APPENDIX B –
HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

Human Health and Ecological Risk Assessment - DRAFT

Watts Bar Fossil Plant
Spring City, Tennessee

December 5, 2025

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Revision Record

Revision	Description	Date
0	DRAFT Submittal to TDEC	March 29, 2024
1	Addresses June 18, 2024 TDEC Review Comments and Issued for TDEC	March 17, 2025
2	Memo added for USEPA Updated Arsenic Toxicity Values	December 5, 2025

Sign-off Sheet

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Executive Summary

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to Tennessee Valley Authority (TVA) to establish a process for investigating, assessing, and remediating unacceptable risks from management of coal combustion residuals (CCR) at TVA coal-fired plants in the state of Tennessee. TVA constructed the Watts Bar Fossil Plant (WBF Plant) that included four generating units between 1940 and 1945 and began generating power in 1942. TVA retired the four steam plant generating units in 1982. There are two CCR units at the WBF Plant included in the TDEC Order: the Ash Pond and the Slag Disposal Area. Each of the CCR units was previously closed.

In accordance with the TDEC Order, TVA and Stantec Consulting Services Inc. (Stantec), on behalf of TVA, prepared an Environmental Investigation Plan (EIP) for the WBF Plant to obtain and provide information requested by TDEC. As specified in the TDEC Order, the objective of the EIP was to "identify the extent of soil, surface water, and groundwater contamination by CCR" from onsite management of CCR material in impoundments and landfills. In addition, per TDEC's information requests, the EIP included assessment of CCR unit structural stability and integrity.

Stantec has prepared this human health and ecological risk assessment (HHERA) report to evaluate potential risks to human and ecological receptors from potential exposures to CCR constituents released from the two CCR units at the WBF Plant. Results of this HHERA were used in the Corrective Action/Risk Assessment (CARA) Plan to evaluate whether corrective measures are needed for the protection of human and ecological receptors, and if so, provide information for the schedule for corrective action implementation.

The United States Environmental Protection Agency (USEPA) encourages the use of multiple lines of evidence (LOEs) in HHERAs such that a weight of evidence (WOE) approach can be used to characterize risk. In their guidance, USEPA also makes clear that determining "acceptable/unacceptable" risk should go beyond solely calculating numerical risk estimates. It is the combined results of these LOEs rather than any single LOE that are used to determine if risk is present at a level that warrants further evaluation or consideration of corrective measures (i.e., "acceptable/unacceptable levels"). As such, the objective of the HHERA is to provide quantitative and qualitative statements of potential risks to human and ecological receptors, based on multiple LOEs.

Environmental media samples collected as part of the WBF Plant Environmental Investigation (EI) and other ongoing environmental programs being conducted at the plant were analyzed for CCR constituents listed in the USEPA Title 40, Code of Federal Regulations Part 257, Subpart D (CCR Rule), Appendices III and IV and Appendix I of Tennessee Rule 0400-11-01-.04. Collectively these are referred to as "CCR Parameters" and form the basis of the HHERA evaluations.

The EI results characterized the current environmental conditions of the two CCR units (located onsite) at the WBF Plant and surface stream waters, sediments, and aquatic communities at the WBF Plant and in the vicinity of the CCR units (located offsite; i.e., the Tennessee River). Because the focus of the human health risk assessment (HHRA) is on the CCR units (not historical WBF Plant operations or the closure



activities for the CCR units), only exposures under anticipated future, post-closure conditions of the CCR units are evaluated in the HHERA. Potential future risks associated with onsite exposures to CCR Parameters in CCR material are limited to exposure scenarios where receptors could reasonably be expected to penetrate the geosynthetic cover system of closed CCR units, such as a worker making repairs to infrastructure associated with the closed CCR units. Potential future risks to human and ecological receptors from exposures to CCR Parameters in offsite abiotic (surface stream water and sediment) and biotic (benthic invertebrate and fish tissue) media assume current environmental conditions are representative of post-closure conditions and consider current and anticipated future land uses.

HHRA: The HHRA process was used to evaluate potential carcinogenic risks and noncarcinogenic hazards to onsite human receptors potentially exposed to CCR material, and to offsite human receptors potentially exposed to CCR Parameters in groundwater, surface stream water, and fish tissue. Exposure to sediment was not evaluated in the HHRA because no seasonally exposed sediment locations adjacent or downstream of the WBF Plant were identified. The overall HHRA findings are as follows:

- The results of the water use survey indicate current and historical CCR management associated with the WBF Plant has not affected water supply wells or springs located downgradient of the WBF Plant
- No constituents of potential concern (COPCs) were identified for surface stream water
- COPCs were identified for CCR material and Tennessee River fish filet tissue. Exposures to these media were quantitatively evaluated in the HHRA for the onsite worker and recreational user – consumer of locally-caught sport fish
- There are no unacceptable risks to offsite human receptors related to the CCR units. Estimated risks to an onsite worker potentially exposed to CCR material within the Ash Pond is greater than the noncancer threshold of 1; however, when standard health and safety protocols are used, potential risks to onsite workers are expected to be lower than estimated.

Ecological Risk Assessment (ERA): The ERA process was used to evaluate potential hazards to aquatic ecological community receptors and to populations of avian and mammalian receptors from exposure to CCR Parameters measured in environmental media samples collected from the Tennessee River. The assessment endpoints included protection of abundance and diversity of community receptors (i.e., benthic invertebrate, aquatic vegetation, fish, and aquatic/riparian feeding amphibian and reptile communities); and protection of populations of avian and mammalian receptors (i.e., aquatic/riparian feeding birds, aquatic/riparian feeding mammals, and aerial-feeding birds and mammals), by limiting acute and chronic effects from exposure to site-related constituents of potential ecological concern (COPECs). The overall ERA findings are as follows:

- **Tennessee River:**
    - No COPECs were identified for the Tennessee River



- There are no unacceptable risks to abundance and diversity in community receptors and populations of avian and mammalian receptors inhabiting or using the Tennessee River.

Confidence in the conclusions of the HHERA is supported by the use of multiple LOEs in a WOE approach and by incorporation of protective assumptions for and approaches to important uncertainties in the assessments.

In accordance with the TDEC Order, TVA is submitting the HHERA with the CARA Plan, which includes further evaluations of the risk assessment findings to determine whether corrective measures are needed for the protection of human and ecological receptors. The CARA Plan specifies the actions TVA plans to take at the CCR units (if needed), the basis of those actions, and incorporates any other operational changes planned or in progress by TVA.



Abbreviations

AOI	Areas of Interest
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	Below Ground Surface
CalEPA	California Environmental Protection Agency
CARA	Corrective Action/Risk Assessment
CBR_{fish}	Critical Body Residue in Fish Tissue
CCR	Coal Combustion Residuals
CCR Parameters	CCR Constituents listed in 40 CFR 257, Appendices III and IV, and the five inorganic constituents listed in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations Part 257, Subpart D
CFR	Code of Federal Regulations
COPC	Constituent of Potential Concern
COPEC	Constituent of Potential Ecological Concern
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
°F	Degrees Fahrenheit
EAR	Environmental Assessment Report
EI	Environmental Investigation
EIP	Environmental Investigation Plan
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESV	Ecological Screening Value
g	Gram
GWPS	Groundwater Protection Standards
HBI	Hilsenhoff Biotic Index
HHERA	Human Health and Ecological Risk Assessment
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System
kg	Kilogram
KRP	Kingston Recovery Project
L	Liter
LMS	Linearized Multistage
LOE	Line of Evidence
m^3	Cubic Meters
mg	Milligrams
µg	Microgram
NHANES	National Health and Nutrition Examination Survey

NPDES	National Pollutant Discharge Elimination System
%	Percent
pCi	Picocuries
ppm	Parts per Million
PPRTV	Provisional Peer Reviewed Toxicity Values
PRG	Preliminary Remediation Goal
RAIS	Risk Assessment Information System
RBI	Reservoir Benthic Index
RFAI	Reservoir Fish Assemblage Index
RfC	Reference Concentration
RfD	Reference Dose
RRI	Reservoir Release Improvement
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SSL_{HH}	Human Health Receptor-Specific Screening Level
Stantec	Stantec Consulting Services, Inc.
TDEC	Tennessee Department of Environment and Conservation
TDEC Order	Commissioner's Order OGC15-0177
TO	Target Organ
TTR	Total Taxa Richness
TVA	Tennessee Valley Authority
UCL	Upper Confidence Limit
URF	Unit Risk Factor
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WBF Plant	Watts Bar Fossil Plant
WBN Plant	Watts Bar Nuclear Plant
WOE	Weight of Evidence
ww	Wet Weight



1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec), on behalf of the Tennessee Valley Authority (TVA), has prepared this human health and ecological risk assessment (HHERA) report for the Watts Bar Fossil Plant (WBF Plant) located in Spring City, Tennessee (Exhibit 1-1). The WBF Plant is a former TVA coal-fired power plant. This HHERA evaluates potential risks to human and ecological receptors from potential exposures to coal combustion residuals (CCR) constituents released from CCR units at the WBF Plant. Results of this HHERA were used in the Corrective Action/Risk Assessment (CARA) Plan to evaluate whether corrective measures are needed for the protection of human and ecological receptors, and if so, provide information for the schedule for corrective action implementation.

1.1 BACKGROUND

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to TVA (TDEC 2015). The TDEC Order established a process whereby TDEC would oversee TVA's implementation of the United States Environmental Protection Agency (USEPA) Title 40, Code of Federal Regulations (CFR) Part 257, Subpart D (CCR Rule) for coordination and compliance with Tennessee's solid waste management program. The two CCR units at the WBF Plant included in the TDEC Order are: the Ash Pond and Slag Disposal Area. Each of these CCR units was previously closed in accordance with applicable regulations in effect at the time of closure. In accordance with the TDEC Order, TVA prepared an Environmental Investigation Plan (EIP) for the WBF Plant (TVA 2018a) to obtain and provide information requested by TDEC. Following public review and comment on the draft, the EIP was approved by TDEC on June 28, 2018, and TVA implemented the activities between 2018 and 2021 in accordance with the approved EIP. As specified in the TDEC Order, the objective of the EIP was to "identify the extent of soil, surface water, and ground water contamination by CCR" from onsite management of CCR material in impoundments and landfills. In addition, per TDEC's information requests, the EIP included assessment of CCR unit structural stability and integrity.

