arsenic	7440-38-2	0.08927	3.84E-05	7.10E-06	4.55E-05
Boron	7440-42-8	0.984	4.24E-04	7.82E-05	5.02E-04
Cadmium	7440-43-9	0.000752	3.24E-07	5.98E-08	3.83E-07
Cobalt	7440-48-4	0.1297	5.58E-05	4.12E-06	6.00E-05
Fluoride	16984-48-8	0.36	1.53E-04	2.83E-05	1.82E-04
Lithium	7439-93-2	0.008629	3.71E-06	6.86E-07	4.40E-06
Molybdenum	7439-98-7	0.009672	4.16E-06	7.69E-07	4.93E-06
Total Radium	7440-14-4	6.084	3.53E+03	5.40E+00	3.54E+03
Sulfate	14808-79-8	185	7.95E-02	No Kp	7.95E-02
Thallium	7440-28-0	0.000288	1.24E-07	2.29E-08	1.47E-07

Notes:
EPC - Exposure point concentration
No Kp - No dermal water uptake factor
Radium units are pCi/L for concentration, pCi for ingestion, and pCi-yr/L for immersion (dermal column)

Cancer Risk - Recreational Visitor - Child				
Analyte Name	CAS No.	Surface Water Exposure Pathways		Total Cancer Risk
		Ingestion	Dermal Contact	
Antimony	7440-36-0	No CSF	No CSF	0E+00
Arsenic	7440-38-2	6E-05	1E-05	7E-05
Boron	7440-42-8	No CSF	No CSF	0E+00
Cadmium	7440-43-9	No CSF	No CSF	0E+00
Cobalt	7440-48-4	No CSF	No CSF	0E+00
Fluoride	16984-48-8	No CSF	No CSF	0E+00
Lithium	7439-93-2	No CSF	No CSF	0E+00
Molybdenum	7439-98-7	No CSF	No CSF	0E+00
Total Radium	7440-14-4	1E-05	1E-10	1E-05
Sulfate	14808-79-8	No CSF	No CSF	NA
Thallium	7440-28-0	No CSF	No CSF	0E+00
Cumulative Cancer Risk				8E-05

Notes:
CSF - Cancer slope factor *Shaded cells- exceed cancer risk of 1x10^{-6}*

Carcinogenic Intake - Recreational Visitor - Adult					
Analyte Name	CAS No.	Ground Water EPC	Ground Water/Seep Exposure Pathways		Total Intake
			Ingestion	Dermal Contact	
		(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	0.0005	1.26E-07	3.48E-08	1.61E-07
Arsenic	7440-38-2	0.08927	2.23E-05	6.18E-06	2.85E-05
Boron	7440-42-8	0.984	2.46E-04	6.81E-05	3.14E-04
Cadmium	7440-43-9	0.000752	1.88E-07	5.21E-08	2.40E-07
Cobalt	7440-48-4	0.1297	3.24E-05	3.59E-06	3.60E-05
Fluoride	16984-48-8	0.36	8.92E-05	2.47E-05	1.14E-04
Lithium	7439-93-2	0.008629	2.16E-06	5.97E-07	2.76E-06
Molybdenum	7439-98-7	0.009672	2.42E-06	6.70E-07	3.09E-06
Total Radium	7440-14-4	6.084	3.11E+03	5.00E+00	3.12E+03
Sulfate	14808-79-8	185	4.62E-02	No Kp	4.62E-02
Thallium	7440-28-0	0.000288	7.20E-08	1.99E-08	9.20E-08

Notes:
EPC - Exposure point concentration
No Kp - No dermal water uptake factor
Radium units are pCi/L for concentration, pCi for ingestion, and pCi-yr/L for immersion (dermal column)

Cancer Risk - Recreational Visitor - Adult				
Analyte Name	CAS No.	Surface Water Exposure Pathways		Total Cancer Risk
		Ingestion	Dermal Contact	
Antimony	7440-36-0	No CSF	No CSF	0E+00
Arsenic	7440-38-2	3E-05	9E-06	4E-05
Boron	7440-42-8	No CSF	No CSF	0E+00
Cadmium	7440-43-9	No CSF	No CSF	0E+00
Cobalt	7440-48-4	No CSF	No CSF	0E+00
Fluoride	16984-48-8	No CSF	No CSF	0E+00
Lithium	7439-93-2	No CSF	No CSF	0E+00
Molybdenum	7439-98-7	No CSF	No CSF	0E+00
Total Radium	7440-14-4	3E-06	8E-11	3E-06
Sulfate	14808-79-8	No CSF	No CSF	NA
Thallium	7440-28-0	No CSF	No CSF	0E+00
Cumulative Cancer Risk				5E-05

Notes:
CSF - Cancer slope factor *Shaded cells- exceed cancer risk of 1x10^{-6}*

Table 22. Intakes, Hazard and Risk for Upper Ash Pond Ground Water Contaminants of Potential Concern

Noncarcinogenic Intake - Recreational Visitor - Child					
Analyte Name	CAS No.	Ground Water EPC	Ground Water/Seep Exposure Pathways		Total Intake
			Ingestion	Dermal Contact	
		(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	0.00045	1.41E-06	7.48E-08	1.49E-06
Arsenic	7440-38-2	0.02073	6.54E-05	3.47E-06	6.89E-05
Barium	7440-39-3	0.1233	3.89E-04	2.06E-05	4.10E-04
Beryllium	7440-41-7	0.00314	9.91E-06	5.26E-07	1.04E-05
Boron	7440-42-8	1.933	6.10E-03	3.24E-04	6.42E-03
Cadmium	7440-43-9	0.000424	1.34E-06	7.10E-08	1.41E-06
Cobalt	7440-48-4	0.03236	1.02E-04	2.17E-06	1.04E-04
Fluoride	16984-48-8	0.3934	1.24E-03	6.59E-05	1.31E-03
Lead	7439-92-1	0.003944	1.24E-05	6.60E-08	1.25E-05
Lithium	7439-93-2	0.069	2.17E-04	1.15E-05	2.29E-04
Molybdenum	7439-98-7	0.0284	8.97E-05	4.76E-06	9.44E-05
Total Radium	7440-14-4	3.86	2.67E+02	2.54E-01	2.67E+02
Sulfate	14808-79-8	486	1.53E+00	No Kp	1.53E+00
Thallium	7440-28-0	0.00036	1.15E-06	6.08E-08	1.21E-06

Notes:

EPC - Exposure point concentration

No Kp - No dermal water uptake factor

Radium units are pCi/L for concentration, pCi for ingestion, and pCi-yr/L for immersion (dermal column)

Hazard Quotients - Recreational Visitor - Child				
Analyte Name	CAS No.	Ground Water Exposure Pathways		Total HQ
		Ingestion	Dermal Contact	
		(mg/kg-d)	(mg/kg-d)	
Antimony	7440-36-0	3.5E-03	1.2E-03	5E-03
Arsenic	7440-38-2	2.2E-01	1.2E-02	2E-01
Barium	7440-39-3	1.9E-03	1.5E-03	3E-03
Beryllium	7440-41-7	5.0E-03	3.8E-02	4E-02
Boron	7440-42-8	3.1E-02	1.6E-03	3E-02
Cadmium	7440-43-9	2.7E-03	2.8E-03	6E-03
Cobalt	7440-48-4	3.4E-01	7.2E-03	3E-01
Fluoride	16984-48-8	3.1E-02	1.6E-03	3E-02
Lead	7439-92-1	No RfD	No RfD	EPC<MCL
Lithium	7439-93-2	1.1E-01	5.8E-03	1E-01
Molybdenum	7439-98-7	1.8E-02	9.5E-04	2E-02
Total Radium	7440-14-4	No RfD	No RfD	0E+00
Sulfate	14808-79-8	No RfD	No RfD	EPC >SMCL
Thallium	7440-28-0	1.1E-01	6.1E-03	1E-01
Total HI				1E+00

Notes:

RfD - Reference dose

SMCL - secondary drinking water standard for SO4=250 mg/L

MCL - drinking water standard for Pb = 0.015 mg/L

Noncarcinogenic Intake - Recreational Visitor - Adult					
Analyte Name	CAS No.	Ground Water EPC	Ground Water/Seep Exposure Pathways		Total Intake
			Ingestion	Dermal Contact	
		(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	0.0004	3.91E-07	1.08E-07	5.00E-07
Arsenic	7440-38-2	0.0207	1.81E-05	5.02E-06	2.32E-05
Barium	7440-39-3	0.123	1.08E-04	2.99E-05	1.38E-04
Beryllium	7440-41-7	0.0031	2.75E-06	7.61E-07	3.51E-06
Boron	7440-42-8	1.933	1.69E-03	4.68E-04	2.16E-03
Cadmium	7440-43-9	0.00042	3.71E-07	1.03E-07	4.74E-07
Cobalt	7440-48-4	0.032	2.83E-05	3.14E-06	3.15E-05
Fluoride	16984-48-8	0.39	3.44E-04	9.53E-05	4.40E-04
Lead	7439-92-1	0.0039	3.45E-06	9.56E-08	3.55E-06
Lithium	7439-93-2	0.069	6.02E-05	1.67E-05	7.69E-05
Molybdenum	7439-98-7	0.0284	2.49E-05	6.88E-06	3.18E-05
Total Radium	7440-14-4	3.86	1.97E+03	3.17E+00	1.97E+03
Sulfate	14808-79-8	486	4.25E-01	No Kp	4.25E-01
Thallium	7440-28-0	0.00036	3.18E-07	8.79E-08	4.06E-07

Notes:

EPC - Exposure point concentration

No Kp - No dermal water uptake factor

Radium units are pCi/L for concentration, pCi for ingestion, and pCi-yr/L for immersion (dermal column)

Hazard Quotients - Recreational Visitor - Adult				
Analyte Name	CAS No.	Ground Water Exposure Pathways		Total HQ
		Ingestion	Dermal Contact	
		(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	9.8E-04	1.8E-03	3E-03
Arsenic	7440-38-2	6.0E-02	1.7E-02	8E-02
Barium	7440-39-3	5.4E-04	2.1E-03	3E-03
Beryllium	7440-41-7	1.4E-03	5.4E-02	6E-02
Boron	7440-42-8	8.5E-03	2.3E-03	1E-02
Cadmium	7440-43-9	7.4E-04	4.1E-03	5E-03
Cobalt	7440-48-4	9.4E-02	1.0E-02	1E-01
Fluoride	16984-48-8	8.6E-03	2.4E-03	1E-02
Lead	7439-92-1	No RfD	No RfD	EPC<MCL
Lithium	7439-93-2	3.0E-02	8.3E-03	4E-02
Molybdenum	7439-98-7	5.0E-03	1.4E-03	6E-03
Total Radium	7440-14-4	No RfD	No RfD	0E+00
Sulfate	14808-79-8	No RfD	No RfD	EPC >SMCL
Thallium	7440-28-0	3.2E-02	8.8E-03	4E-02
Total HI				4E-01

Notes:

RfD - Reference dose

MCL - primary or secondary drinking water standard

Table 22. Intakes, Hazard and Risk for Upper Ash Pond Ground Water Contaminants of Potential Concern, Cont.