The WBF Plant Environmental Assessment Report (EAR; TVA 2024) presents the results of those investigations and an evaluation of recent and historical data to provide conceptual site models (CSMs) for the CCR units and overall findings for environmental media at the WBF Plant. CSMs describe sources of CCR constituents, pathways by which they can move, and environmental media potentially impacted if they are released. In accordance with the TDEC Order, TVA is submitting this HHERA with the CARA Plan, which includes further evaluation to determine whether corrective measures are needed. The CARA Plan, which will be subject to a public review and comment process, specifies the actions TVA plans to take at the TDEC Order CCR units (if needed), the basis of those actions, and incorporates any other operational changes planned or in progress by TVA.

1.2 OBJECTIVES

As stated in the TDEC Order, the CARA Plan "shall specify all actions TVA plans to take at the site and the basis of those actions" and that "corrective measures may include (1) soil, surface water and ground water remediation; (2) risk assessment and institutional controls; or (3) no further corrective action." This HHERA has been prepared to inform TVA whether the measured CCR constituent(s) in environmental media at the WBF Plant may present unacceptable risks to human health and the environment. As such, the objective of the HHERA is to provide quantitative and qualitative statements of potential risks to human and ecological receptors from exposures to CCR constituents in environmental media, based on multiple lines of evidence (LOEs) as outlined in the *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A).

1.3 SCOPE

Environmental media samples, collected as part of the Environmental Investigation (EI), and other ongoing environmental programs being conducted at the plant, were analyzed for CCR constituents listed in the CCR Rule, Appendices III and IV (i.e., antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium [total], cobalt, fluoride, lead, lithium, mercury [inorganic], molybdenum, pH, radium 226 & 228, selenium, sulfate, thallium, and total dissolved solids). Five additional inorganic parameters listed in Appendix I of Tennessee Rule 0400-11-01-.04 that are not included in the CCR Rule Appendices III and IV were also analyzed to maintain continuity with TDEC environmental programs (i.e., copper, nickel, silver, vanadium, and zinc). The combined CCR Rule Appendices III and IV parameters and TDEC Appendix I inorganic parameters are referenced collectively herein as "CCR Parameters."

As documented in the WBF Plant EAR, the EI was implemented in accordance with the sampling and analysis plans (SAPs). EI results were evaluated and presented in the WBF Plant EAR, with details of each investigation provided in technical evaluation summaries and associated sampling and analysis reports. Applicable EI results and information from investigations and subsequent assessments completed pursuant to the EIP SAPs were evaluated and relied on in the HHERA.

The EI results characterized the current environmental conditions of the CCR units at the WBF Plant (located onsite) and of surface stream waters, sediments, and aquatic communities at the WBF Plant and in the vicinity of the CCR units (located offsite; i.e., the Tennessee River). Because the focus of the human health risk assessment (HHRA) is on the CCR units (not historical WBF Plant operations or the closure activities themselves), only exposures under anticipated future, post-closure conditions of the CCR units are evaluated in the HHERA. Therefore, potential risks associated with onsite exposures to CCR material are limited to exposure scenarios where receptors could reasonably be expected to penetrate the geosynthetic cover system, such as a worker making repairs to infrastructure associated with the closed CCR units. Potential risks to human and ecological receptors from exposures to CCR Parameters in offsite abiotic (surface stream water and sediment) and biotic (benthic invertebrate and fish tissue) media assume current environmental conditions are representative of post-closure conditions (i.e., closed CCR units covered by geosynthetic cover systems) and consider current and anticipated future land use.



1.4 REPORT ORGANIZATION

This HHERA report is organized as follows:

- **Executive Summary:** Describes the principal elements and overall findings of the HHERA
- **Chapter 1 – Introduction:** Describes the regulatory framework, objectives, scope, and organization of the HHERA
- **Chapter 2 – Background and Risk Assessment Approach:** Describes the background for the CARA Plan and the general approach for conducting HHERAs for the TDEC Order plants
- **Chapter 3 – Site History and Environmental Characteristics:** Describes the operations, history, and environmental characteristics of the WBF Plant and the CCR units that are relevant to the assessment of potential risks to human and ecological receptors from possible exposure to the CCR Parameters
- **Chapter 4 – Summary of Environmental Investigations and Data for Use in the Risk Assessment:** Describes the data available from the EI and other studies that were completed at the WBF Plant, provides a summary of data quality and useability assessment, and provides a summary of data for use in the HHERA
- **Chapter 5 – Human Health Risk Assessment:** Describes the constituents of potential concern (COPCs), human receptors potentially exposed to COPCs, potential exposure routes for COPCs and human receptors, toxicity of the COPCs, the potential cancer risks and noncancer health hazards from exposure to COPCs, weight of evidence (WOE) evaluation, and uncertainty assessment
- **Chapter 6 – Ecological Risk Assessment:** Describes the constituents of potential ecological concern (COPECs), ecological receptors potentially exposed to CCR Parameters, potential exposure routes for ecological receptors, assessment endpoints that are evaluated, WOE evaluation of the LOEs, and uncertainty assessment
- **Chapter 7 – Summary:** Summarizes the findings of the HHERA
- **Chapter 8 – References:** Lists the reference documents cited in this HHERA report
- **Tables and Exhibits:** Presented following the main text of this report and are numbered according to the chapter in which they are first discussed
- **Photographs:** Provides relevant photographs of the WBF Plant
- **Appendices:** Includes sources of screening levels and multiple LOEs methodology, detailed calculation tables and statistical outputs supporting the HHERA results described in the main report.

2.0 BACKGROUND AND RISK ASSESSMENT APPROACH

2.1 BACKGROUND

The nature and extent of CCR Parameters in environmental media at the WBF Plant were characterized during the EI, as documented in the WBF Plant EAR. In cases where new data were required to address TDEC information requests, TVA developed SAPs for the WBF Plant as noted in Section 1.3. The data collected during the following investigations and subsequent assessments completed pursuant to the EIP SAPs are applicable for evaluating risks to human and/or ecological receptors:

- Sediment and benthic investigation (sediment, benthic invertebrate community assessment, Asiatic clam tissue samples)
- Surface stream investigation
- Fish tissue investigation
- Groundwater investigation
- Water use survey
- CCR material characteristics investigation.

In the WBF Plant EAR, sampling results obtained during these investigations were compared to TDEC-approved screening levels (Appendix B.1, Attachment A). These screening levels are generic (not specific to an individual human or ecological receptor) and protective. Most screening levels are not regulatory standards but are conservatively based on published health or toxicological studies. Concentrations above screening levels do not necessarily mean that adverse health effects are present, but that further evaluation is required in the CARA Plan to determine if an unacceptable risk exists, and if corrective measures are required. The concentrations of CCR Parameters in surface stream water, sediment, and biological tissues from locations upstream of the WBF Plant were also compared to results from locations adjacent to, or downstream of the WBF Plant to help identify potential impacts from CCR units that may require further evaluation in the CARA Plan.

Except for surface stream water used as domestic water supply, the generic screening levels used in the EAR are not applicable to human health exposure assessment. Human health receptor-specific screening levels (SSL_{HH}) were developed for soil or CCR material, sediment, and fish tissue because generic human health screening levels applicable to the receptors evaluated in TDEC Order HHRAs are not available. The SSL_{HH} were developed using a scientifically defensible, risk-based approach that incorporated a number of protective assumptions and values. For example, the SSL_{HH} were calculated using risk-based targets that are ten times more protective than regulatory targets. As a result, CCR Parameters with concentrations higher than the SSL_{HH} should not be interpreted as evidence of unacceptable human health risk. The methods used to derive SSL_{HH} are described in *Proposed Receptor-Specific Screening Levels for Human Health (SSL_{HH})* (Appendix B.1).

The document, *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A), outlined a WOE approach using multiple quantitative and qualitative LOEs such that future CCR management decisions at the TDEC Order plants are informed by assessing risks based on the combined LOEs results rather than any single LOE.

2.2 RISK ASSESSMENT APPROACH

The purpose of the HHERA is to inform management decisions in the CARA Plan by evaluating the risks that potential exposures to current concentrations of CCR Parameters in environmental media at the WBF Plant may pose to human and ecological receptors.

For the HHERA, concentrations of CCR Parameters reported in each medium were compared to medium-specific and receptor group-specific human health and ecological screening criteria. CCR Parameters with concentrations below applicable human health or ecological screening criteria by media are screened out of the HHRA or ERA, respectively. This screening process allows the HHERA to focus on the subset of CCR Parameters (i.e., COPCs and COPECs) that have the potential to be significant contributors to risk. CCR Parameters with concentrations higher than human health and/or ecological screening criteria require further evaluation but should not be interpreted as evidence of unacceptable risk to human health or the environment.

The USEPA encourages the use of multiple LOEs in a HHERA such that a WOE approach can be used to characterize risk. In their guidance, USEPA also makes clear that determining unacceptable risk should go beyond solely calculating numerical risk estimates (e.g., USEPA 2000a). As such, to achieve the objectives provided in Section 1.2, both quantitative and qualitative LOEs were used in this HHERA.

- Quantitative LOEs include: 1) comparing concentrations of CCR Parameters measured at the WBF Plant to medium-specific and receptor-specific human health and ecological screening levels, and 2) calculating carcinogenic risk and noncancer hazard index (HI) for the HHRA and hazard quotients (HQs) for the ERA.
- Qualitative LOEs include: 1) the use of published information on CCR material and CCR Parameters, 2) results of the EI and other studies conducted at the WBF Plant, and 3) findings from the environmental sampling, biological studies, and HHERAs conducted as part of the Kingston Recovery Project (KRP, also known as the Kingston Ash Recovery Project).

In brief, the KRP took place after the 2008 structural failure at TVA's Kingston Fossil Plant that resulted in the release of approximately 5.4 million cubic yards of CCR material into the adjacent Swan Pond Embayment with transport into the Emory, Clinch, and Tennessee rivers. The information available from the KRP is especially useful because it is directly applicable to the WBF Plant based on similar stressors, receptors, and exposure pathways, and is well documented (Appendix A).

Confidence in the conclusions of the HHERA is supported by the use of multiple LOEs in a WOE approach and by incorporation of protective assumptions and approaches in the assessments. A



discussion of these assumptions and how estimated risks most likely represent upper bound estimates of risks can be found in Sections 5.4 (HHRA).

2.2.1 Human Health Risk Assessment

Consistent with USEPA Guidance, the HHRA consists of the primary steps of data collection and evaluation, exposure assessment, toxicity assessment, risk characterization and uncertainty analysis (USEPA 1989a). Data collection and evaluation were conducted as part of the WBF Plant EI (Sections 3.2 and 4.1). The exposure assessment consists of: (1) development of a CSM, which includes evaluating potential release mechanisms, identifying potential human receptors and exposure pathways, and selecting COPCs for each medium, (2) derivation of exposure assumptions, chemical-specific parameters, and exposure point concentrations (EPCs), and (3) estimation of exposure dose. The toxicity assessment includes the selection of toxicity values used in the HHRA. Risk characterization includes the components of risk estimation and risk description. Risk estimation combines the results of the exposure assessment and toxicity assessment to quantitatively estimate cancer risk and noncancer hazards for potential human receptors. Risk description provides information for interpreting quantitative results for human receptors evaluated in the HHRA with a WOE approach using multiple LOEs. The uncertainty analysis describes the primary sources of uncertainty for each step of the HHRA and how these might affect the risk estimates, establishing a level of confidence in the HHRA conclusions. The HHRA is presented in Section 5.0.

2.2.2 Ecological Risk Assessment

Consistent with USEPA Guidance, ERAs typically consist of the primary steps of problem formulation, exposure assessment, effects assessment, risk characterization and uncertainty analysis (USEPA 1997; 1998). The problem formulation consists of the development of a CSM which includes the selection of COPECs. No COPECs were identified for the WBF Plant (Section 6.1.1), and as a result, an exposure assessment and effects assessment were not included in the ERA, and the risk characterization does not include risk estimation but is limited to a risk description. For the risk description, multiple LOEs are considered in a WOE approach used to characterize risks and potential impacts of CCR Parameters on the selected assessment endpoints. The uncertainty analysis describes the primary sources of uncertainty for each step of the ERA and how these might affect the ERA conclusions. The ERA is presented in Section 6.0.



3.0 SITE HISTORY AND ENVIRONMENTAL CHARACTERISTICS

Sections 3.1 through 3.2.4 summarize information presented in the WBF Plant EAR relevant to this HHERA. Additional details are provided in the WBF Plant EAR.

3.1 SITE OPERATIONS

After the construction of Watts Bar Dam and Chickamauga Dam, TVA constructed the WBF Plant between 1940 and 1945, with the first two of four generating units being placed into commercial operation in 1942 (TVA 1949). The third unit became operational in 1943, and the fourth (and final) unit became operational in 1945. TVA idled operation of the WBF Plant in 1957, then resumed operations from 1970 to 1982. These generating units and the main powerhouse were located northeast of the Slag Disposal Area (Former Watts Bar Fossil Plant Site on Exhibit 1-1). TVA retired the four generating units in 1982. TVA terminated the air permit for the WBF Plant in 1997 and deconstructed the main powerhouse in 2012 (CDM Smith 2013).

The WBF Plant has two CCR units under the TDEC Order, as shown on Exhibit 1-1: the Slag Disposal Area and Ash Pond. The total area of the CCR units is approximately 34 acres. These CCR units were previously closed in accordance with applicable regulations in effect at the time of closure.

Stormwater discharges from the adjacent TVA Equipment Support Services facility, the southern area of the closed Slag Disposal Area, and the closed Ash Pond are conveyed to the Stormwater Pond prior to discharging through the National Pollutant Discharge Elimination System (NPDES)-permitted Outfall F03 to the Tennessee River (also referred to as Chickamauga Lake or Chickamauga Reservoir). The northern area of the closed Slag Disposal Area is conveyed to the small detention basin on the north end of the Slag Disposal Area prior to discharging through NPDES-permitted Outfall F02 to the Tennessee River.

3.1.1 CCR Unit History and Land Use

CCR material in the forms of fly ash, bottom ash, and slag were sluiced to the Slag Disposal Area from 1942 to 1957. The Slag Disposal Area was formed by a railroad embankment and a natural knoll to the west, stacked CCR material to the east, and a dike and spillway to the south constructed to discharge process water (TVA 1969). TVA raised this dike using borrow soil material in 1969 to prepare for resuming power generation operations in 1970 (TVA 1973). During operation of the Slag Disposal Area, process water and CCR material were also sent into the area now identified as the Drainage Improvements Area (TVA 1977).

TVA constructed dikes with borrow material on the south and east sides of the borrow area to form the Ash Pond in 1974 (TVA 1977). Process water flow was relocated to the west of the Slag Disposal Area and ultimately to the Ash Pond. A divider dike was constructed in 1977 to form a stilling pool within the Ash Pond (TVA 1977). TVA ceased CCR material management operations in 1982 when all four steam plant generation units were retired (CDM Smith 2013).



In 2009, the Metal Cleaning Pond was filled with soil, and both the Slag Disposal Area and Metal Cleaning Pond were capped with soil and closed under TDEC Permit TNR190741 in accordance with applicable regulations in effect at the time of closure. The Slag Disposal Area cap consisted of a one-foot thick vegetative cover over a one-foot thick compacted clay layer. The Metal Cleaning Pond cap consisted of a one-foot thick vegetative cover above the soil fill (TVA 2009). During inspections following the closure, poor surface drainage was observed in the area west of the Slag Disposal Area. A separate drainage improvements project was completed in 2015 at the Drainage Improvements Area to place fill, improve drainage, and remove water around the Slag Disposal Area (AECOM 2016).

The Ash Pond was closed in 2015 under TDEC Permit TN0005461 in accordance with applicable regulations in effect at the time of closure. As part of the closure project, CCR material was excavated from the southern area of the Ash Pond and consolidated and capped in the northern area of the Ash Pond using a geosynthetic and soil cap (CDM Smith 2015). A clay divider dike was constructed between the capped portion of the Ash Pond and the remaining area of the Ash Pond (CDM Smith 2015). The southern portion of the former Ash Pond was converted into a permitted stormwater pond (Permit No. TNR058427) for the site.

3.1.2 Ownership and Surrounding Land Use

The WBF Plant is owned and operated by TVA, a corporate agency of the United States, and is located on the Tennessee River approximately one river mile downstream of Watts Bar Dam (Exhibit 1-1). The WBF Plant is also situated approximately 0.5 miles northeast of the Watts Bar Nuclear Plant (WBN Plant). Land use surrounding the WBF Plant is primarily undeveloped and includes forest, agriculture areas, and rural residential areas, with the nearest residence located approximately 1.4 miles northwest of the WBF Plant in Spring City. Public water surrounding the WBF Plant is supplied by the Town of Decatur Water System, Watts Bar Utility District, and Town of Spring City Water Utility that source their water from locations either upstream of the WBF Plant or a spring located 3.5 miles south of the WBF Plant.

3.2 ENVIRONMENTAL CHARACTERISTICS

3.2.1 Regional and Site Physiography

The WBF Plant is located within the Valley and Ridge physiographic province of the Appalachian Highlands physiographic division (Fenneman 1938). The Valley and Ridge Physiographic Province consists of a belt of northeast / southwest trending ridges and valleys formed by the differential erosion of a thick sequence of folded and faulted Paleozoic sedimentary rocks (USGS 1995). The elevations within the province range from about 380 feet above sea level to 4,604 feet above sea level. The WBF Plant is located in a topographically low area between higher elevation ridges to the north and west and the Tennessee River on the east.

3.2.2 Regional Geology, Hydrogeology, and Surface Stream Water Hydrology

Regionally, the Valley and Ridge province is a series of northeast trending Paleozoic sedimentary rocks that form the alternating valleys and ridges (USGS 1995). Much of the valleys are made up of carbonates and shales, which are more susceptible to erosion, while the more resistant siltstone, sandstones and

conglomerates form the ridges (USGS 1978). The folded strata are the result of thrust faulting and various deformation events that produced the Appalachian Mountains (USGS 1979). The folding is less intense in the Tennessee portion of the province, but major faults are common and vertical to overturned beds appear in many places, particularly on the northwestern sides of anticlines (USGS 1997).

3.2.2.1 Regional Geology

The WBF Plant sits on the east limb of a large anticline or the west limb of a large syncline where the average dip of the strata is 35 degrees southeast (Fox 1942). Onsite geologic mapping indicates that the plant is underlain by Cambrian age limestone and shale bedrock of the Conasauga Group Middle, and the Nolichucky Shale. A large majority of the area and unconsolidated deposits around the WBF Plant have been disturbed due to construction related to plant operations (TVA 2015).

3.2.2.2 Surface Stream Water Hydrology

The WBF Plant is located on the south-flowing Tennessee River approximately one river mile downstream of TVA Watts Bar Dam (Exhibit 1-1) and 58 miles upstream of TVA Chickamauga Dam. Under normal conditions, the Tennessee River flow in the vicinity of the WBF Plant depends primarily upon releases from the Watts Bar Dam. After the construction of these dams, the WBF Plant was constructed in dry conditions between 1940 and 1945. Prior to the construction of the WBF Plant, a small tributary to the Tennessee River followed an alignment through the Slag Disposal Area.

3.2.2.3 Regional Hydrogeology

The principal aquifers in the Valley and Ridge Province in the region of the WBF Plant consist of carbonate rocks that are Cambrian, Ordovician, and Mississippian in age (USGS 1995). Groundwater in the Valley and Ridge aquifers is primarily stored in and moves through fractures, bedding planes, and solution openings in the rocks. The sequence of Cambrian and Ordovician formations that includes some of the carbonate-rock aquifers in the Valley and Ridge Province is repeated several times by thrust faults in eastern Tennessee. Discussion of the uppermost aquifer beneath the CCR units is provided in Appendix H.1 of the WBF Plant EAR.

3.2.3 Local Climate

The average monthly high temperature at the Spring City, Tennessee weather station USC00408540 (NOAA 2022), located approximately seven miles northwest of the WBF Plant, ranges between 47 degrees Fahrenheit (°F) in January to 87°F in July, and the average monthly low ranges between 26°F in January to 67°F in July. Average annual precipitation at this location is 57.03 inches, with July being the wettest month, averaging 5.61 inches, and August being the driest month, averaging 3.07 inches.

3.2.4 Cultural and Historical Resources

As part of the extensive history of environmental review of constructing and operating the WBN Plant, which is adjacent to the WBF Plant, TVA has considered the potential impact on historic and archaeological resources associated with each project undertaking. Four archaeological sites are located

within the WBN Plant property (40RH6, 40RH7, 40RH8, and 40RH64). The first three sites were recorded as part of the Watts Bar Basin survey in 1936. The latter was recorded later during a post-inundation shoreline survey. These sites are considered eligible or potentially eligible for the National Register of Historic Places based on the potential for intact buried archaeological deposits.