Carcinogenic Intake - Recreational Visitor - Child					
Analyte Name	CAS No.	Ground Water EPC	Ground Water/Seep Exposure Pathways		Total Intake
			Ingestion	Dermal Contact	
		(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	0.00045	1.92E-07	3.55E-08	2.28E-07
Arsenic	7440-38-2	0.021	8.92E-06	1.65E-06	1.06E-05
Barium	7440-39-3	0.123	5.31E-05	9.80E-06	6.29E-05
Beryllium	7440-41-7	0.0031	1.35E-06	2.50E-07	1.60E-06
Boron	7440-42-8	1.93	8.32E-04	1.54E-04	9.86E-04
Cadmium	7440-43-9	0.00042	1.83E-07	3.37E-08	2.16E-07
Cobalt	7440-48-4	0.0324	1.39E-05	1.03E-06	1.50E-05
Fluoride	16984-48-8	0.39	1.69E-04	3.13E-05	2.01E-04
Lead	7439-92-1	0.0039	1.70E-06	3.14E-08	1.73E-06
Lithium	7439-93-2	0.069	2.96E-05	5.47E-06	3.51E-05
Molybdenum	7439-98-7	0.0284	1.22E-05	2.26E-06	1.45E-05
Total Radium	7440-14-4	3.86	2.24E+03	3.42E+00	2.24E+03
Sulfate	14808-79-8	486	2.09E-01	No Kp	2.09E-01
Thallium	7440-28-0	0.0004	1.56E-07	2.89E-08	1.85E-07

Notes:
EPC - Exposure point concentration
No Kp - No dermal water uptake factor
Radium units are pCi/L for concentration, pCi for ingestion, and pCi-yr/L for immersion (dermal column)

Cancer Risk - Recreational Visitor - Child				
Analyte Name	CAS No.	Surface Water Exposure Pathways		Total Cancer Risk
		Ingestion	Dermal Contact	
Antimony	7440-36-0	No CSF	No CSF	0E+00
Arsenic	7440-38-2	1.3E-05	2.5E-06	2E-05
Barium	7440-39-3	No CSF	No CSF	0E+00
Beryllium	7440-41-7	No CSF	No CSF	0E+00
Boron	7440-42-8	No CSF	No CSF	0E+00
Cadmium	7440-43-9	No CSF	No CSF	0E+00
Cobalt	7440-48-4	No CSF	No CSF	0E+00
Fluoride	16984-48-8	No CSF	No CSF	0E+00
Lead	7439-92-1	No CSF	No CSF	0E+00
Lithium	7439-93-2	No CSF	No CSF	0E+00
Molybdenum	7439-98-7	No CSF	No CSF	0E+00
Total Radium	7440-14-4	6.8E-06	7.9E-11	7E-06
Sulfate	14808-79-8	No CSF	No CSF	0E+00
Thallium	7440-28-0	No CSF	No CSF	0E+00
Cumulative Cancer Risk				2E-05

Notes:
CSF - Cancer slope factor
Shaded cells- exceed cancer risk of $1x10^{-6}$

Carcinogenic Intake - Recreational Visitor - Adult					
Analyte Name	CAS No.	Ground Water EPC	Ground Water/Seep Exposure Pathways		Total Intake
			Ingestion	Dermal Contact	
		(mg/L)	(mg/kg-d)	(mg/kg-d)	(mg/kg-d)
Antimony	7440-36-0	0.00045	1.12E-07	3.09E-08	1.43E-07
Arsenic	7440-38-2	0.021	5.18E-06	1.44E-06	6.62E-06
Barium	7440-39-3	0.123	3.08E-05	8.54E-06	3.94E-05
Beryllium	7440-41-7	0.0031	7.86E-07	2.17E-07	1.00E-06
Boron	7440-42-8	1.93	4.83E-04	1.34E-04	6.17E-04
Cadmium	7440-43-9	0.00042	1.06E-07	2.94E-08	1.35E-07
Cobalt	7440-48-4	0.032	8.09E-06	8.96E-07	8.99E-06
Fluoride	16984-48-8	0.39	9.84E-05	2.72E-05	1.26E-04
Lead	7439-92-1	0.0039	9.86E-07	2.73E-08	1.01E-06
Lithium	7439-93-2	0.069	1.72E-05	4.76E-06	2.20E-05
Molybdenum	7439-98-7	0.0284	7.11E-06	1.97E-06	9.07E-06
Total Radium	7440-14-4	3.86	1.97E+03	3.17E+00	1.97E+03
Sulfate	14808-79-8	486	1.22E-01	No Kp	1.22E-01
Thallium	7440-28-0	0.0004	9.08E-08	2.51E-08	1.16E-07

Notes:
EPC - Exposure point concentration
No Kp - No dermal water uptake factor
Radium units are pCi/L for concentration, pCi for ingestion, and pCi-yr/L for immersion (dermal column)

Cancer Risk - Recreational Visitor - Adult				
Analyte Name	CAS No.	Surface Water Exposure Pathways		Total Cancer Risk
		Ingestion	Dermal Contact	
Antimony	7440-36-0	No CSF	No CSF	0E+00
Arsenic	7440-38-2	7.8E-06	2.2E-06	1E-05
Barium	7440-39-3	No CSF	No CSF	0E+00
Beryllium	7440-41-7	No CSF	No CSF	0E+00
Boron	7440-42-8	No CSF	No CSF	0E+00
Cadmium	7440-43-9	No CSF	No CSF	0E+00
Cobalt	7440-48-4	No CSF	No CSF	0E+00
Fluoride	16984-48-8	No CSF	No CSF	0E+00
Lead	7439-92-1	No CSF	No CSF	0E+00
Lithium	7439-93-2	No CSF	No CSF	0E+00
Molybdenum	7439-98-7	No CSF	No CSF	0E+00
Total Radium	7440-14-4	2.1E-06	5.3E-11	2E-06
Sulfate	14808-79-8	No CSF	No CSF	0E+00
Thallium	7440-28-0	No CSF	No CSF	0E+00
Cumulative Cancer Risk				1E-05

Notes:
CSF - Cancer slope factor
Shaded cells- exceed cancer risk of $1x10^{-6}$

6.1.2. Ecological Risk Assessment for Ground Water

Ecological receptors could potentially be exposed to ground water discharging at seeps and springs where wetlands and surface water occur downgradient of the ash ponds. While often surface water dilution could reduce potential impacts in areas outside of a mixing zone, ground water discharge could still impact benthic communities and areas along embankments that juvenile fish use as refugia.

Maximum detected concentrations in ground water were compared to ecological screening levels. Many constituents exceeded benchmarks established for aquatic life (Table 23 and 24). At the LAP, the maximum HQ for arsenic was just above 1 for comparison to the VA and EPA chronic aquatic life criteria, and selenium concentrations also exceeded the EPA chronic criterion (Table 23). Cadmium, chromium, lead, and selenium exceeded both the Virginia and USEPA chronic aquatic life criteria at the UAP (Table 24).

Ground water at the LAP also exceeded a 500 mg/L recommended TDS level protective of crops (Table 23). TDS in ground water at the UAP was elevated and exceeded the EPA chronic water quality criterion narrative standard for aquatic life adjusted with an uncertainty factor of 10 to be protective of multiple species, and exceeded values that could be toxic in irrigation water for crops (Table 24).

Other analytes exceeded other surface water criteria (Tables 23 and 24) that are not from USEPA or VA that are “to be considered values” (TBVs) or concentrations indicative of toxicity to aquatic life used in the absence of regulations or guidelines. Barium, beryllium, boron, cobalt, molybdenum, and thallium concentrations exceeded these other surface water criteria or TBVs based on aquatic life toxicity at the LAP (Table 23) and UAP (Table 24). In addition, lithium concentrations at the UAP exceeded the other surface water criterion or TBV (Table 24).

The evaluation suggests toxicity to aquatic life and plants. Ground water could negatively affect benthic and aquatic life communities near the point of discharge based on the comparison of maximum detected concentrations to criteria and benchmark values.

6.1.3. Uncertainty Analysis for Ground Water Data

Ground Water Data

The ground water data have multiple sampling events over the course of a year, making them fairly robust as a snapshot in time. The multiple sampling events reduce the uncertainty in the risk assessment. However, groundwater samples do not always meet the definition of independent samples required for many statistical tests because the value of one sample is influenced by previously collected information, especially if sampling points are close in time or ground water flow rates are slow. Ground water data therefore have the risk of being repeated measures samples.

There are also too few background wells, and these wells are potentially contaminated by on-site sources or radial flow from the ash ponds. There is also uncertainty with aquifers because there are few samples in both aquifers at each location.

Dominion’s reports did not identify plume boundaries. This adds uncertainty to the analysis. Maximum concentrations of CCR and other analytes were used to tentatively identify plume wells. More data and/or evaluation of existing data regarding aquifer characteristics would be required to fully identify plume boundaries since there seem to be gaps in the potentiometric surface maps, particularly to the east of the LAP where it is presumed ground water moves towards the James River.

Table 23. Comparison of Maximum Lower Ash Pond Impacted Ground Water Concentrations to Water Quality Criteria

Analyte	CAS	Ground Water EPC		Water Quality Criteria				Hazard Quotients		
		Maximum Detected Total Value (mg/L)	Dissolved Basis (mg/L)	VA Chronic Aquatic Life (mg/L)	EPA Chronic AWQC (mg/L)	Other Aquatic Life SW SL and Basis (mg/L)		VA Aquatic Life Chronic HQ	EPA Aquatic Life Chronic HQ	Other SW HQ
Antimony	7440-36-0	0.0022	0.0022	NV	NV	0.03	Draft NAWQC Chronic	NV	NV	0.1
Arsenic	7440-38-2	0.177	0.177	0.15	0.15	NA	NA	1	1	NA
Barium	7440-39-3	0.34	0.34	NV	NV	0.0039	OSWER Tier II Secondary	NV	NV	87
Beryllium	7440-41-7	0.003	0.003	NV	NV	0.00053	EPA R4 Chronic	NV	NV	6
Boron	7440-42-8	1.81	1.81	NV	NV	0.0016	SW EPA R6 FW	NV	NV	1131
Cadmium	7440-43-9	0.0024	0.0022	0.0011	0.00072	NA	NA	2	3	NA
Calcium	7440-70-2	85.8	85.8	NV	NV	NV	NV	NV	NV	NV
Chloride	16887-00-6	200	200	230	230	NA	NA	0.9	0.9	NA
Chromium	16065-83-1	0.0211	0.018	0.074	0.074	NA	NA	0.24	0.24	NA
Cobalt	7440-48-4	0.26	0.26	NV	NV	0.003	OSWER Tier II Secondary	NV	NV	87
Fluoride	16984-48-8	0.72	0.72	NV	NV	NV	NA	NV	NV	NV
Lead	7439-92-1	0.00079	0.0006	0.011	0.003	NA	NA	0.06	0.2	NA
Lithium	7439-93-2	0.0157	0.0157	NV	NV	0.014	SW EPA R6 FW	NV	NV	1
Mercury	7487-94-7	0.00011	0.00011	0.00077	0.00077	NA	NA	0.1	0.1	NA
Molybdenum	7439-98-7	0.022	0.022	NV	NV	0.000034	Australian and New Zealand	NV	NV	647
Selenium	7782-49-2	0.0033	0.0033	0.005	0.0015	NA	NA	0.7	2	NA
Sulfate	14808-79-8	380	380	NV	NV	NV	NV	NV	NV	NV
TDS	NA	720	720	NV	1000	NA	NA	NV	1	NA
Thallium	7440-28-0	0.00061	0.00061	NV	NV	0.00003	Australian and New Zealand	NV	NV	20
Total Radium	7440-14-4	6.52	6.52	NV	NV	NV		NV	NV	NV
Hazard Index								5	9	1979

Notes:

AWQC results based on an EPC may differ from those on a sample by sample analysis because maximum concentrations are not always found where hardness is minimal

■ The dissolved solids criterion was derived from the narrative standard. It states that 10,000 mg/L are "survivable by a few species" of aquatic life. Divided by an uncertainty factor of 10 for "survivable by a few species" to a presumed no effect level for many species. Note that water with >500 mg/L may adversely affect crops if used for irrigation, so this level could still be toxic to plants growing nearby.

Red highlighted cells have HQs>1 and indicate the analyte is a contaminant of potential concern (COPC) for further evaluation

Blue highlighted cells represent hardness dependent criteria shown at 100 mg/L CaCO3. They are dissolved form.

Yellow shaded cells - concentration corrected for fraction dissolved: C_{TOTAL}* f_D=$C_{DISSOLVED}$, where the chronic freshwater conversion factor is used for f_D from USEPA (1996b)

Total Radium is in units of pCi/L

Abbreviations:

AWQC - ambient water quality criteria for the protection of freshwater aquatic life and their uses
HQ - hazard quotient
mg/L - milligram per liter
NA - not applicable
NV - no value

Source:

Va Chronic	9VAC25-260-140. Criteria for surface water. http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140
EPA Chronic AWQC	National Recommended Water Quality Criteria - Aquatic Life Criteria Table. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table
Other SW Criteria	If no AWQC, value is lowest output from RAIS Ecological Benchmark Tool The Risk Assessment Information System https://rais.ornl.gov/tools/eco_search.php RAIS. 2016. Ecological Benchmark Tool. Accessed November 18, 2016. https://rais.ornl.gov/tools/eco_search.php - See Appendix A.4 for references and information for the basis of the RAIS surface water benchmarks

Table 24. Comparison of Maximum Upper Ash Pond Impacted Ground Water Concentrations to Water Quality Criteria

Analyte	CAS	Ground Water EPC		Water Quality Criteria				Hazard Quotients		
		Maximum Detected Total Value (mg/L)	Dissolved Basis (mg/L)	VA Chronic Aquatic Life (mg/L)	EPA Chronic AWQC (mg/L)	Other Aquatic Life SW SL and Basis (mg/L)		VA Aquatic Life Chronic HQ	EPA Aquatic Life Chronic HQ	Other SW HQ
Antimony	7440-36-0	0.0029	0.0029	NV	NV	0.03	Draft NAWQC Chronic	NV	NV	0.1
Arsenic	7440-38-2	0.11	0.11	0.15	0.15	NA	NA	0.73	0.73	NA
Barium	7440-39-3	0.83	0.83	NV	NV	0.0039	OSWER Tier II Secondary	NV	NV	213
Beryllium	7440-41-7	0.034	0.034	NV	NV	0.00053	EPA R4 Chronic	NV	NV	64
Boron	7440-42-8	3.02	3.02	NV	NV	0.0016	SW EPA R6 FW	NV	NV	1888
Cadmium	7440-43-9	0.002	0.0018	0.0011	0.00072	NA	NA	1.60	2.53	NA
Calcium	7440-70-2	397	397.0	NV	NV	NV	NV	NV	NV	NV
Chloride	16887-00-6	219	219	230	230	NA	NA	1.0	1.0	NA
Chromium	16065-83-1	0.19	0.163	0.074	0.074	NA	NA	2.20	2.20	NA
Cobalt	7440-48-4	0.135	0.135	NV	NV	0.003	OSWER Tier II Secondary	NV	NV	45
Fluoride	16984-48-8	1.1	1.1	NV	NV	NV	NA	NV	NV	NV
Lead	7439-92-1	0.048	0.0380	0.011	0.003	NA	NA	3.55	15.1	NA
Lithium	7439-93-2	0.17	0.17	NV	NV	0.014	SW EPA R6 FW	NV	NV	12
Mercury	7487-94-7	0.00012	0.00012	0.00077	0.00077	NA	NA	0.2	0.2	NA
Molybdenum	7439-98-7	0.0891	0.0891	NV	NV	0.000034	Australia and New Zealand	NV	NV	2621
Selenium	7782-49-2	0.0131	0.0131	0.005	0.0015	NA	NA	2.6	9	NA
Sulfate	14808-79-8	820	820	NV	NV	NV	NV	NV	NV	NV
TDS	NA	1600	1600	NV	1000	NA	NA	NV	2	NA
Thallium	7440-28-0	0.002	0.002	NV	NV	0.00003	Australia and New Zealand	NV	NV	67
Total Radium	7440-14-4	10.7	10.7	NV	NV	NV		NV	NV	NV
Hazard Index								12	32	4909

Notes:

AWQC results based on an EPC may differ from those on a sample by sample analysis because maximum concentrations are not always found where hardness is minimal

■ The dissolved solids criterion was derived from the narrative standard. It states that 10,000 mg/L are "survivable by a few species" of aquatic life. Divided by an uncertainty factor of 10 for "survivable by a few species" to a presumed no effect level for many species. Note that water with >500 mg/L may adversely affect crops if used for irrigation, so this level could still be toxic to plants growing nearby.

Red highlighted cells have HQs>1 and indicate the analyte is a contaminant of potential concern (COPC) for further evaluation

Blue highlighted cells represent hardness dependent criteria shown at 100 mg/L CaCO3. They are dissolved form.

Yellow shaded cells - concentration corrected for fraction dissolved: $C_{TOTAL} * f_D = C_{DISSOLVED}$, where the chronic freshwater conversion factor is used for f_D from USEPA (1996b)

Total Radium is in units of pCi/L

Abbreviations:

AWQC - ambient water quality criteria for the protection of freshwater aquatic life and their uses
HQ - hazard quotient
mg/L - milligram per liter
NA - not applicable
NV - no value

Source:

Va Chronic	9VAC25-260-140. Criteria for surface water. http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140
EPA AWQC	National Recommended Water Quality Criteria - Aquatic Life Criteria Table. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table
Other SW Criteria	If no AWQC, value is lowest output from RAIS Ecological Benchmark Tool The Risk Assessment Information System https://rais.ornl.gov/tools/eco_search.php RAIS. 2016. Ecological Benchmark Tool. Accessed November 18, 2016. https://rais.ornl.gov/tools/eco_search.php - See Appendix A.4 for references and information for the basis of the RAIS surface water benchmarks

Potential Effect of Repeated Measures

Multiple samples separated by only one month may not represent true statistically and physically independent samples. This means that statistical tests, such as analysis of variance (ANOVA) should adjust for this with a mathematical/statistical approach called repeated measures. There is no method in ProUCL to adjust for repeated measures, although other statistical programs may account for this. The UCLs do not account for this, and therefore the UCL concentrations may be artificially low and not conservative enough.

Background Wells

The overall effect of low numbers of background wells, particularly for the Upper Ash Pond, is to increase uncertainty in the risk assessment results. The number of background wells is limited to three for the Upper Ash Pond (MW-29, 30, and 35) and two for the Lower Ash Pond (MW-29 and 35). The background wells are potentially impacted by site-related activities and radial ground water flow. This could artificially elevate background concentrations above true background, reducing the apparent inherent risk due to the site. The overall effect of this is to increase uncertainty in the risk results, and potentially bias results low.

Ground Water Discharge to Surface Water

Ground water is likely discharging to surface water given the shallow nature of ground water. The ground water data support previous assumptions in this analysis that surface water is being impacted by the site. To further support this, ground water data from MW13 were compared to surface water data for Red Cove. Surface water data for an area distant from the site, Osborne Landing, are also included (Figure 10).

The surface water samples from Red Cove closely track the pattern observed in ground water at MW-13, close to the Red Cove surface water sampling point, suggesting a ground water discharge effect. In contrast, the more distant reference sample looks more different from both Red Cove and MW-13. This link between ground water and surface water reduces uncertainty in the risk assessment results and conclusions for surface water and sediment.

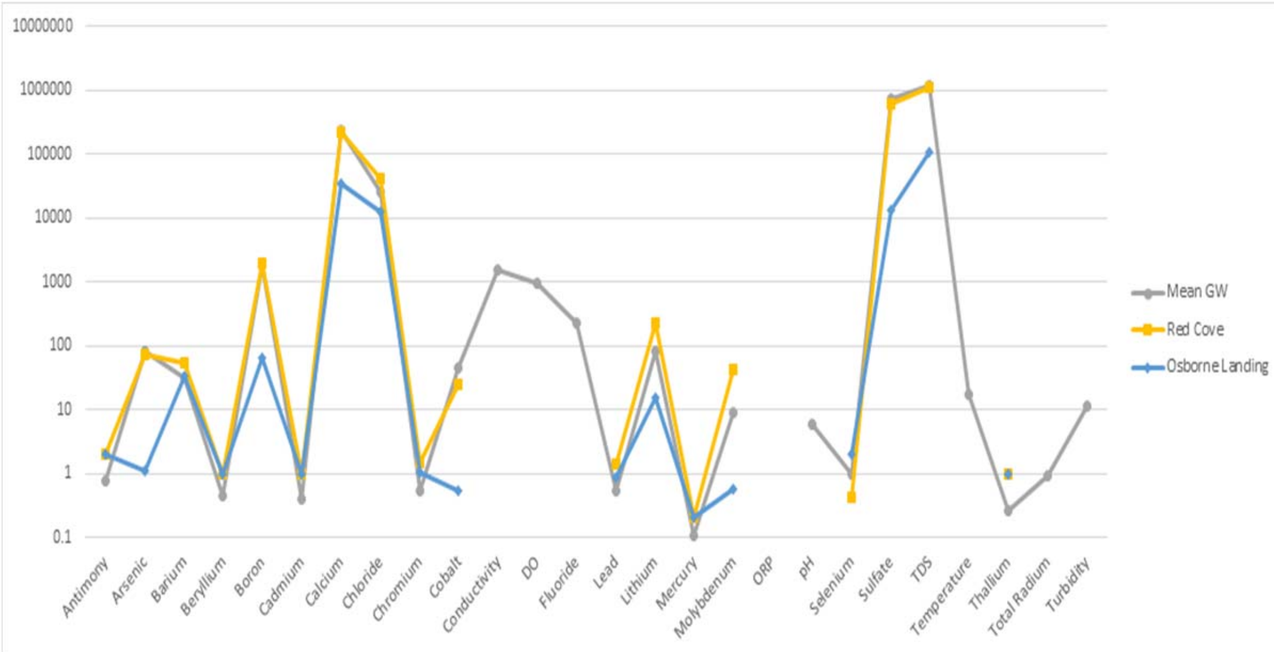


Figure 10. Comparison of MW-13 Ground Water Data to Surface Water Data from Red Cove and a Reference Area.

7. Conclusions

There are elevated noncancer hazards and cancer risks for recreational visitors who interact with areas where contamination from the coal ash ponds is migrating into Dutch Gap Conservation Area, or ingest plants or fish from these areas. Ecological receptors are also threatened by site conditions. These risk estimates exceed target and acceptable risk levels, and suggest that remediation is necessary to halt the flow of contamination from the coal ash ponds into the Dutch Gap Conservation Area, although much more work needs to be done to fully delineate and understand the risks site-wide.

Surface water samples from Red Cove and other locations downgradient of the Upper and Lower Ash Ponds have higher concentrations of numerous analytes relative to an unimpacted reference area (Figure 5). Sediment (Table 6) and surface water (Table 7) exposure pathways indicate elevated ecological risks.

The ground water upgradient (i.e., background) wells may be impacted by the site based on their locations near site-related sources such as the railroads tracks or metal holding pond, and because of radial ground water flow patterns, and therefore concentrations of constituents in these wells is artificially high and not representative of true background. This would reduce the likelihood of being able to discern site-related impacts because background wells have artificially high concentrations of CCR and other constituents. While the evaluation of ground water data comparing samples from the compliance monitoring event in September 2017 for the background to downgradient wells indicates ground water is in fact impacted by the Ash Ponds (Figures 6, 7, 8, and 9), the perceived impacts could be higher if data from unimpacted background wells were available.

Since this risk assessment focuses on areas where coal ash contamination is migrating into public lands and public waters, more widespread sampling and evaluation could be performed to better understand risks to visitors across the entire site. It is important to note that only recreational visitors, which are intermittent receptors, were evaluated in the human health risk assessment. If the area was ever developed for residential use, human health risks would be even higher because residents would be exposed more frequently. Workers also are exposed more frequently, and also would likely be at higher risk levels than identified for recreational visitors. For example, workers in the park who are there on a regular basis would have higher exposure rates than an intermittent recreational visitor. In addition, several potentially complete pathways were not included in this risk assessment, including inhalation of fugitive dust generating from the ash ponds themselves, or inhalation of fugitive dust from nearby surface soils or dry sediments that received site-related metals or inorganics contamination. These pathways could further increase the risk present at the site.