It was determined during the initial environmental review that two archaeological sites (40RH6 and 40RH7) would be adversely affected by construction of the plant (TVA 2017a). Based on this finding, TVA proceeded with data recovery of these sites (Calabrese 1976; Schroedl 1978). One historic cemetery (Leuty Cemetery) was located on the property prior to plant construction. Two graves were removed in 1974 and placed in the Ewing Cemetery. Subsequent environmental reviews conducted resulted in a "no-effect finding" for archaeological resources.

3.2.5 Habitat, Flora, and Fauna

3.2.5.1 Terrestrial Habitat in the Vicinity of the WBF Plant

Much of the area at the WBF Plant site has been altered because of construction and operation of the Watts Bar Dam, the WBN Plant, and the WBF Plant. Because of extensive disturbance, much of WBF Plant site is open grasslands, covered with old field vegetation, limited deciduous and evergreen-deciduous forest, and paved and unpaved roads and parking areas (TVA 2011a). The CCR units and closed metal cleaning pond are capped. The Slag Disposal Area and closed Metal Cleaning Pond caps have vegetative covers.

The area around the WBF Plant provides habitat for common wildlife species tolerant of disturbance (TVA 2011a). Bird species found in these habitats include northern cardinal (*Cardinalis cardinalis*), American robin (*Turdus migratorius*), song sparrow (*Melospiza melodia pusillula ssp.*), and red-tailed hawk (*Buteo jamaicensis*). Mammals such as white-footed mouse (*Peromyscus leucopus*) and prairie vole (*Microtus ochrogaster*) and larger mammals such as eastern cottontail (*Sylvilagus floridanus*), common raccoon (*Procyon lotor*), and white-tailed deer (*Odocoileus virginianus*) can be abundant in these habitats. Reptiles often found in these habitats include yellow-bellied slider (*Trachemys scripta scripta*), black rat snake (*Pantherophis obsoletus*), and common garter snake (*Thamnophis sirtalis*) (TVA 2011a).

3.2.5.2 Aquatic Habitat in the Vicinity of the WBF Plant

The primary aquatic environment associated with the WBF Plant is the Tennessee River. Other surface water features identified at the WBF Plant include one intermittent/perennial stream, one perennial stream, and one wet-weather conveyance. The two streams are first-order tributaries to the Tennessee River in the Watts Bar tailwater (TVA 2011a).

Low-quality streams found near the WBF Plant provide habitat for disturbance-tolerant amphibians including American toad (*Anaxyrus americanus*), green frog (*Lithobates clamitans*), upland chorus frog (*Pseudacris feriarum*), and red-backed salamander (*Plethodon cinereus*). The adjacent Tennessee River provides riparian habitat for raptors such as bald eagle (*Haliaeetus leucocephalus*) and osprey (*Pandion haliaetus*), as well as other birds including great egret (*Ardea alba*), great blue heron (*Ardea herodias*), and belted kingfisher (*Megaceryle alcyon*) (TVA 2011a). Catfish (*Siluriformes sp.*) were the main species

sought by anglers in the Watts Bar Dam tailwater area. Sauger (*Sander canadensis*), white bass (*Morone chrysops*), black basses (*Micropterus*), and striped bass (*Morone saxatilis*) were also identified as important to the fishery (TVA 2001).

Two wetlands were identified along the intermittent/perennial stream north of the former powerhouse. Both wetlands are palustrine scrub-shrub, broadleaf deciduous and are seasonally flooded (TVA 2011a). Dominant vegetation includes soft rush (*Juncus effuses*), fescue (*Festuca*), black willow, and sycamore (*Platanus*). The total area of both wetlands is approximately 0.1 acre (TVA 2011a).

3.2.5.3 Flora and Fauna

A review of the TVA Natural Heritage Database in November 2023 indicated that of the wildlife listed by United States Fish and Wildlife Service (USFWS) or TDEC as being of conservation concern, the bald eagle and osprey have been documented to occur within three miles of the WBF Plant, and gray bat (*Myotis grisescens)*, northern long-eared bat (*Myotis septentrionalis*), and meadow jumping mouse (*Zapus hudsonius*) have been documented to occur beyond the three-mile radius of the WBF Plant within Rhea County, Tennessee (TVA 2023). Small numbers (less than 500) of gray bats were observed roosting in a cave approximately 3.3 miles from the WBN Plant (TVA 2007a). Bald eagles nest on Chickamauga and Watts Bar Reservoirs approximately 1.8 and 4.7 miles, respectively, from the WBN Plant.

Colonial wading birds have also been observed within a three-mile radius of the WBF Plant. The Natural Heritage Database (TVA 2023) also identified the lake sturgeon (*Acipenser fulvescens*), highfin carpsucker (*Carpiodes velifer*), laurel dace (*Chrosomus saylori*), fanshell (*Cyprogenia stegaria*), longsolid (*Fusconaia subrotunda*), pink mucket (*Lampsilis abrupta*), sheepnose (*Plethobasus cyphyus*), and Ohio pigtoe (*Pleurobema cordatum*) as aquatic species of concern documented to occur in the vicinity of the WBF Plant. Possible historical observations have also included one terrestrial species, the hellbender (*Cryptobranchus alleganiensis*), and seven aquatic species, the dromedary pearly mussel (*Dromus dromas)*, shiny pigtoe pearly mussel (*Fusconaia cor*), snail darter (*Percina tanasi)*, orange-foot pimpleback (*Plethobasus cooperianus*), Tennessee clubshell (*Pleurobema oviforme*), rough pigtoe (*Pleurobema plenum*), and pyramid pigtoe (*Pleurobema rubrum*).

The WBF Plant is located within the reach of the Chickamauga Reservoir State Mussel Sanctuary, where federally listed endangered mussel species (fanshell, dromedary pearly mussel, pink mucket, and rough pigtoe) are known to occur. The snail darter, pyramid pigtoe and Tennessee clubshell are also known to occur in this reach (TVA 2007a).



4.0 SUMMARY OF ENVIRONMENTAL INVESTIGATION AND DATA FOR USE IN THE RISK ASSESSMENT

4.1 SUMMARY OF ENVIRONMENTAL INVESTIGATIONS

In accordance with the TDEC Order, TVA and Stantec, on behalf of TVA, prepared an EIP for the WBF Plant to obtain and provide information requested by TDEC. Following public review and comment on the draft, the EIP was approved by TDEC on November 27, 2018, and TVA implemented the EI activities between 2019 and 2021 in accordance with the approved EIP and associated SAPs. As specified in the TDEC Order, the objective of the EIP was to "identify the extent of soil, surface water, and groundwater contamination by CCR" from onsite management of CCR material in impoundments and landfills. In addition, per TDEC's information requests, the EIP included assessment of CCR unit structural stability and integrity.

The investigations and subsequent assessments completed pursuant to the EIP SAPs at the WBF Plant CCR units are listed below:

- Background Soil Investigation
- CCR Material Investigations: Geotechnical Investigation (Exploratory Drilling), CCR Material Characteristics Investigation, Material Quantity Assessment
- Hydrogeological Investigations: Hydrogeological Investigation, Groundwater Investigation (Sampling), Geochemical Evaluation, Water Use Survey
- Seep Investigation
- Surface Stream, Sediment and Ecological Investigations: Surface Stream Investigation, Sediment and Benthic Investigation, Fish Tissue Investigation.

The results and findings of the EI relevant to this HHERA (i.e., CCR material characteristics investigation, water use survey, and the surface stream, sediment, and ecological investigations) are summarized below. The findings of the EI are discussed in greater detail in the WBF Plant EAR.

4.1.1 CCR Material Characteristics

To evaluate the characteristics of CCR material in the CCR units, TVA reviewed information from historical studies and performed investigations as part of the EI including an exploratory drilling field program. The CCR material characteristics investigation included collecting CCR material samples (saturated and unsaturated) from temporary well locations within the consolidated and capped Ash Pond CCR Unit and the Slag Disposal Area (Exhibit 4-1). Collected samples were analyzed for CCR Parameters and additional parameters of interest for the CCR material characteristics investigation (i.e., total organic carbon, iron, and manganese). The CCR material sampling results and statistical analyses relevant to the HHERA are provided in Appendix C.1.

4.1.2 Seep Investigation

To evaluate potentially active seeps and collect data to assess potential seepage to surface stream water adjacent to the WBF Plant CCR units, TVA reviewed historical seep management information and conducted a seep investigation as part of the TDEC Order EI. The seep investigation included identifying and collecting information regarding the potential presence of active seepage and provided information to assess potential movement of groundwater or pore water with dissolved CCR constituents into adjacent surface water streams.

Two areas of interest (AOIs [AOI01 and AOI02]) were identified downslope of the Slag Disposal Area in accessible areas during a visual inspection. Based upon monitoring evidence, it was demonstrated that AOI01 was the result of poor drainage along the roadway. Agreement was reached between TVA and TDEC in meetings during August 2019 to cease monitoring at the AOI01 location, with the conclusion that no active seep was present at AOI01. Sampling at AOI02 was not conducted due to the presence of riprap. Additional AOIs, AOI03 and AOI04, were identified in inaccessible areas (i.e., covered by riprap) adjacent to the Slag Disposal Area along the Tennessee River bank. Based on a statistical analysis of water quality data collected adjacent to and upstream of the identified AOI locations, three AOIs (AOI02, AOI03 and AOI04) will be further evaluated in the CARA Plan to determine if corrective measures are needed.