Importantly, the data indicate that contaminated ground water is not confined to Dominion’s property. The ground water potentiometric surface at both Ash Ponds indicates that ground water is likely discharging the short distance from the Ash Ponds to the adjacent surface water, and ultimately the James River (Aquilogic 2018, Dominion 2018a, Dominion 2018b). Surface water concentrations appear to follow groundwater concentrations, and be higher than an upgradient reference area, for many analytes (Figure 10).

Given these conditions (i.e., the documented contamination, the likelihood that background is elevated due to site-related influences, ground water flow into public lands, ground water discharge into surface waters, and elevated risk estimates for surface water exposure pathways), there is no valid basis for Dominion’s claim that “the data do not indicate that ground water from the Upper Ash Pond is impacting public drinking water supplies or presenting an environmental risk” (Dominion 2018b). Even though there may be no current residential or industrial receptors using existing wells as a drinking water source, ground water should be considered impacted and migrating beyond site boundaries. This ground water could be contacted by recreationalvisitors, as noted in Section 5.3.1, because the data indicate that contaminated ground water is discharging to surface water. In addition, environmental risk in surface water was identified to various ecological receptors. Impacts to surface water identified in Section 5.3.2 may be associated with discharging ground water as well as other migration pathways from the ash ponds.

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APPENDIX A. SCREENING LEVELS AND CRITERIA

APPENDIX A.1 USEPA AWQC Hardness Equations

Conversion Factors for Dissolved Metals

Metal	Freshwater CMC	Freshwater CCC	Saltwater CMC	Saltwater CCC
Arsenic	1.000	1.000	1.000	1.000
Cadmium	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]	0.994	0.994
Chromium III	0.316	0.860	—	—
Chromium VI	0.982	0.962	0.993	0.993
Copper	0.960	0.960	0.83	0.83
Lead	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]	0.951	0.951
Mercury	0.85	0.85	0.85	0.85
Nickel	0.998	0.997	0.990	0.990
Selenium	—	—	0.998	0.998
Silver	0.85	—	0.85	—
Zinc	0.978	0.986	0.946	0.946

Parameters for Calculating Hardness-Dependent Freshwater Dissolved Metals Criteria

Chemical	mA	bA	mC	bC	Freshwater Conversion Factors (CF)	
					CMC	CCC
Cadmium	0.9789	-3.866	0.7977	-3.909	1.136672-[(*ln*hardness)(0.041838)]	1.101672-[(*ln*hardness)(0.041838)]
Chromium III	0.8190	3.7256	0.8190	0.6848	0.316	0.860
Copper	0.9422	-1.700	0.8545	-1.702	0.960	0.960
Lead	1.273	-1.460	1.273	-4.705	1.46203-[(*ln*hardness)(0.145712)]	1.46203-[(*ln*hardness)(0.145712)]
Nickel	0.8460	2.255	0.8460	0.0584	0.998	0.997
Silver	1.72	-6.59	—	—	0.85	—
Zinc	0.8473	0.884	0.8473	0.884	0.978	0.986

Hardness-dependant metals' criteria may be calculated from the following:

Acute (ug/L): CMC (dissolved) = exp{mA [*ln*(hardness)]+ bA} (CF)

Chronic (ug/L): CCC (dissolved) = exp{mC [ln(hardness)]+ bC} (CF)

Source:

USEPA. 2016. National Recommended Water Quality Criteria - Aquatic Life Criteria Table. October 20, 2016. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table

Appendix A.2 Virginia Hardness Dependent Metal Equations

Analyte	WER	Chronic Criterion Equation	Value at 100 mg/L CaCO3 (ug/L)	Value at 100 mg/L CaCO3 (mg/L)
Cadmium	1	$= WER^* \; [e^{\{0.7852[In(hardness)] – 3.490\}}]$	1.1	0.0011
Chromium III	1	$= WER^* \; [e^{\{0.8190[In(hardness)]+0.6848\}}] * (CF_c \text{ of } 0.860)$	74	0.074
Copper	1	$= WER^* \; [e^{\{0.8545[In(hardness)]-1.702\}}] * (CF_c \text{ of } 0.960)$	9	0.009
Lead	1	$= WER * [e^{\{1.273[In(hardness)]-3.259\}}]$	14	0.014
Nickel	1	$= WER^* \; [e^{\{0.8460[In(hardness)] - 0.8840\}}] * (CF_c \text{ of } 0.997)$	20	0.020
Zinc	1	$= WER \; [e^{\{0.8473[In(hardness)]+0.884\}}] * (CF_c \text{ of } 0.986)$	100	0.1

Notes:

The minimum hardness allowed for use in the equation below shall be 25 and the maximum hardness shall be 400 even when the actual ambient hardness is less than 25 or greater than 400.

Four-day average concentration not to be exceeded more than once every 3 years on the average, unless otherwise noted.

Acute and chronic saltwater and freshwater aquatic life criteria apply to the biologically available form of the metal and apply as a function of the pollutant's water effect ratio (WER) as defined in 9VAC25-260-140 F (WER X criterion). Metals measured as dissolved shall be considered to be biologically available, or, because local receiving water characteristics may otherwise affect the biological availability of the metal, the biologically available equivalent measurement of the metal can be further defined by determining a Water Effect Ratio (WER) and multiplying the numerical value shown in 9VAC25-260-140 B by the WER. Refer to 9VAC25-260-140 F. Values displayed above in the table are examples and correspond to a WER of 1.0. Metals criteria have been adjusted to convert the total recoverable fraction to dissolved fraction using a conversion factor. Criteria that change with hardness have the conversion factor listed in the table above.

Mercury: A WER shall not be used for freshwater acute and chronic criteria.

Selenium: A WER shall not be used for freshwater acute and chronic criteria. Freshwater criteria expressed as total recoverable.

Source:

VA. Numeric Standards. http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140

Appendix A.3. Ecological Benchmarks for Sediment, Soil, or Fish Tissue

		Fish Tissue										
Analyte	**CAS Number**	**BCMOELP 1998 Fish Screening Benchmark mg/kg1**	**CCME 1999 Piscivorous Wildlife Screening Benchmark mg/kg2**	**CCME Piscivorous Wildlife Screening Benchmark mg/kg2**	**CEC 1988 Fish Screening Benchmark mg/kg3**	**ECW Fish Muscle Screening Benchmark mg/kg14**	**ECW Fish Whole Body Screening Benchmark mg/kg15**	**Environment Ontario 1984 Piscivorous Wildlife Screening Benchmark mg/kg20**	**New York State DEC Cancer Piscivorous Wildlife Screening Benchmark mg/kg21**	**New York State DEC Noncancer Piscivorous Wildlife Screening Benchmark mg/kg22**	**Swain and Holms 1985 Fish Screening Benchmark mg/kg23**	**Minimum Fish Tissue SV**
Acenaphthene	83-32-9											0
Acenaphthylene	208-96-8											0
Aluminum	7429-90-5											0
Anthracene	120-12-7											0
Antimony (metallic)	7440-36-0											0
Arsenic (III)	22569-72-8											0
Arsenic V	17428-41-0											0
Arsenic, Inorganic	7440-38-2											0
Barium	7440-39-3											0
Benz[a]anthracene	56-55-3											0
Benzo(b+k)fluoranthene	0-07-8											0
Benzo[a]pyrene	50-32-8											0
Benzo[b]fluoranthene	205-99-2											0
Benzo[g,h,i]perylene	191-24-2											0
Benzo[k]fluoranthene	207-08-9											0
Benzofluoranthenes, total	0-04-0											0
Beryllium and compounds	7440-41-7											0
Chloronaphthalene, Beta-	91-58-7											
Boron And Borates Only	7440-42-8											0
Cadmium (Diet)	7440-43-9											0
Cadmium (Water)	7440-43-9											0
Calcium	7440-70-2											0
Chloride	16887-00-6											0
Chromium(III) (Soluble Particulates)	16065-83-1											0
Chromium(III), Insoluble Salts	16065-83-1											0
Chromium(VI)	18540-29-9											0
Chromium, Total	7440-47-3											0
Chrysene	218-01-9											0
Cobalt	7440-48-4											0
Copper	7440-50-8											0
Dibenz[a,h]anthracene	53-70-3											0
Fluoranthene	206-44-0											0
Fluorene	86-73-7											0
Indeno[1,2,3-cd]pyrene	193-39-5											0
Iron	7439-89-6											
Lead and Compounds	7439-92-1											0
Lithium	7439-93-2											
Magnesium	7439-95-4											0
Manganese (Non-diet)	7439-96-5											0
Mercury (elemental)	7439-97-6				0.3	5	3					0.3
Methyl Mercury	22967-92-6			0.033								0.033
Methylnaphthalene, 1-	90-12-0											
Methylnaphthalene, 2-	91-57-6											
Molybdenum	7439-98-7											0
Naphthalene	91-20-3											0
Nickel Soluble Salts	7440-02-0											0
Nitrate	14797-55-8											0
Nitrite	14797-65-0											0
Nitrite (cold water)	0-08-2											0
Nitrite (warm water)	0-08-3											0
Phenanthrene	85-01-8											0
Phosphorus	7723-14-0											0
Pyrene	129-00-0											0
Selenium	7782-49-2											0
Sodium	7440-23-5											0
Strontium, Stable	7440-24-6											0
Sulfur	7704-34-9											0
Thallium (Soluble Salts)	7440-28-0											
Vanadium Pentoxide	1314-62-1											0
Vanadium and Compounds	7440-62-2											0
Zinc (Metallic)	7440-66-6											0

Appendix A.3. Ecological Benchmarks, cont.

Analyte	CAS Number	Sediment							
		ARCS NEC Sediment Screening Benchmark mg/kg24	ARCS PEC Sediment Screening Benchmark mg/kg25	ARCS TEC Sediment Screening Benchmark mg/kg26	Canadian ISQG Sediment Screening Benchmark mg/kg27	Canadian PEL Sediment Screening Benchmark mg/kg28	Consensus PEC Sediment Screening Benchmark mg/kg29	Consensus TEC Sediment Screening Benchmark mg/kg30	NOAA ERL Sediment Screening Benchmark mg/kg33
Acenaphthene	83-32-9				0.00671	0.0889			0.016
Acenaphthylene	208-96-8				0.00587	0.128			0.044
Aluminum	7429-90-5	73200	58000						
Anthracene	120-12-7	1.7	0.845	0.0572	0.0469	0.245	0.845	0.0572	0.0853
Antimony (metallic)	7440-36-0								2
Arsenic (III)	22569-72-8								
Arsenic V	17428-41-0								
Arsenic, Inorganic	7440-38-2	92.9	33	9.79	5.9	17	33	9.79	8.2
Barium	7440-39-3								
Benz[a]anthracene	56-55-3	3.5	1.05	0.108	0.0317	0.385	1.05	0.108	0.261
Benzo(b+k)fluoranthene	0-07-8								
Benzo[a]pyrene	50-32-8	0.44	1.45	0.15	0.0319	0.782	1.45	0.15	0.43
Benzo[b]fluoranthene	205-99-2	4		0.0272					
Benzo[g,h,i]perylene	191-24-2	3.8	6.3	0.29					
Benzo[k]fluoranthene	207-08-9	4		0.0272					
Benzofluoranthenes, total	0-04-0								
Beryllium and compounds	7440-41-7								
Chloronaphthalene, Beta-	91-58-7								
Boron And Borates Only	7440-42-8								
Cadmium (Diet)	7440-43-9	41.1	4.98	0.99	0.6	3.5	4.98	0.99	1.2
Cadmium (Water)	7440-43-9								
Calcium	7440-70-2								
Chloride	16887-00-6								
Chromium(III) (Soluble Particulates)	16065-83-1								
Chromium(III), Insoluble Salts	16065-83-1								
Chromium(VI)	18540-29-9								
Chromium, Total	7440-47-3	312	111	43.4	37.3	90	111	43.4	81
Chrysene	218-01-9	4	1.29	0.166	0.0571	0.862	1.29	0.166	0.384
Cobalt	7440-48-4								
Copper	7440-50-8	54.8	149	31.6	35.7	197	149	31.6	34
Dibenz[a,h]anthracene	53-70-3	0.87	0.0282	0.033	0.00622	0.135		0.033	0.0634
Fluoranthene	206-44-0	7.5	2.23	0.423	0.111	2.355	2.23	0.423	0.6
Fluorene	86-73-7	1.8	0.652	0.0346	0.0212	0.144	0.536	0.0774	0.019
Indeno[1,2,3-cd]pyrene	193-39-5	3.8	0.837	0.078					
Iron	7439-89-6								
Lead and Compounds	7439-92-1	68.7	128	35.8	35	91.3	128	35.8	46.7
Lithium	7439-93-2								
Magnesium	7439-95-4								
Manganese (Non-diet)	7439-96-5	819	1080	1670					
Mercury (elemental)	7439-97-6		1.06	0.18	0.17	0.486	1.06	0.18	0.15
Methyl Mercury	22967-92-6								
Methylnaphthalene, 1-	90-12-0								
Methylnaphthalene, 2-	91-57-6				0.0202	0.201			0.07
Molybdenum	7439-98-7								
Naphthalene	91-20-3	0.29	0.561	0.176	0.0346	0.391	0.561	0.176	0.16
Nickel Soluble Salts	7440-02-0	37.9	48.6	22.7			48.6	22.7	20.9
Nitrate	14797-55-8								
Nitrite	14797-65-0								
Nitrite (cold water)	0-08-2								
Nitrite (warm water)	0-08-3								
Phenanthrene	85-01-8		1.17	0.204	0.0419	0.515	1.17	0.204	0.24
Phosphorus	7723-14-0								
Pyrene	129-00-0	6.1	1.52	0.195	0.053	0.875	1.52	0.195	0.665
Selenium	7782-49-2								
Sodium	7440-23-5								
Strontium, Stable	7440-24-6								
Sulfur	7704-34-9								
Thallium (Soluble Salts)	7440-28-0								
Vanadium Pentoxide	1314-62-1								
Vanadium and Compounds	7440-62-2								
Zinc (Metallic)	7440-66-6	541	459	121	123	315	459	121	150

Appendix A.3. Ecological Benchmarks for Sediment, Soil, or Fish Tissue

Analyte	CAS Number	Sediment							
		NOAA ERM Sediment Screening Benchmark mg/kg[34]	Ontario Low Sediment Screening Benchmark mg/kg[35]	Ontario Severe Sediment Screening Benchmark mg/kg[36]	ORNL Lowest Chronic Value Daphnids Equilibrium Partitioning EqP Benchmark mg/kg[37]	ORNL Lowest Chronic Value Fish EqP Sediment Screening Benchmark mg/kg[38]	ORNL Lowest Chronic Value Nondaphnid InvertsEqP Sediment Screening Benchmark mg/kg[39]	ORNL Secondary Chronic Value EqP Sediment Screening Benchmark mg/kg[40]	OSWER Ecotox Thresholds Sediment Screening Benchmark mg/kg[41]
Acenaphthene	83-32-9	0.5							0.62
Acenaphthylene	208-96-8	0.64							
Aluminum	7429-90-5								
Anthracene	120-12-7	1.1	0.22	3.7					
Antimony (metallic)	7440-36-0	25							
Arsenic (III)	22569-72-8								
Arsenic V	17428-41-0								
Arsenic, Inorganic	7440-38-2	70	6	33					8.2
Barium	7440-39-3								
Benz[a]anthracene	56-55-3	1.6	0.32	14.8					
Benzo(b+k)fluoranthene	0-07-8								
Benzo[a]pyrene	50-32-8	1.6	0.37	14.4					0.43
Benzo[b]fluoranthene	205-99-2								
Benzo[g,h,i]perylene	191-24-2		0.17	3.2					
Benzo[k]fluoranthene	207-08-9		0.24	13.4					
Benzofluoranthenes, total	0-04-0								
Beryllium and compounds	7440-41-7								
Chloronaphthalene, Beta-	91-58-7								
Boron And Borates Only	7440-42-8								
Cadmium (Diet)	7440-43-9	9.6	0.6	10					1.2
Cadmium (Water)	7440-43-9								
Calcium	7440-70-2								
Chloride	16887-00-6								
Chromium(III) (Soluble Particulates)	16065-83-1								
Chromium(III), Insoluble Salts	16065-83-1								
Chromium(VI)	18540-29-9								
Chromium, Total	7440-47-3	370	26	110					81
Chrysene	218-01-9	2.8	0.34	4.6					
Cobalt	7440-48-4								
Copper	7440-50-8	270	16	110					34
Dibenz[a,h]anthracene	53-70-3	0.26	0.06	1.3					
Fluoranthene	206-44-0	5.1	0.75	10.2					2.9
Fluorene	86-73-7	0.54	0.19	1.6					0.54
Indeno[1,2,3-cd]pyrene	193-39-5		0.2	3.2					
Iron	7439-89-6		20000	40000					
Lead and Compounds	7439-92-1	218	31	250					47
Lithium	7439-93-2								
Magnesium	7439-95-4								
Manganese (Non-diet)	7439-96-5		460	1100					
Mercury (elemental)	7439-97-6	0.71	0.2	2					0.15
Methyl Mercury	22967-92-6								
Methylnaphthalene, 1-	90-12-0								
Methylnaphthalene, 2-	91-57-6	0.67							
Molybdenum	7439-98-7								
Naphthalene	91-20-3	2.1							0.48
Nickel Soluble Salts	7440-02-0	51.6	16	75					21
Nitrate	14797-55-8								
Nitrite	14797-65-0								
Nitrite (cold water)	0-08-2								
Nitrite (warm water)	0-08-3								
Phenanthrene	85-01-8	1.5	0.56	9.5					0.85
Phosphorus	7723-14-0		600	2000					
Pyrene	129-00-0	2.6	0.49	8.5					0.66
Selenium	7782-49-2								
Sodium	7440-23-5								
Strontium, Stable	7440-24-6								
Sulfur	7704-34-9								
Thallium (Soluble Salts)	7440-28-0								
Vanadium Pentoxide	1314-62-1								
Vanadium and Compounds	7440-62-2								
Zinc (Metallic)	7440-66-6	410	120	820					150

Appendix A.3. Ecological Benchmarks

Analyte	CAS Number	OSWER ET Benchmark Identifier mg/kg42	SD EPA R4 Sediment Screening Benchmark mg/kg43	EPA R4 benchmark Identifier mg/kg44	SD EPA R5 ESL Sediment Screening Benchmark mg/kg45	SD EPA R6 FW Sediment Screening Benchmark mg/kg46	EPA R3 BTAG Freshwater Sediment Screening Benchmark mg/kg86	MINIMUM SEDIMENT SV
Acenaphthene	83-32-9	SQC	0.33	PQL	0.00671		0.0067	0.0067
Acenaphthylene	208-96-8		0.33	PQL	0.00587		0.0059	0.00587
Aluminum	7429-90-5							58000
Anthracene	120-12-7		0.33	PQL	0.0572	0.0572	0.0572	0.0469
Antimony (metallic)	7440-36-0		12	PQL		2	2	2
Arsenic (III)	22569-72-8							0
Arsenic V	17428-41-0							0
Arsenic, Inorganic	7440-38-2	ER-L	7.24	TEL	9.79	5.9	9.8	5.9
Barium	7440-39-3							0
Benz[a]anthracene	56-55-3		0.33	PQL	0.108	0.0317	0.108	0.0317
Benzo(b+k)fluoranthene	0-07-8						0.0272	0.0272
Benzo[a]pyrene	50-32-8	ER-L	0.33	PQL	0.15	0.0319	0.15	0.0319
Benzo[b]fluoranthene	205-99-2				10.4			0.0272
Benzo[g,h,i]perylene	191-24-2				0.17		0.17	0.17
Benzo[k]fluoranthene	207-08-9				0.24		0.24	0.0272
Benzofluoranthenes, total	0-04-0							0
Beryllium and compounds	7440-41-7							0
Chloronaphthalene, Beta-	91-58-7				0.41723			0.41723
Boron And Borates Only	7440-42-8							0
Cadmium (Diet)	7440-43-9	ER-L	1	PQL	0.99	0.596		0.596
Cadmium (Water)	7440-43-9						0.99	0.99
Calcium	7440-70-2							0
Chloride	16887-00-6							0
Chromium(III) (Soluble Particulates)	16065-83-1							0
Chromium(III), Insoluble Salts	16065-83-1							0
Chromium(VI)	18540-29-9							0
Chromium, Total	7440-47-3	ER-L	52.3	TEL	43.4	37.3	43.4	26
Chrysene	218-01-9		0.33	PQL	0.166	0.0571	0.166	0.0571
Cobalt	7440-48-4				50		50	50
Copper	7440-50-8	ER-L	18.7	TEL	31.6	35.7	31.6	16
Dibenz[a,h]anthracene	53-70-3		0.33	PQL	0.033	0.033	0.033	0.00622
Fluoranthene	206-44-0	SQC	0.33	PQL	0.423	0.111	0.423	0.111
Fluorene	86-73-7	SQB	0.33	PQL	0.0774	0.0774	0.0774	0.019
Indeno[1,2,3-cd]pyrene	193-39-5				0.2		0.017	0.017
Iron	7439-89-6					20000	20000	20000
Lead and Compounds	7439-92-1	ER-L	30.2	TEL	35.8	35	35.8	30.2
Lithium	7439-93-2							0
Magnesium	7439-95-4							0
Manganese (Non-diet)	7439-96-5					460	460	460
Mercury (elemental)	7439-97-6	ER-L	0.13	TEL	0.174	0.174	0.18	0.13
Methyl Mercury	22967-92-6				0.00001			0.00001
Methylnaphthalene, 1-	90-12-0							0
Methylnaphthalene, 2-	91-57-6		0.33	PQL	0.0202		0.0202	0.0202
Molybdenum	7439-98-7							0
Naphthalene	91-20-3	SQB	0.33	PQL	0.176	0.176	0.176	0.0346
Nickel Soluble Salts	7440-02-0	ER-L	15.9	ER-L	22.7	18	22.7	15.9
Nitrate	14797-55-8							0
Nitrite	14797-65-0							0
Nitrite (cold water)	0-08-2							0
Nitrite (warm water)	0-08-3							0
Phenanthrene	85-01-8	SQC	0.33	PQL	0.204	0.0419	0.204	0.0419
Phosphorus	7723-14-0							600
Pyrene	129-00-0	ER-L	0.33	PQL	0.195	0.053	0.195	0.053
Selenium	7782-49-2						2	2
Sodium	7440-23-5							0
Strontium, Stable	7440-24-6							0
Sulfur	7704-34-9							0
Thallium (Soluble Salts)	7440-28-0							0
Vanadium Pentoxide	1314-62-1							0
Vanadium and Compounds	7440-62-2							0
Zinc (Metallic)	7440-66-6	ER-L	124	TEL	121	123	121	120