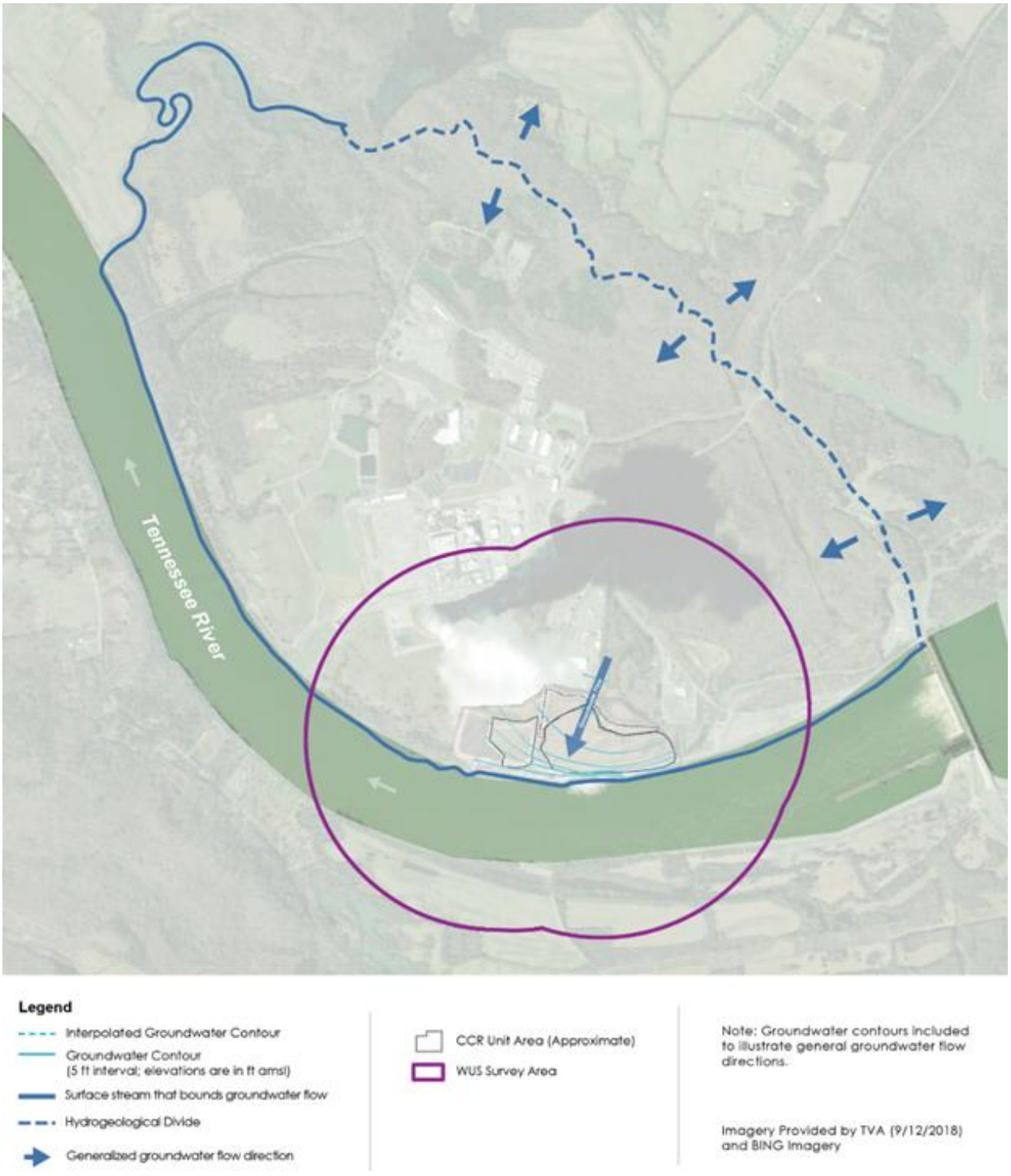
4.1.3 Water Use Survey

The water use survey began with a desktop survey which identified usable private water supply wells and surface stream water sources potentially being used for domestic purposes within 0.5-mile of the boundary of the WBF Plant, including water well inventory records on file with TDEC for Rhea and Meigs Counties (i.e., the water use survey area, as shown on the figure below).

The groundwater flow direction within the uppermost aquifer beneath the CCR units is generally from the west-northwest to the east-southeast toward the Tennessee River. Groundwater flow in the vicinity of the CCR units is bounded to the east by the Tennessee River. Groundwater movement toward the Tennessee River and the water use survey area is shown on the following figure. Based on the results of the desktop survey, no wells or springs potentially used for domestic or business purposes were identified in the Survey Area.

Public water surrounding the WBF Plant is supplied by the Town of Decatur Water System, Watts Bar Utility District, and Town of Spring City Water Utility that source their water from locations either upstream of the WBF Plant or a spring located 3.5 miles south of the WBF Plant.

WATER USE SURVEY AREA



4.1.4 Surface Streams, Sediment, and Ecological Investigation

To characterize environmental conditions and evaluate potential impacts to surface streams, sediments, and associated ecological receptors in the vicinity of the WBF Plant, TVA reviewed information from historical studies, and performed surface stream water, sediment, benthic macroinvertebrate community, Asiatic clam tissue, and fish tissue investigations as part of the EI.

The ecological investigations characterized water quality, sediment chemistry, benthic macroinvertebrate community composition, Asiatic clam tissue, and fish tissue in the vicinity of the WBF Plant and provided information to evaluate if CCR material and/or dissolved CCR constituents have moved from the CCR units, potentially impacting these environmental media. In addition, sediment, Asiatic clam, and fish tissue data were collected to evaluate potential bioaccumulation impacts. Surface stream samples were collected from transects located upstream, adjacent, and downstream of the CCR units in the Tennessee River. Sediment sampling was proposed along seven transects in the Tennessee River located downstream of the Watts Bar Dam; however, due to high flow velocities in this river reach, sediment depositional areas were lacking. Due to the absence of depositional substrates, it was only possible to collect sediment samples from locations immediately adjacent to the CCR units and farther downstream in the Tennessee River. Mayflies (*Hexgenia* spp.) were not encountered in sufficient numbers for collection of composite samples in the study area which has sand-gravel substrates. Composite Asiatic clam (*Corbicula* spp.) tissue samples were therefore collected in lieu of mayflies. Asiatic clam and fish tissue samples were collected in sampling areas and reaches located in similar areas as the surface stream and sediment transects within the Tennessee River. Benthic macroinvertebrate community samples were collected from seven transects located in the Tennessee River. Asiatic clam tissue samples were collected during EI activities from individual areas in the Tennessee River. Five fish species consisting of bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), and gizzard shad (*Dorosoma cepedianum*) were targeted for the EI in sampling reaches located in the Tennessee River. The fish were resected and composited to provide a total of 39 fish tissue samples comprised of muscle, liver, and ovary tissue samples for the gamefish, and whole fish for the shad. General surface stream, sediment and ecological sampling locations and reaches upstream, adjacent, and downstream of the WBF Plant for these investigations are displayed on Exhibit 4-2. Adjacent and downstream sample locations for the Tennessee River are displayed on Exhibit 4-3.

4.1.4.1 Surface Stream Water, Sediment, and Asiatic Clam and Fish Tissue Analyses

As noted in the EAR, surface water screening levels for human health, which are based on use of surface water as a drinking water supply source, are applied to surface stream results for the Tennessee River, as it is a potable surface water source potentially affected by the WBF Plant CCR units (Section 4.1.3). CCR Parameter concentrations in surface stream samples from the Tennessee River were below these human health screening levels (Table 4-2).

The EAR ecological screening values (ESVs), which are based on published studies of CCR Parameters' health effects on ecological receptors, were applied to surface stream and sediment results (Tables 4-3 and 4-4, respectively). Surface stream sampling results for the Tennessee River were below chronic

ESVs and indicate no potential water quality impacts from the CCR units. Sediment quality is within ranges protective of aquatic life in the Tennessee River. Sampling results for percent (%) ash and CCR Parameter concentrations in sediment samples from the Tennessee River were below the % ash threshold of 20% and chronic ESVs, respectively. These results indicate that sediment quality in the Tennessee River is within ranges that are protective of aquatic life.

The adjacent and downstream Asiatic clam and fish tissue sampling results for the Tennessee River were similar to upstream control locations (Table J.3-2 [Asiatic clam] and Table J.5-1 and Exhibit J.5-3 [fish tissue] of Appendices J.3 and J.5 of the WBF Plant EAR, respectively). Non-depurated and depurated composite Asiatic clam tissue sample concentrations for mercury and selenium were very low in the three reaches and, only minimal variability was identified in the concentrations of each relative to the sampling reach locations (i.e., upstream versus adjacent and downstream). Although there are clear differences between the ecosystems in Chickamauga Reservoir adjacent to the WBF Plant and upstream in Watts Bar Reservoir, there was minimal variability in the mercury and selenium concentrations relative to sampling locations (i.e., upstream of the dam versus adjacent and downstream of the WBF Plant). The Asiatic clam tissue sample results therefore suggest that measured mercury or selenium concentrations are not related to WBF Plant CCR unit activities. Selenium and mercury (total) concentrations in fish tissue samples from the Tennessee River were detected above Critical Body Residues in fish tissue (CBR_{fish}) values. Similarly, although there are clear differences between the ecosystems in Chickamauga Reservoir adjacent to the WBF Plant and upstream in Watts Bar Reservoir, the overall mercury and selenium fish tissue results were similar between the reaches. This indicates that fish tissue concentrations greater than CBR_{fish} values are not related to potential impacts from the CCR units. These results do not indicate potential impacts or bioaccumulation effects within these populations related to the WBF Plant CCR units.

4.1.4.2 Benthic Invertebrate Community Analysis

Benthic invertebrate community metrics were used as indicators of biological integrity and surface stream water and sediment quality, including a reservoir benthic index (RBI) Total Score and supplemental metrics. Sampling transects were established at locations adjacent to and downstream of the WBF Plant CCR units, as well as upstream of the Watts Bar Dam within the Reservoir. As discussed in the WBF Plant EAR, upstream communities are likely affected by habitat-related stress associated with the impounded waters of the Watts Bar Reservoir and are not ideal as study controls. In 2019, the RBI categorized all adjacent and downstream EI sampling locations as having ‘Excellent’ biological integrity, while upstream communities scored comparably much lower. The RBI results for the Tennessee River are depicted on Exhibit 4-4. This is consistent with historical results, and an ‘Excellent’ rating has been continuously maintained since 2011, as shown on Exhibit 4-5. As such, EI results show that conditions have been largely unchanged in the long term and that benthic communities remain productive and healthy. Therefore, they do not reflect impacts associated with the WBF Plant CCR units.

In addition to the inclusive multi-metric RBI results, supplemental metrics were calculated, including Total Taxa Richness (TTR) and the Hilsenhoff Biotic Index (HBI). TTR for the Tennessee River is depicted on Exhibit 4-6. Exhibit 4-7 present HBI results for the Tennessee River. TTR generally increased moving from upstream to downstream, with the greatest richness observed at the farthest downstream transect



(TR07), and communities adjacent to and downstream of the WBF Plant were consistently richer than those in the reservoir upstream of the Plant. There is no indication that the WBF Plant CCR units are constraining local communities, resulting in reduced richness. HBI scores were consistently higher adjacent to and downstream of the WBF Plant than upstream within the reservoir. Scores in potential impact areas (adjacent and downstream) all fell within the same rating category, as well, demonstrating similarly sensitive benthic communities in these areas. The evaluation of these metrics corroborates the findings of the RBI evaluation.