Appenidx A.3. Ecological Benchmarks

Analyte	CAS Number	Soil														
		Eco-SSL Avian Soil Screening Benchmark mg/kg52	Eco-SSL Inverts Soil Screening Benchmark mg/kg53	Eco-SSL Mammalian Soil Screening Benchmark mg/kg54	Eco-SSL Plants Soil Screening Benchmark mg/kg55	EPA R6 Earthworms Surface Soil Screening Benchmark mg/kg56	EPA R6 Plants Surface Soil Screening Benchmark mg/kg57	ORNL Invertebrates Soil Screening Benchmark mg/kg58	ORNL Microbes Soil Screening Benchmark mg/kg59	ORNL Plants Screening Benchmark mg/kg60	SO EPA R4 Soil Screening Benchmark mg/kg61	SO EPA R5 ESL Soil Screening Benchmark mg/kg62	MINIMUM SOIL SV Plants	MINIMUM SOIL SV Invert	MINIMUM SOIL SV Birds	MINIMUM SOIL SV Mammals
Acenaphthene	83-32-9						20			20	20	682	20	20	20	20
Acenaphthylene	208-96-8											682	682	682	682	682
Aluminum	7429-90-5						50		600	50	50		50	50	50	50
Anthracene	120-12-7										0.1	1480	0.1	0.1	0.1	0.1
Antimony (metallic)	7440-36-0		78	0.27			5			5	3.5	0.142	0.142	0.142	0.142	0.142
Arsenic (III)	22569-72-8												NV	0	0	0
Arsenic V	17428-41-0												NV	0	0	0
Arsenic, Inorganic	7440-38-2	43		46	18	60	37	60	100	10	10	5.7	5.7	5.7	5.7	5.7
Barium	7440-39-3		330	2000			500		3000	500	165	1.04	1.04	1.04	1.04	1.04
Benz[a]anthracene	56-55-3											5.21	5.21	5.21	5.21	5.21
Benzo(b+k)fluoranthene	0-07-8												NV	0	0	0
Benzo[a]pyrene	50-32-8										0.1	1.52	0.1	0.1	0.1	0.1
Benzo[b]fluoranthene	205-99-2											59.8	59.8	59.8	59.8	59.8
Benzo[g,h,i]perylene	191-24-2											119	119	119	119	119
Benzo[k]fluoranthene	207-08-9											148	148	148	148	148
Benzofluoranthenes, total	0-04-0												NV	0	0	0
Beryllium and compounds	7440-41-7		40	21			10			10	1.1	1.06	1.06	1.06	1.06	1.06
Chloronaphthalene, Beta-	91-58-7											0.0122	0.0122	0.0122	0.0122	0.0122
Boron And Borates Only	7440-42-8						0.5		20	0.5	0.5		0.5	0.5	0.5	0.5
Cadmium (Diet)	7440-43-9	0.77	140	0.36	32	110	29	20	20	4	1.6	0.00222	0.00222	0.00222	0.00222	0.00222
Cadmium (Water)	7440-43-9												NV	0	0	0
Calcium	7440-70-2												NV	0	0	0
Chloride	16887-00-6												NV	0	0	0
Chromium(III) (Soluble Particulates)	16065-83-1												NV	0	0	0
Chromium(III), Insoluble Salts	16065-83-1	26		34									NV	0	26	34
Chromium(VI)	18540-29-9			130				0.40		1			1	0.4	0	130
Chromium, Total	7440-47-3					0.4	5	0.4	10	1	0.4	0.4	0.4	0.4	0.4	0.4
Chrysene	218-01-9											4.73	4.73	4.73	4.73	4.73
Cobalt	7440-48-4	120		230	13		20		1000	20	20	0.14	0.14	0.14	0.14	0.14
Copper	7440-50-8	28	80	49	70	61	100	50	100	100	40	5.4	5.4	5.4	5.4	5.4
Dibenz[a,h]anthracene	53-70-3											18.4	18.4	18.4	18.4	18.4
Fluoranthene	206-44-0										0.1	122	0.1	0.1	0.1	0.1
Fluorene	86-73-7					30		30			30	122	30	30	30	30
Indeno[1,2,3-cd]pyrene	193-39-5											109	109	109	109	109
Iron	7439-89-6								200		200		200	200	200	200
Lead and Compounds	7439-92-1	11	1700	56	120	500	50	500	900	50	50	0.0537	0.0537	0.0537	0.0537	0.0537
Lithium	7439-93-2				2		2		10	2	2		2	2	2	2
Magnesium	7439-95-4												NV	0	0	0
Manganese (Non-diet)	7439-96-5	4300	450	4000	220		500		100	500	100		100	100	100	100
Mercury (elemental)	7439-97-6					0.1	0.3	0.1	30	0.3	0.1	0.1	0.1	0.1	0.1	0.1
Methyl Mercury	22967-92-6							0.1			0.67	0.00158	0.00158	0.00158	0.00158	0.00158
Methylnaphthalene, 1-	90-12-0												NV	0	0	0
Methylnaphthalene, 2-	91-57-6											3.24	3.24	3.24	3.24	3.24
Molybdenum	7439-98-7						2		200	2	2		2	2	2	2
Naphthalene	91-20-3										0.1	0.0994	0.0994	0.0994	0.0994	0.0994
Nickel Soluble Salts	7440-02-0	210	280	130	38	200	30	200	90	30	30	13.6	13.6	13.6	13.6	13.6
Nitrate	14797-55-8												NV	0	0	0
Nitrite	14797-65-0												NV	0	0	0
Nitrite (cold water)	0-08-2												NV	0	0	0
Nitrite (warm water)	0-08-3												NV	0	0	0
Phenanthrene	85-01-8										0.1	45.7	0.1	0.1	0.1	0.1
Phosphorus	7723-14-0												NV	0	0	0
Pyrene	129-00-0										0.1	78.5	0.1	0.1	0.1	0.1
Selenium	7782-49-2	1.2	4.1	0.63	0.52	70	1	70	100	1	0.81	0.0276	0.0276	0.0276	0.0276	0.0276
Sodium	7440-23-5												NV	0	0	0
Strontium, Stable	7440-24-6												NV	0	0	0
Sulfur	7704-34-9										2		2	2	2	2
Thallium (Soluble Salts)	7440-28-0						1			1	1	0.0569	0.0569	0.0569	0.0569	0.0569
Vanadium Pentoxide	1314-62-1												NV	0	0	0
Vanadium and Compounds	7440-62-2	7.8		280	2		2		20	2	2	1.59	1.59	1.59	1.59	1.59
Zinc (Metallic)	7440-66-6	46	120	79	160	120	190	100	100	50	50	6.62	6.62	6.62	6.62	6.62

Appendix A.3. Notes and References Obtained from RAIS to Support Benchmarks

Fish Tissue Benchmarks

BCMOELP 1998 pw Fish Screening Benchmark

BCMOELP (British Columbia Ministry of Environment, Land, and Parks). 1988. British Columbia approved water quality guidelines (Criteria): 1998 Edition. British Columbia Ministry of Environment, Land, and Parks. Environmental Protection Department. Water Management Branch. Victoria, British Columbia.

CCME 1999

Environment Canada, National Guidelines and Standards Office website http://ceqg-rcqe.ccme.ca and http://st-ts.ccme.ca. Updated 2002.

CEC 1988 Fish

CEC (Commission of European Communities). 1988. European community environmental legislation: 1967-1987. Document number XI/989/87. Directorate-General for Environment, Consumer Protection and Nuclear Safety. Brussels, Belgium.

ECW avian and mammalian tissue concentrations

Beyer, W.N. , G.H. Heinz and A.W. Redmon-Norwood (eds.). 1996. Environmental Contaminants in Wildlife - Interpreting Tissue Concentrations, Special Publication of SETAC, CRC Press, Inc. 494 p.

Environment Ontario 1984

Environment Ontario 1984. Water management: Goals, policies, objectives, and implementation procedures of the Ministry of the Environment. Water Resources Branch, Toronto, Ontario. 70 p.

Newell et al. 1987

Newell, A.J. , D.W. Johnson, and L.K. Allen. 1987. Niagara River biota contamination project: Fish flesh criteria for piscivorous wildlife. Technical Report 87-3. Division of Fish and Wildlife. Bureau of Environmental Protection. New York State Department for Environmental Conservation. New York, NY.

New York State DEC Noncancer Piscivorous Wildlife (PW) and New York State DEC Cancer PW

Swain and Holmes 1985 Fish

Swain, L.G. and G.B. Holms. 1985. Fraser- Delta Area: Fraser River Sub-basin from Kanaka Creek to the mouth water quality assessment and objectives. Water Management Branch. British Columbia Ministry of Environment. Victoria, British Columbia.

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ARCS NEC

EPA (U.S. Environmental Protection Agency) 1996. Calculation and evaluation of sediment effect concentrations for the amphipod Hyalella azteca and the midge Chironomus riparius. EPA 905/R96/008. Great Lakes National Program Office, Chicago, IL. (http://www.cerc.usgs.gov/clearinghouse/data/brdcerc0004.html) (http://www.cerc.usgs.gov/pubs/sedtox/sec-dev.html)

ARCS PEC

EPA (U.S. Environmental Protection Agency) 1996. Calculation and evaluation of sediment effect concentrations for the amphipod Hyalella azteca and the midge Chironomus riparius. EPA 905/R96/008. Great Lakes National Program Office, Chicago, IL. (http://www.cerc.usgs.gov/clearinghouse/data/brdcerc0004.html) (http://www.cerc.usgs.gov/pubs/sedtox/sec-dev.html)

ARCS TEC

EPA (U.S. Environmental Protection Agency) 1996. Calculation and evaluation of sediment effect concentrations for the amphipod Hyalella azteca and the midge Chironomus riparius. EPA 905/R96/008. Great Lakes National Program Office, Chicago, IL. (http://www.cerc.usgs.gov/clearinghouse/data/brdcerc0004.html) (http://www.cerc.usgs.gov/pubs/sedtox/sec-dev.html)

Canadian ISQG

Obtained from Environment Canada's Canadian Environmental Quality Guidelines web page at http://ceqg-rcqe.ccme.ca and http://st-ts.ccme.ca. PDF 2012.

Canadian PEL

Obtained from Environment Canada's Canadian Environmental Quality Guidelines web page at http://ceqg-rcqe.ccme.ca and http://st-ts.ccme.ca. PDF 2012.

Consensus PEC

MacDonald, D.D. , C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol. 39: 20-31.

Consensus TEC

MacDonald, D.D. , C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol. 39: 20-31.

EPA Region 3 Biological Technical Assistance Group Freshwater Sediment Screening Benchmarks

http://www.epa.gov/reg3hwmd/risk/eco/index.htm

EPA Region 4

EPA Region IV (U.S. Environmental Protection Agency Region IV) 1995. Ecological screening values, Ecological Risk Assessment Bulletin No. 2, Waste Management Division. Atlanta, Georgia. (superceded by http://www.epa.gov/region04/waste/ots/ecolbul.html#tbl3).

EPA Region 5 ESLs - Sed

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EPA Region 6 Ecological Screening Benchmarks: Freshwater Sediment

Texas Natural Resource Conservation Commission. 2001. Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Toxicology and Risk Assessment Section, Texas Natural Resource Conservation Commission, Austin, TX. RG-263 (revised).

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Long, E. R. , D. D. MacDonald, S. L. Smith, and F. D. Calder. 1995. “Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments,” Environ. Manage.19: 81-97. (Values for metals and organics not listed in 1 or 3 were obtained from this source.)

Long, E. R. and L. G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program, National Oceanographic and Atmospheric Administration, Tech. Memorandum NOS OMA 52, August 1991. Seattle, Washington. (Values for DDD, DDT, Antimony, Chlordane, Dieldrin, and Endrin were obtained from this source.)

NOAA SQUIRT (http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html)

Ontario Low and Severe

Persaud, D. , R. Jaagumagi, and A. Hayton. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Ontario Ministry of the Environment and Energy. August. ISBN 0-7729-9248-7. (Available at http://www.ene.gov.on.ca/envision/gp/B1_3.pdf)

ORNL EqP

The ORNL EqP sediment values are sediment values derived from the corresponding water quality benchmarks using equilibrium partitioning (i.e., ORNL_SCV_EqP is from Jones et al. sediment benchmarks and is the sediment benchmark derived from the surface water Secondary Chronic Value).