The adjacent and downstream benthic communities in the Tennessee River appear to be healthy, rich, and sensitive, and they demonstrate more favorable ecological conditions than upstream locations in the reservoir above Watts Bar Dam. Collectively, the benthic community data reflect no impacts from the CCR units.

4.2 OTHER SOURCES OF DATA FOR THE WBF PLANT

WBN Plant pre-operational aquatic monitoring was conducted between 1973 and 1985 (two sample periods: 1973 to 1977 and 1982 to 1985), and operational aquatic monitoring conducted in 1996 and 1997 included trace metals, solids (suspended and dissolved), turbidity, phosphorous and other parameters in addition to general water quality measurements (e.g., temperature, dissolved oxygen). Surface stream monitoring for general water quality parameters has been conducted near the WBF Plant under TVA's Reservoir Release Improvement (RRI) program established in 1991, after the WBF Plant became inactive. No specific sampling to evaluate potential CCR contamination was performed under the RRI program. TVA is currently conducting ongoing monitoring of surface stream water quality in the Tennessee River at the WBN Plant along with Whole Effluent Toxicity testing twice per year at each outfall in accordance with its NPDES Permit.

TVA has conducted biological assessments by periodically monitoring aquatic communities (fish and benthic invertebrates) to evaluate their status upstream and downstream of the WBF Plant. Since 2001, benthic invertebrate assessments have been conducted annually during 2001 to 2005, 2007 to 2013, 2015, 2017, and 2020 in accordance with the WBN Plant NPDES permit. Historical sediment sampling for CCR constituents has not been conducted in the Tennessee River adjacent to the WBF Plant. Since initiation of benthic sampling in 2001, the WBF Plant benthic sample results have shown consistently higher biological integrity adjacent to and downstream of the WBF Plant compared to upstream conditions, located above the Watts Bar Dam. RBI outcomes for upstream communities reflect a level of habitat-related stress associated with the impounded waters of the Watts Bar Reservoir, and therefore, the upstream transects are not ideal control locations. However, historical monitoring data, demonstrated consistently 'Excellent' biological integrity in downstream reaches from 2003 through 2005 and since 2011 (Appendix J.3 of the WBF Plant EAR).

Located adjacent to the WBF Plant, the WBN Plant has similar ecological ranges for fishery study evaluation, and fishery studies completed between 1977 and 1985 were often completed as pre-operational studies for the WBN Plant. Historical fish population assessments were completed from the 1970s through 2015. Additionally, sport fish surveys, fish impingement monitoring, entrainment studies, and fish tissue studies were conducted. Biological assessment data has demonstrated, with acceptance



by TDEC and USEPA Region 4, that the presence, protection, and maintenance of a balanced indigenous population in the Chickamauga Reservoir support the continuance of the alternate thermal limits in the WBN Plant NPDES permit (TVA 2018b). Overall, the fish community sampling events and Reservoir Fish Assemblage Index (RFAI) results showed that a balanced indigenous population is currently being demonstrated in Chickamauga Reservoir (i.e., in the Tennessee River in the vicinity of the WBF Plant). Results of the 1970s and 2000s impingement monitoring concluded that no fish species were impinged at those facilities in sufficient numbers to impact Watts Bar and Chickamauga Reservoir fish communities (TVA 1975, 2007b, 2011b, and 2017b). With the exception of mercury concentrations in largemouth bass collected from the Hiwassee River arm of the Chickamauga Reservoir in the 1990s, historical fish tissue contaminant concentrations were either below detectable levels or below TDEC fish consumption advisory levels (Appendix J.5 of the WBF Plant EAR).

4.3 DATA QUALITY AND USEABILITY FOR RISK ASSESSMENT

Only data collected during the EI at the WBF Plant and reported and evaluated in the WBF Plant EAR were considered usable for quantitative evaluation in the HHERA. Other data described in Section 4.2 were only considered for qualitative use in the risk assessments. The EI data were further reviewed to identify data acceptable for risk assessment use (Section 4.4). In addition to the criteria followed per the Quality Assurance program, the following general criteria, based on USEPA guidance (USEPA 1992a) were followed in the WBF Plant EAR and in generating risk assessment datasets:

- Estimated values (flagged with a “J” qualifier) were treated as detected concentrations
- Where field duplicate data were present, the primary sample was used in the quantitative evaluation
- Statistical outlier screening in the WBF Plant EAR (Appendix C.1) consisted of visual inspection of data using side-by-side box plots. If suspected visual outliers were identified, then statistical procedures (i.e., Tukey’s procedure and Dixon and Rosner’s test) were used to determine whether the potential outliers were statistically significant outliers. Multiple LOEs, such as verification of whether data points were errors (e.g., laboratory or transcriptional error) and review of final outlier disposition (e.g., frequency of detection, spatial and temporal variability) were then considered to determine whether statistical outliers were suitable for removal from further statistical analysis. Statistical outliers identified in the WBF Plant EAR were reviewed and considered for exclusion from the risk assessment dataset. Outlier screening included in the WBF Plant EAR identified one outlier in the surface stream water dataset. Statistical outliers were not identified for CCR material or sediment data. As a result, one statistical outlier was excluded from the risk assessment dataset.

4.4 SUMMARY OF DATA FOR USE IN THE RISK ASSESSMENT

The datasets for the WBF Plant HHRA and ERA consist of data selected following the general criteria provided in Section 4.3 for the applicable media, and as described in Sections 5.1.1 and 6.1.1. Additional media-specific criteria applied to data selection are discussed below. The data used in the HHRA and ERA are summarized in Tables 4-1 through 4-5 and Appendix C, and by media type in the following



sections. These datasets were further refined for the risk evaluation (e.g., only data collected from the region adjacent to or near downstream of the WBF Plant), as described in Section 5.1.3.

4.4.1 CCR Material

The use of CCR material data is limited to the HHRA evaluation. Ecological receptors are not expected to be exposed to CCR material (i.e., incomplete exposure pathway) as described in Section 6.1.1. As described in Section 4.1.1, CCR material data were collected in the Ash Pond and Slag Disposal Area and were combined into a single dataset for COPC identification. The CCR material data summary is provided in Table 4-1. The results of the WBF Plant EAR statistical analyses are presented in Appendix C.1. Additional analysis of the CCR material datasets used in the HHRA for risk evaluation are summarized in Appendix C.2. The rationale for these additional analyses for the HHRA is provided in Section 5.0.

4.4.2 Groundwater

As described in the *Proposed Receptor-Specific Screening Levels for Human Health (SSL_{HH})* (Appendix B.1), the potential migration of CCR Parameters in onsite groundwater to offsite locations where there may be private potable wells or springs was addressed by the water use survey. In addition, analytical results of groundwater samples collected as part of the EI were compared to approved groundwater screening levels and presented in the WBF Plant EAR. These approved human health screening levels for CCR Parameters in groundwater are based on regulatory standards. Summary statistics of CCR Parameters in groundwater are provided in Appendix E.3 of Appendix C.1. Based on the overall results of the water use survey as discussed in Section 4.1.3 (i.e., groundwater flow is generally from the west-northwest to the east-southeast toward the Tennessee River, groundwater flow in the vicinity of the CCR units is bounded to the east by the Tennessee River, and no wells or springs potentially used for domestic or business purposes were identified in the Survey Area), current and historical CCR management associated with the WBF Plant has not affected water supply wells or springs located downgradient of the WBF Plant. Therefore, exposure pathways associated with offsite use of groundwater and springs as a drinking water source were not considered complete, and as a result, no further quantitative assessment of groundwater is presented in this report. However, TVA will implement corrective actions to meet groundwater protection standards (GWPS) as part of the CARA Plan.

4.4.3 Surface Stream Water

The surface stream water datasets for the HHRA and ERA consist of surface stream water data selected following the general criteria described in Section 4.3, and the following surface stream water-specific criteria:

- Surface stream data were segregated into datasets for each waterbody (i.e., Tennessee River)
- Surface stream data collected from all water column depths (i.e., surface, middle and bottom) and positions along the sample transects (i.e., left and right banks and center channel) were included in the HHRA and ERA datasets

- Surface stream data collected from locations adjacent to or downstream of the WBF Plant CCR units were included in the HHRA and ERA datasets
- Surface stream data collected from locations upstream of the WBF Plant CCR units were excluded from the HHRA and ERA datasets. Upstream data were used qualitatively in the HHERA
- Where CCR Parameters were reported for both dissolved and total fractions (from filtered or unfiltered samples, respectively), both dissolved and total concentrations were included.

The surface stream data summary for use in the HHRA and ERA is provided in Tables 4-2 and 4-3, respectively. The results of the WBF Plant EAR statistical analyses are presented in Appendix C.1.

4.4.4 Sediment

The sediment dataset for the ERA consists of sediment data selected following the general criteria described in Section 4.3, and the following sediment-specific criteria:

- Sediment data were segregated into datasets for each waterbody (i.e., Tennessee River).
- Sediment data collected from the three transect locations (left and right banks and center channel) adjacent to or downstream of the WBF Plant CCR units and all sampling depths were included in the ERA dataset used to identify COPECs.

The sediment data summary for use in the ERA is provided in Tables 4-4. Only sediment data representative of seasonally exposed sediment locations above the water line during low pool and accessible to recreational users of the river are applicable to the HHRA. No seasonally exposed sediment locations adjacent or downstream of the WBF Plant were identified for the Tennessee River sediment samples collected as part of the EI. The results of the WBF Plant EAR statistical analyses are presented in Appendix C.1.

4.4.5 Fish Tissue

Selection of the fish tissue datasets for the HHRA followed the general criteria described in Section 4.4, and the following fish-specific criteria:

- Fish tissue data were segregated into datasets for each waterbody (i.e., Tennessee River)
- The HHRA included fish tissue data collected from locations in the Tennessee River adjacent to (WBF-TRA) and downstream (WBF-TRD) of the WBF Plant CCR units
- The HHRA datasets were limited to fish filet[1] data since these data best reflect the tissues consumed by anglers.

[1] Muscle tissue used for the HHRA will be referred to herein as “filet”.

The fish tissue data summary for HHRA is provided in Table 4-5. The results of the WBF Plant EAR statistical analyses are presented in Appendix C.1. Additional analyses of the fish tissue datasets used in the HHRA for risk evaluation are summarized in Appendix C.2. The rationales for these additional analyses for the HHRA are provided in Section 5.0.



5.0 HUMAN HEALTH RISK ASSESSMENT

Potential human health risks were evaluated in the HHRA assuming the concentrations and distribution of CCR Parameters in abiotic media and fish filet tissue (described in the EAR) represent current and future conditions at the CCR units at the WBF Plant. The HHRA results will be used to evaluate whether concentrations of CCR Parameters in CCR material, surface stream water, and fish filet tissue for the WBF Plant are protective of human health. Results of this HHRA were used in the CARA Plan to evaluate whether corrective measures are needed for the protection of human and ecological receptors.

The HHRA methodology described herein is in accordance with the following USEPA guidance documents and/or reference materials:

- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)* (USEPA 1989a)
- *Exposure Assessment Guidelines* (USEPA 1992b)
- *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA 2002)
- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004)
- *Guidelines for Carcinogen Risk Assessment* (USEPA 2005)
- *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment*) (USEPA 2009a)
- *Exposure Factors Handbook: 2011 Edition* (USEPA 2011)
- *Compilation and Review of Data on Relative Bioavailability of Arsenic in Soil* (USEPA 2012a)
- *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors* (USEPA 2014a)
- *Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations*, National Health and Nutrition Examination Survey (NHANES) 2003-2010 (USEPA 2014b)
- *Region 4 Human Health Risk Assessment Supplemental Guidance* (USEPA 2018a)
- *Preliminary Remediation Goals (PRGs) for Radionuclides* (USEPA 2021)
- *Regional Screening Levels (RSLs) – User's Guide* (USEPA 2024).

The general framework for conducting HHRAs is provided in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)* (USEPA 1989a). Consistent with this guidance, the HHRA consists of the following primary steps:

- Data collection and evaluation
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty analysis.

The methods and procedures to perform the exposure assessment, toxicity assessment, and risk characterization steps are described in the following subsections. Data collection and evaluation were conducted as part of the WBF Plant EAR as summarized in Section 4.

5.1 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of human exposure to CCR Parameters present at or near the WBF Plant. The exposure assessment includes development of a CSM, derivation of exposure assumptions and EPCs, and estimation of doses. The methods and assumptions used in the quantification of exposure are presented in Sections 5.1.2 through 5.1.4. Sections 5.1.2 through 5.1.3 present the exposure assumptions and chemical-specific parameters and describe how EPCs were estimated. Section 5.1.4 references the equations used to calculate exposure doses for COPCs. Risks for radionuclides are quantified using PRGs calculated using the 'peak risk' option from USEPA's PRG calculator (USEPA 2021) as described in Section 5.3.2.

5.1.1 Conceptual Site Model for the Human Health Risk Assessment

The human health CSM for the WBF Plant presents the potential human receptors and pathways through which those receptors could be exposed to CCR Parameters. The human health CSM includes the identification of COPCs and describes the relationships between the CCR Parameter source, release mechanisms to environmental (exposure) media, transport mechanisms, and routes of exposure to potential human receptors. An exposure pathway is considered potentially complete if the following elements are present: 1) a source and mechanism for release of CCR Parameters, 2) a transport or retention medium, 3) a point of potential human contact (exposure point) with affected medium, and 4) an exposure route at the exposure point. The CSM for the WBF Plant HHRA is presented as Exhibit 5-1.

5.1.1.1 Release Mechanisms

The EI assessed the potential current and future releases of CCR Parameters from the potential loss of structural integrity of the CCR units and by potential movement of dissolved CCR Parameters in pore water from the CCR units to groundwater and then into adjacent surface water streams. A seep investigation was conducted as part of the EI to identify the potential presence of active seepage and

assess the potential movement of groundwater or pore water with dissolved CCR constituents into adjacent surface water streams.

As reported in the WBF Plant EAR, the CCR units have adequate structural integrity, and there is no evidence of voids/cavities in bedrock that could lead to loss of structural support and potential release of overlying CCR material. The slope stability for the CCR Units meet the factor of safety criteria, except for the post-earthquake, global stability at the Ash Pond and Slag Disposal Area. TVA will be evaluating mitigation alternatives as part of the CARA Plan. An onsite worker engaged in minor repairs to the infrastructure of the closed CCR units (e.g., piping, surface water management) could be exposed to small quantities of CCR material, but these activities would not be considered a substantive release mechanism.

As described in Section 4.1.2, three AOIs (AOI02, AOI03 and AOI04) were further evaluated in the CARA Plan to determine if corrective measures are needed. These AOIs were located in areas covered by riprap, making them inaccessible. Consequently, they are not evaluated further in this HHRA because the exposure pathways are incomplete (Exhibit 5-1).

Movement of dissolved CCR Parameters in pore water to groundwater beneath the CCR units and into the Tennessee River was considered a potential release mechanism. However, based on the overall results of the water use survey, current and historical CCR management associated with the WBF Plant has not affected water supply wells or springs located downgradient of the WBF Plant. Therefore, exposure pathways associated with offsite use of groundwater and springs as drinking water sources were not considered complete and were not quantitatively evaluated in the HHRA. Evaluation of the influence of geochemical processes on groundwater quality were further evaluated in the CARA Plan as part of the assessment of corrective measures, where needed.

5.1.1.2 Receptor Identification

A human receptor is a hypothetical person (child or adult) who resides, visits, or works on or near the WBF Plant and is, or could potentially be, exposed to COPCs from the CCR units. General physical and behavioral characteristics specific to the receptor type (e.g., body weight, breathing rate, amount of fish consumed) are used to estimate the amount of chemical exposure for each receptor.

Since people have varying physical features, lifestyles, and habits, it is not possible to evaluate every type of individual. Due to differences in physiological characteristics and activity patterns between young children and adults, the exposures received by a young child and an adult will be different. Consequently, the potential risks estimated for the same COPC will differ depending on the receptor. The HHRA must be sufficiently comprehensive and robust to confirm that the receptors with the greatest potential for exposure to COPCs and have the greatest sensitivity or potential for developing adverse health effects from such exposures are included in the evaluation. Consequentially, the HHRA is based on hypothetical receptors with exaggerated behaviors and activity patterns. If no potential for adverse health risks is identified for these more exposed and more sensitive receptors, then no adverse health effects would be expected for less exposed, less sensitive receptors.

For the purposes of the HHRA, human receptors have been grouped as described below:

- Onsite receptors, who may be present on or near the CCR units
- Offsite receptors, who may use the Tennessee River for recreation or as a public water supply, or who use groundwater and springs as sources of potable water.

The human receptors proposed for the WBF Plant HHRA are described below.

5.1.1.2.1 Potential Onsite Receptors

Land use within the WBF Plant property is industrial. There are no planned changes in land use. The majority of the WBF Plant, including the location of the former powerhouse and the closed and covered CCR units, is maintained grassy areas. Because the HHRA is based on post-closure conditions of the CCR units, potential risks associated with onsite exposures to CCR material are limited to exposure scenarios where receptors could reasonably be expected to penetrate the geosynthetic cover system, such as a worker making repairs to infrastructure associated with the CCR units during post closure. TVA employees and contractors who work at the WBF Plant are not relevant receptors for the purpose of the TDEC Order as reflected in the approved EIP as they would not be expected to penetrate the geosynthetic cover system.

Trespasser

Casual unauthorized visitors (trespassers) might access closed CCR units in locations where there are no physical barriers (e.g., fencing or barricades). Although the WBF Plant is not fully fenced, a trespasser identified on or around the CCR units would be quickly intercepted. The post-closure CCR units are covered by geosynthetic cover systems that preclude potential exposures by casual trespassers. Much of the Tennessee River shoreline adjacent to the WBF Plant is bulkheaded and inaccessible from the water. The exterior perimeter dikes of the CCR units along the Tennessee River where bulkheads are not present are steep and covered with riprap. While potentially accessible from the water, access of these areas by trespassers is unlikely. As such, trespassers were not assessed further in the HHRA.

Onsite Worker

An onsite worker is defined as an adult receptor engaged in minor repairs to the infrastructure (e.g., piping, surface water management) of the CCR units during post closure. Such projects would be conducted in response to a specific situation (e.g., a broken or leaking pipe), would be limited to shallow depths (i.e., 0 to 10 feet below ground surface [bgs]), and not associated with routine maintenance of the geosynthetic cover systems of closed CCR units. These one-time events are expected to be infrequent, non-recurring, and of short duration (i.e., no more than 20 days within a single one-year period), which is consistent with the excavation worker scenario included in the Risk Assessment Information System (RAIS) Chemical Risk Calculator (RAIS 2024a). If substantive repairs that would take more than 20 days to complete are necessary, a site-specific health and safety plan specifying procedures to protect onsite workers would be required. Other excavation and construction activities are considered part of ongoing operations at the WBF Plant and are not considered as relevant receptors per the requirements of the TDEC Order.



5.1.1.2.2 Potential Offsite Receptors

Land use surrounding the WBF Plant is primarily undeveloped and includes forest, agriculture areas, and rural residential areas, with the nearest residence located approximately 1.4 miles northwest of the WBF Plant in Spring City. While there are several local recreational areas (e.g., small parks, local boat ramp, and fishing access) along the Tennessee River that offer public access for a variety of outdoor activities, there are a limited number of human receptors possibly relevant to the scope of the TDEC Order.

Potential future offsite receptor scenarios identified for the WBF Plant under current and reasonable future land use are as follows:

- Residential use of the Tennessee River as a public water supply
- Private residential use of groundwater and springs for potable water
- Recreational use of the Tennessee River (recreational user – beachcomber, recreational user – swimmer, and consumers of fish taken from the Tennessee River).

These receptor scenarios are described in more detail below.

Resident

Residents are defined as adults, adolescents, young children, and infants who use potable water from municipal water departments that withdraw water in the vicinity of the WBF Plant or who reside within a 0.5-mile radius of the WBF Plant parcel boundary and use groundwater or springs as a potable water source. As described in Section 4.1.2, no wells or springs potentially used for domestic or business purposes were identified in the water use survey; therefore, ingestion of groundwater is not a complete pathway. As described in Section 1.3, the focus of the HHERA is on the post-closure conditions of the CCR units. As there is not any exposed CCR material post closure (and therefore no source of particulates), the offsite resident exposure to CCR material via particulate migration pathway is incomplete and not further assessed.