OSWER

OSWER (Office of Solid Waste and Emergency Response). 1996. Ecotox thresholds. U.S. Environmental Protection Agency. ECO Update 3 (2):1-12. (http://www.epa.gov/superfund/programs/risk/eco_updt.pdf)

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EPA Eco-SSLs

Updates were also performed since 2005. The RAIS retrieved current values in November 2010.

EPA Region IV

EPA. 2001. Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment. Originally published: EPA Region IV. 1995. Ecological Risk Assessment Bulletin No. 2: Ecological Screening Values. U.S. Environmental Protection Agency Region 4, Waste Management Division, Atlanta, GA. Website version last updated 30 November 2001: http://www.epa.gov/region4/waste/ots/epatab4.pdf

EPA Region 5 ESLs – Soil

August 2003 revision of the ESLs (formerly EDQLs) at EPA_RS_ESL.pdf

EPA Region 6 Ecological Screening Benchmarks: Surface Soil – Plants

Texas Natural Resource Conservation Commission. 2001. Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Toxicology and Risk Assessment Section, Texas Natural Resource Conservation Commission, Austin, TX. RG-263 (revised).

EPA Region 6 Ecological Screening Benchmarks: Surface Soil – Soil Invertebrates

Texas Natural Resource Conservation Commission. 2001. Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Toxicology and Risk Assessment Section, Texas Natural Resource Conservation Commission, Austin, TX. RG-263 (revised).

ORNL Invertebrates, Microbes

Efroymson, R.A. , M.E. Will, and G.W. Suter II. 1997b. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)

ORNL Plants

Efroymson, R.A. , M.E. Will, G.W. Suter II, and A.C. Wooten. 1997a. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)

Appendix A.4. Surface Water Benchmarks

Analyte	CAS Number	Australian and New Zealand Surface Water Screening Benchmark mg/L 88	British Columbia Surface Water Screening Benchmark mg/L 89	Canadian WQG Surface Water Screening Benchmark mg/L 63	EC20 Daphnids Surface Water Screening Benchmark mg/L 64	EC20 Fish Surface Water Screening Benchmark mg/L 65	EC20 Sensitive Species Surface Water Screening Benchmark mg/L66	EC25 Bass Population Surface Water Screening Benchmark mg/L67	EPA R4 Acute Surface Water Screening Benchmark mg/L68	EPA R4 Chronic Surface Water Screening Benchmark mg/L69	LCV Aquatic Plants Surface Water Screening Benchmark mg/L70	LCV Daphnids Surface Water Screening Benchmark mg/L71	LCV Fish Surface Water Screening Benchmark mg/L72	LCV Non-Daphnid Inverts Surface Water Screening Benchmark mg/L73	NAWQC Acute Surface Water Screening Benchmark mg/L74	NAWQC Chronic Surface Water Screening Benchmark mg/L75	OSWER Ambient Water Quality Criteria mg/L76	OSWER Tier II Secondary Surface Water Screening Benchmark mg/L77	SW EPA R5 ESL Surface Water Screening Benchmark mg/L78	SW EPA R6 FW Surface Water Screening Benchmark mg/L79	Tier II SAV Surface Water Screening Benchmark mg/L81	Tier II SCV Surface Water Screening Benchmark mg/L82	EPA R3 BTAG Freshwater Screening Benchmark mg/L85	Minimum
Antimony (metallic)	7440-36-0				1.9	2.31		0.079	1.3	0.16	0.61	5.4	1.6		0.088	0.03			0.08	0.692	0.18	0.03	0.03	0.03
Barium	7440-39-3																	0.0039	0.22	0.004	0.11	0.004	0.004	0.0039
Beryllium and compounds	7440-41-7				0.0038	0.148		0.021	0.016	0.00053	100	0.0053	0.057					0.0051	0.0036	0.0053	0.035	0.00066	0.00066	0.00053
Boron And Borates Only	7440-42-8			1.5	7					0.75		8.83								0.0016	0.03	0.0016	0.0016	0.0016
Cobalt	7440-48-4				0.0044	0.81		0.00398				0.0051	0.29					0.003	0.024	1.5	1.5	0.023	0.023	0.003
Lithium	7439-93-2																			0.014	0.26	0.014	0.014	0.014
Magnesium	7439-95-4											82								0.647			82	0.647
Manganese (Non-diet)	7439-96-5				1.1	1.27		0.112				1.1	1.78					0.08		0.12	2.3	0.12	0.12	0.08
Molybdenum	7439-98-7	0.000034		0.073	0.36							0.88						0.24		2	16	0.37	0.073	0.000034
Sodium	7440-23-5											680											680	680
Strontium, Stable	7440-24-6											42								1.5	15	1.5	1.5	1.5
Sulfur	7704-34-9																							0
Thallium (Soluble Salts)	7440-28-0	0.00003		0.0008	0.064	0.081		0.067	0.14	0.004	0.1	0.13	0.057						0.01	0.04	0.11	0.012	0.0008	0.00003
Vanadium and Compounds	7440-62-2				0.43	0.041		0.032				1.9	0.08					0.019	0.012	0.02	0.28	0.02	0.02	0.012

The minimum value for antimony is not found in the current NAWQC, but according to Suter and Tsao (1996) traces back to draft FAV and FCV values (EPA 1988. Ambient water quality criteria for antimony(III). Draft. August 30th, 1988)

G. W. Suter II, and C. L. Tsao. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Oak Ridge National Laboratory. ES/ER/TM-96/R2

Appendix A.4, cont.

Canadian WQG

Aluminum is dependent on pH:
0.005 mg/L if pH < 6.5, or
0.1 mg/L if pH >=6.5
SADA does not include a default CWQG for aluminum.

Cadmium is hardness dependent:
RAIS and SADA use 0.000017 as default

Copper is hardness dependent:
0.002 mg/L at hardness 0-120 mg/L CaCO3
0.003 mg/L at hardness 120-180 mg/L
0.004 mg/L at hardness >180
RAIS and SADA use 0.002 as default

Lead is hardness dependent:
0.001 mg/L at hardness from 0-60 mg/L CaCO3
0.002 from 60-120
0.004 from 120-180
0.007 at hardness >180
RAIS and SADA use 0.002 as default.

Nickel is hardness dependent:
0.025 mg/L at hardness from 0-60 mg/L CaCO3
0.065 from 60-120
0.11 from 120-180
0.15 at hardness >180
RAIS and SADA use 0.065 as default.

Obtained from Environment Canada's Canadian Environmental Quality Guidelines web page at http://ceqg-rcqe.ccme.ca and http://st-ts.ccme.ca. PDF 2012.

EC20 Daphnids
Suter, G.W. II. 1996. Toxicological benchmarks for screening contaminants of potential concern for effects on freshwater biota. Environ. Toxic. Chem. 15:1232-1241.

EC20 Fish
Suter, G.W. II. 1996. Toxicological benchmarks for screening contaminants of potential concern for effects on freshwater biota. Environ. Toxic. Chem. 15:1232-1241.

EC20 Sensitive Species
Suter, G.W. II. 1996. Toxicological benchmarks for screening contaminants of potential concern for effects on freshwater biota. Environ. Toxic. Chem. 15:1232-1241.

EC25 Bass Population
Suter, G.W. II. 1996. Toxicological benchmarks for screening contaminants of potential concern for effects on freshwater biota. Environ. Toxic. Chem. 15:1232-1241.

EPA Region 4- Acute
See http://www.epa.gov/region04/waste/ots/ecolbul.html#tbl1.

EPA Region 4- Chronic
See http://www.epa.gov/region04/waste/ots/ecolbul.html#tbl1

Appendix A.4, cont.

LCV Aquatic Plants
Suter, G.W. II and C.L. Tsao 1996. Toxicological benchmarks for screening potential contaminants of concern for effects on aquatic biota: 1996 revision. ES/ER/TM-96/R2. Oak Ridge National Laboratory, Oak Ridge, TN. (http://www.hsrd.ornl.gov/ecorisk/tm96r2.pdf)

LCV Daphnids
Suter, G.W. II and C.L. Tsao 1996. Toxicological benchmarks for screening potential contaminants of concern for effects on aquatic biota: 1996 revision. ES/ER/TM-96/R2. Oak Ridge National Laboratory, Oak Ridge, TN. (http://www.hsrd.ornl.gov/ecorisk/tm96r2.pdf)

Suter, G.W. II, A.E. Rosen, E. Linder, and D.F. Parkhurst 1987. End points for responses of fish to chronic toxic exposures. Environmental Toxicology and Chemistry 6:793-809.

Suter, G.W. II. 1993. Ecological Risk Assessment. Lewis Publishers, Chelsea, MI.

LCV Fish

Suter, G.W. II and C.L. Tsao 1996. Toxicological benchmarks for screening potential contaminants of concern for effects on aquatic biota: 1996 revision. ES/ER/TM-96/R2. Oak Ridge National Laboratory, Oak Ridge, TN. (http://www.hsrd.ornl.gov/ecorisk/tm96r2.pdf)

Suter, G.W. II, A.E. Rosen, E. Linder, and D.F. Parkhurst 1987. End points for responses of fish to chronic toxic exposures. Environmental Toxicology and Chemistry 6:793-809.

Suter, G.W. II. 1993. Ecological Risk Assessment. Lewis Publishers, Chelsea, MI.

NAWQC- Acute and Chronic

United States Environmental Protection Agency. 2002. National Recommended Water Quality Criteria :2002. Office of Water, U.S. Environmental Protection Agency, Washington, D.C. November. EPA 822-R-02-047. (Available at http://www.epa.gov/ost/pc/revcom.pdf.)

OSWER AWQC

NAWQC or FCV's (final chronic values) as of 1996.

OSWER Tier II

Secondary chronic values derived using EPA's Tier II methodology.

EPA Region 5 ESLs - SW

August 2003 revision of the ESLs (formerly EDQLs) at EPA_RS_ESL.pdf

EPA Region 6 Ecological Screening Benchmarks: Freshwater

Texas Natural Resource Conservation Commission. 2001. Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas. Toxicology and Risk Assessment Section, Texas Natural Resource Conservation Commission, Austin, TX. RG-263 (revised).

Tier II SAV, SCV

Suter, G.W. , II, and C.L. Tsao. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. 104pp. ES/ER/TM-96/R2. http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf.

EPA Region 3 Biological Technical Assistance Group Freshwater Screening Benchmarks
http://www.epa.gov/reg3hwmd/risk/eco/index.htm

Austrailan and New Zealand Guidelines for Fresh and Marine Water Quality Screening Benchmarks (October 2000)

British Columbia Compendium of Working Water Quality Guidelines Screening Benchmarks

Appendix B. Raw Data

Appendix B.1. Raw Water Quality Data

Client Sample ID			1 SAMPLE BY BIRD HOUSE		2 SAMPLE 2 RED COVE		3 SAMPLE 3 OUTFALL 005		4 SAMPLE 4 OSBORNE	
Date Collected			07/06/2016		07/06/2016		07/06/2016		07/06/2016	
Method	Analyte	Units	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
200.7	ALUMINUM	mg/l	8.09		0.717		0.0921	J	0.471	
200.7	BORON	mg/l	0.121	J	1.99		0.22		0.0631	J
200.7	CALCIUM	mg/l	25.1		217		17.5		35.3	
200.7	IRON	mg/l	19		66.1		0.167		1.04	
200.7	LITHIUM	mg/l	0.013	J	0.22		0.015	U	0.015	U
200.7	MAGNESIUM	mg/l	6.21		42.3		5		3.41	
200.7	SILICON	mg/l	13		8.47		1.18		3.87	
200.7	SODIUM	mg/l	10.3		23.1		3.91		8.41	
200.7	STRONTIUM	mg/l	0.143		5.73		0.333		0.0799	
200.7	SULFUR	mg/l	13.5		179		5.27		6.71	
200.8	ANTIMONY	mg/l	0.002	U	0.002	U	0.000851	J	0.002	U
200.8	ARSENIC	mg/l	0.00634		0.0741		0.0139		0.00107	
200.8	BARIUM	mg/l	0.152		0.0549		0.071		0.0324	
200.8	BERYLLIUM	mg/l	0.0011		0.001	U	0.001	U	0.001	U
200.8	CADMIUM	mg/l	0.000262	J	0.001	U	0.001	U	0.001	U
200.8	CHROMIUM	mg/l	0.0154		0.00148		0.001	U	0.00104	B
200.8	COBALT	mg/l	0.0103		0.024		0.002	U	0.000523	J
200.8	COPPER	mg/l	0.0237		0.00303		0.00171		0.0016	
200.8	LEAD	mg/l	0.0156		0.00141		0.001	U	0.000878	J
200.8	MANGANESE	mg/l	0.597		6.57		0.227		0.0808	
200.8	MOLYBDENUM	mg/l	0.00162	J	0.0431		0.00327	J	0.000565	J
200.8	NICKEL	mg/l	0.014		0.0537		0.000913	J	0.00169	
200.8	SELENIUM	mg/l	0.00134	J	0.000418	J	0.00103	J	0.002	U
200.8	THALLIUM	mg/l	0.001	U	0.001	U	0.001	U	0.001	U
200.8	VANADIUM	mg/l	0.0366		0.00416	J	0.00184	J	0.00226	J
200.8	ZINC	mg/l	0.0947		0.0108	B	0.00698	B J	0.54	
245.1	MERCURY	mg/l	0.0002	U	0.0002	U	0.0002	U	0.0002	U
2540 C-	DISSOLVED SC	mg/l	143		1100		95		106	
300	CHLORIDE	mg/l	16.2		41.7		4.14		12.3	
300	SULFATE	mg/l	39.3		594		14.3		12.9	
3500Cr	HEXAVALENT C	mg/l	0.0005	U	0.0005	U	0.0005	U	0.0005	U
353.2	NITRATE-NITRIT	mg/l	0.354		0.02	J	0.034	J	0.39	
365.4	PHOSPHORUS	mg/l	0.526		0.0836	J	0.0762	J	0.0843	J
Hardness (mg/L CaCO3)			88.2		716 716 but 400 is max allowed		64.3		102	

Criteria obtained from:
http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-140

Hardness calculated with online calculator, where $CaCO3=2.5 * Ca^{+2} + 4.1 * Mg^{+2}$
http://www.lenntech.com/ro/water-hardness.htm

Resume

Terra Technologies Environmental Services, LLC
Carolyn L. Fordham
Toxicologist

Education
Ph.D., Environmental Health, Colorado State University (1999)
Masters of Science, Zoology, Colorado State University (1985)
Bachelor of Science, Zoology, University of Maryland (1980)

Professional Society Membership
SETAC (Society for Environmental Toxicology and Chemistry)

Background
Dr. Fordham has extensive experience in project management, human health and ecological risk assessment, endangered species surveys, wildlife and avian toxicology, ecological modeling, and pharmacokinetic modeling. Dr. Fordham has more than 30 years of professional experience in projects relating to risk assessment, wildlife and avian toxicology studies, and site investigations under CERCLA and RCRA guidelines. Dr. Fordham has designed and performed field investigations at many federal and private facilities. Dr. Fordham performs Monte Carlo uncertainty analyses in Crystal Ball, as well as physiologically based pharmacokinetic modeling efforts (PBPK), and performs exposure modeling with the EPA IEUBK and ALM lead models, indoor air vapor intrusion model (VISL), Virginia DEQ trench air model, and ASTM RBCA models. Dr. Fordham completed the EPA's Radiation Risk Assessment training in October, 2017.

Example Experience
Henderson Mine, Colorado (2012-current). Serve as the agriculture expert for determination of toxicity of molybdenum in drinking water for cattle. Attend meetings with CDPHE. Prepare expert reports. Testify at Water Quality Commission hearings. Assist in design of toxicity studies.

Former Nike Missile Site, Atlas 4, Wyoming. Human Health and Ecological Risk Assessor (2016 - Current). A human health and ecological risk assessment was conducted for a former Nike missile site near Cheyenne, WY for the U.S. Army Corps of Engineers. Volatile organics, particularly TCE, in a large ground water plume were the contaminants of potential concern. Exposure to ecological and human receptors was evaluated. Modeling of subsurface vapor transport was performed.

Denver Federal Center Environmental Assessment, Colorado. Ecologist. 2009 - 2010. Dr. Fordham performed the wildlife assessment for the Environmental Assessment. Impacts to bird and mammal populations due to development and construction were evaluated.

Chalk Creek EECA Risk Assessment, Pike and Isabel National Forests, Colorado. Risk Assessor (2008-2009). Conduct a "streamlined" risk evaluation for human health and the environment at an old abandoned mine site for the USFS. The analysis followed standard screening-level assumptions applicable when data are limited. Numerous waste rock piles were individually addressed. Sites were then ranked for potential hazard using a decision matrix developed by Dr. Fordham. This matrix included risk ratios, estimates of threat to surface water predicted by proximity, estimates of total loading as predicted by size, and potential contaminant mobility as suggested by analytical data such as SPLP.

Captain Jack Mine Site, Ward, Colorado. Risk Assessor (2004-2006). Dr. Fordham conducted the human health and ecological risk assessment for this mine site in Colorado. Onsite receptors as well hypothetical future receptors were evaluated. Native vegetation, surface water, sediment, soil, benthic invertebrates, and fish were sampled and the data incorporated into the risk analysis. Risk assessment work plans were reviewed by EPA Region VIII and approved by CDPHE.

Confidential Client, New Mexico. Ecotoxicologist (2001-2009). Dr. Fordham helped design and implement a large study to characterize the nature and extent of contamination and quantify ecological effects at a mine site near Questa, NM. Numerous metals were of concern, including arsenic, selenium, molybdenum, and copper. Surveys were conducted for edible wild plants to determine potential human health risks as well. Grasses, shrubs, and various small mammals were collected and analyzed for metal concentrations. Co-located soil samples were also collected. Plant and invertebrate community analyses were performed. Waterfowl surveys were conducted to determine if fledgling ducks were a viable dietary pathway to ecological receptors or humans. Surveys were performed to determine the presence of threatened or endangered species. Negotiate appropriate cleanup goals with EPA and the State of New Mexico, identify screening level values for various media, and develop site-specific remedial goals to use in the Feasibility Study. In offsite areas, provide technical expertise in identifying molybdenum and copper interaction effects on wildlife and livestock. Develop drinking water criteria for livestock.

Blackbird Mine Site, Idaho. Aquatic Risk Assessment Manager (2000 -2003). Dr. Fordham performed the aquatic ecological risk assessment for the Blackbird Mine Site, Idaho. Toxicity values for aquatic life had to be developed for cobalt as water quality criteria were lacking. Threatened and endangered salmonid species were the primary receptors of concern. In addition, Dr. Fordham co-authored a biological assessment for this site at the request of EPA and the USFWS. Dr. Fordham has been involved in evaluating remedial options during the Feasibility Study, and also has been assisting EPA in defining an ongoing Statement of Work as part of the remediation process.

Chino Mine Site, New Mexico. Ecological Risk Assessment/Ecologist (1998-2000). Dr. Fordham helped design and implement a large study to characterize the nature and extent of contamination and quantify ecological effects at the Chino Mine Site, Silver City, NM. Plants, invertebrates, and mammals were collected and analyzed for metal concentrations. Co-located soil samples were also collected. Plant and invertebrate community analyses were performed. Dr. Fordham collected rattlesnakes and other reptiles at the request of the USFWS to determine food web transfer of metals to higher predators. Surveys were performed to determine the presence of threatened or endangered species.

Monticello Uranium Mill Operable Unit III Ecological Risk Assessment, Utah. Ecotoxicologist/ Technical Expert (1994 - 1997). Act as liaison and technical expert between DOE contractors and regulatory agencies for this uranium contaminated mill site. Interpret guidance, review comments on work plan, and offer toxicological, health physics, and ecological support. Assist in preparing ecological risk assessment, and statistical support.

California Gulch Aquatic and Terrestrial Ecological Risk Assessments, Leadville, Colorado. Technical Expert, (1991-1997). Performed the aquatic and terrestrial risk assessments as a subcontractor to EPA for a large mining site on the Arkansas River heavily contaminated with various metals. Ground water, surface water, sediment and soil were evaluated. Riverine ecosystems, wetlands, and uplands were evaluated. GIS was utilized in data interpretation and presentation. Field data (aquatic and terrestrial population surveys, tissue analytical data) were used in support of the risk assessment.

Confidential Mining Client, California. Expert Witness (2000). Evaluate the potential effects of mining operations on spawning salmon and other ecological receptors. Evaluate the human health risk due to dust generation. Design sampling program to identify adverse environmental effects.

Publications

Quast, K.W., A. D. Levine, J. E. Kester, and C. L. Fordham. 2016. Forensic Analysis Of Tertiary-Butyl Alcohol (TBA) Detections In A Hydrocarbon-Rich Ground water Basin. Environmental Monitoring and Assessment. 188:208.

Fordham, C. L., J. D. Tessari, H. S. Ramsdell, and T. J. Keefe. 2000. "Effects of Malathion on Survival, Growth, Development, and Equilibrium Posture of Bullfrog *Tadpoles (Rana catesbeiana*)." Environmental Toxicology and Chemistry 20:179-184.

C.L. Fordham. 1999. “Toxicology of Malathion in Bullfrogs and Leopard Frogs.” Ph.D. Dissertation. Colorado State University, Fort Collins, Colorado.

Fordham, C.L. and D.P. Reagan. 1993. “Assessing Ecological Risk at Rocky Mountain Arsenal (Rocky Mountain Arsenal Case Study).” In: A Review of Ecological Assessment Case Studies from a Risk Assessment Perspective. EPA/630/R-92/005.

Fordham, C.L. 1992. “Effects of Composted Sewage Sludge on the Earthworm *Lumbricus terrestris*.” In: *Ecotoxicology of Earthworms.* P.W. Greig-Smith, H. Becker, P.J. Edwards, and F. Heimbach, eds. pp. 238-244.

Chandler, A.B. and C.L. Fordham. 1991. “Development of Uncertainty Factors for Nonhuman Receptors.” In: The Analysis, Communication, and Perception of Risk. Ed: B.J. Garrick and W.C. Gekler. Plenum Press, N.Y. pp. 145-152.

Fordham, C.L. and D.P. Reagan. 1991. “Pathways Analysis Method for Estimating Water and Sediment Criteria at Hazardous Waste Sites.” Environmental Toxicology and Chemistry 10:949-960.

Reagan, D.P. and C.L. Fordham. 1990. “An Approach for Selecting Indicator Species to Monitor Ecosystem Effects Resulting from Chemical Changes in Soil and Water.” Proceedings of the International Symposium on Ecological Indicators. October 16-19, 1990. Miami, FL.

Reagan, D.P., C.L. Fordham, R.H. Chesson, R.D. Beane, and N.W. Clippinger. 1990. “Abnormal Waterfowl Mortality on Eagle River Flats, Alaska.” Annual meeting of the Society for Environmental Toxicology and Chemistry, Arlington, VA. November 1990.

Fordham, C.L. 1988. “Overview of the Endangerment Assessment Process.” First Annual Meeting, Rocky Mountain Chapter, Society for Environmental Toxicology and Chemistry. Laramie, Wyoming, May 21, 1988.

Fordham, C.L. and D.P. Reagan. 1988. “A Bioaccumulation Model to Evaluate Ecological Risk and Estimate Cleanup Criteria for Water and Sediments at Hazardous Waste Sites.” Annual Meeting of the Society for Environmental Toxicology and Chemistry. Arlington, Virginia, November 15, 1988.