Recreational Users

An important part of TVA's mission is to support recreational use of the Tennessee Valley's environmental resources. The rivers and reservoirs around the WBF Plant are used for recreational activities year-round. Fishing from the shore and from boats occurs almost all year in the Tennessee River, with springtime being particularly popular for sport fishing. Water sports such as swimming, water skiing, and jet skiing occur primarily during the warmer months of the year and coincide with high pool levels in the reservoir sections of the major rivers. The cooler months coincide with lower pool levels, which may result in areas of seasonally exposed sediments. Consistent with the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Human Health Risk Assessment* (Jacobs 2012), recreational users of the Tennessee River were further grouped by their primary activities: swimmers, beachcombers, and consumers of locally-caught sport fish, as defined in more detail below.

- *Recreational User – Swimmer*

  Swimming, wading, and other water-contact activities within the Tennessee River occur primarily during the warmer months of the year when water levels are at high pool and most sediments are under water. A recreational user – swimmer may come into contact with CCR Parameters in river or stream water via incidental ingestion of surface stream water and dermal contact with surface stream water. Contact with submerged sediment in the stream channel while wading or swimming is not a complete pathway of exposure (USEPA 2018a) because particles are assumed to be quickly washed from the skin. Therefore, sediments in the stream channels that are submerged under water all year are not a complete pathway of exposure for this receptor and will not be evaluated in the HHRA.

- *Recreational User – Beachcomber*

  During the cooler months, people may engage in activities such as beachcombing, camping, and fishing along the riverbanks and accessible areas of seasonally exposed sediments. For the HHRA, seasonally exposed sediment is defined as sediment in near-shore areas of lakes and streams that is not completely covered by water during seasonally low water levels, thus is accessible to humans and wildlife during those periods. As described in Section 4.4.3, no seasonally exposed sediment locations adjacent or downstream of the WBF Plant were identified for the Tennessee River; therefore, the use of the Tennessee River by a recreational user – beachcomber is not a complete pathway of exposure for this receptor. Sediments in the stream channels that are submerged under water all year are also not a complete pathway of exposure for this receptor. As a result, these two exposure pathways will not be evaluated in the HHRA.

- *Recreational User – Consumer of Locally-Caught Sport Fish*

  Fishing, both from shore and from boats, is a popular activity year-round, and people of all ages (adults [ages 16 years and older], adolescents [6 to <16 years old] and children [0 to <6 years old]) eat locally-caught sport fish. In some cases, recreational user – beachcombers also consume fish that they have caught. Fish are also assumed to be consumed by members of an angler's family who do not themselves catch the fish.

5.1.1.3 Pathways of Exposure

Exposure pathways identified in the HHRA CSM (Exhibit 5-1) for the WBF Plant are classified as:

- Potentially complete
- Potentially complete but contribution to exposure is negligible
- Incomplete.

As discussed in Section 5.1.1, an exposure pathway is considered complete when there is potential for a receptor to be exposed to COPCs in an exposure media through an identified exposure route, as defined for relevant onsite and offsite human receptors in Section 5.1.1.2. For each of the potential human

receptors identified above, potential exposure media and exposure pathways for the WBF Plant are evaluated and classified below. For potentially complete pathways, the following general criteria were applied to identify COPCs in potential exposure media for further evaluation in the HHRA.

1. If a CCR Parameter was not detected in the potential exposure media and the maximum reporting limit for samples collected from that potential exposure media was equal to or below the respective screening level, then the CCR Parameter was not identified as a COPC for the exposure scenario.

2. If a CCR Parameter was detected in the potential exposure media and the maximum detected concentration was equal to or less than the respective screening level, then the CCR Parameter was not identified as a COPC for the exposure scenario.

3. If calcium, chloride, and/or sulfate were detected in the potential exposure media, these CCR Parameters were not identified as COPCs for the exposure scenario. These CCR Parameters are not evaluated in the HHRA because they are essential mineral ions. Calcium is generally toxic only in very high concentrations and is a naturally occurring element known to be essential or beneficial to animal life (e.g., calcium plays an important role in functions such as proper bone development, nerve transmission, and muscle function) (IOM 2011). Chloride is naturally occurring in the environment and is an essential dietary mineral in animals and humans (Deane et al. 1952). It is an important electrolyte in all body fluids where it maintains acid/base balance, it is also critical to neural transmission, heart and muscle contraction, and regulates liquid flow in and out of cells (Raut et al. 2024). Sulfate is an essential mineral in animals and humans (National Academies 2005). It is the fourth most common anion in our blood, a component of vitamin D3, an integral constituent of the myelin sheaths surrounding neuronal axons and prevents blood from coagulating during transit through capillaries. Laboratory studies in animals have shown that growth is stunted when sulfate is eliminated from the diet (National Academies 2005).

4. If a CCR Parameter was not detected in the potential exposure media, but the maximum reporting limit for samples collected from that potential exposure media was greater than the respective screening level, then the CCR Parameter was further evaluated to determine if it should be identified as a COPC for the exposure scenario.

5. If a CCR Parameter was detected in CCR material and the maximum detected concentration is greater than the respective screening level, then the CCR Parameter was identified as a COPC for the exposure scenario.

A summary of COPCs identified for further evaluation in the HHRA is presented in Table 5-1.

5.1.1.3.1 Onsite Worker

An onsite worker engaged in minor repairs to the infrastructure of CCR units during post closure may come into direct contact with CCR material beneath the geosynthetic cover system. This receptor can be exposed to COPCs in CCR material via incidental ingestion and dermal contact with CCR material and

inhalation of particulates released from CCR material for a short duration (i.e., a few days to a few weeks). External exposure to radiation emitted from radionuclides in CCR material may also occur. External exposure to radiation refers to the ability of energy released from radionuclides from an external source to penetrate through the skin (this is different from dermal exposure which occurs when a chemical is absorbed through the skin). Many TVA CCR units are subject to the requirements of the CCR Rule. The CCR Rule focuses on meeting GWPS in compliance wells immediately downgradient of the unit (i.e., onsite), consistent with regulatory requirements, and independent of the results of the HHERA. There are no potable groundwater wells at the WBF Plant, and there are no plans to install potable groundwater wells in the future.

COPC Screening

Although an onsite worker making minor repairs would likely only be exposed to CCR material within 0 to 10 feet bgs, data for CCR material samples collected from all sampling depths were screened against the lowest SSL_{HH} for an onsite worker (Appendix B.1). The SSL_{HH} for onsite workers are based on an exposure frequency of 20 days (five days per week for four weeks) over a one-year exposure duration, and risk targets that are ten times more protective than regulatory targets. CCR material data summary and comparisons to human health screening levels are provided in Table 4-1.

5.1.1.3.2 Resident

As discussed in Section 5.1.1.2.2, no wells or springs potentially used for domestic or business purposes were identified in the water use survey; therefore, ingestion of groundwater is not a complete pathway. Both current and future offsite residents may potentially be exposed to CCR Parameters in surface stream water with public water utilities intakes. Public water surrounding the WBF Plant is supplied by the Town of Decatur Water System, Watts Bar Utility District and Town of Spring City Water Utility that source their water from locations either upstream of the WBF Plant or a spring located 3.5 miles south of the WBF Plant.

Offsite residents using potable water from these municipal water departments may be exposed to CCR Parameters via ingestion of drinking water and dermal contact during household uses such as ingestion of tap water, beverages, and foods prepared with potable water; and dermal contact while bathing, washing dishes or clothing, and performing other domestic activities.

COPC Screening

Data for surface stream water samples from the Tennessee River adjacent and downstream of the WBF Plant have been screened against human health screening levels for domestic water supply and surface stream water (Appendix B.1, Attachment A). The human health screening levels for domestic water supply are protective of residents for the potentially complete exposure pathways noted above. As indicated in Table 4-2, no CCR Parameters were detected above these screening levels, and therefore no COPCs were identified for this exposure scenario.

5.1.1.3.3 Recreational User – Swimmer

A recreational user – swimmer may be exposed to COPCs in surface stream water in the Tennessee River while engaged in activities such as swimming, wading, and other water-contact activities that occur primarily during the warmer months of the year when water levels are at high pool and most sediments are under water. A recreational user – swimmer may come into contact with CCR Parameters in river or stream water via incidental ingestion of and dermal contact with surface stream water. Contact with submerged sediment in the stream channel while wading or swimming is not a complete pathway of exposure (USEPA 2018a) because particles are assumed to be quickly washed from the skin.

COPC Screening

Screening levels used for a recreational user – swimmer are equal to the human health screening levels for domestic water supply (presented in Appendix B.1, Attachment A). The frequency and intensity of exposure to surface stream water used as domestic water supply by receptors of all age groups are greater than exposure to surface stream water through seasonal recreational contact, thus the screening levels for domestic water supply are protective of a recreational user – swimmer for the potentially complete exposure pathways noted above. Surface stream water data summary and comparisons to human health screening levels are provided in Table 4-2. No COPCs were identified in surface stream water for a recreational user – swimmer.

5.1.1.3.4 Recreational User – Consumer of Locally-Caught Sport Fish

Fishing, both from shore and from boats, is a popular activity year-round, and people of all ages (adults [ages 16 years and older], adolescents [six to less than 16 years of age] and children [0 to less than six years of age]) eat locally-caught sport fish. There are a number of public and private boat launches and docks on the Tennessee River in the vicinity of the WBF Plant. Locations along the banks of the Tennessee River are also accessible for fishing.

Consumption of locally caught sport fish that may have accumulated CCR Parameters originating from the CCR units in edible tissue is a potentially complete exposure pathway for a recreational user – consumer of locally-caught sport fish for the Tennessee River. The region of the Tennessee River near the WBF Plant is a popular fishing spot for residents of Spring City and areas near the WBF Plant based on site observations.

COPC Screening

Fish tissue filet data were screened against the lowest fish SSL_{HH} for a consumer of locally-caught sport fish (Appendix B.1). The SSL_{HH} for a recreational user – consumer of locally-caught sport fish were derived using the adult 95th percentile fish consumption rate of 32.7 grams (g) - wet weight (ww) per day (g--ww/day) for the inland south region of the United States (USEPA 2014b). The fish consumption rates are based on total freshwater and estuarine finfish and shellfish, including both locally-caught and store-bought fish (USEPA 2014b).

The adult fish intake rate of 32.7 g-ww/day used in the development of the SSL_{HH} is higher than the current USEPA national-level consumption rate for ambient water quality criteria (22 g-ww/day; USEPA

2015); and nearly twice the previous national-level consumption rate (17.5 g-ww/day; USEPA 2010). The SSL_{HH} were calculated based on a target cancer risk of $1x10^{-6}$, and HQ of 0.1. Based on the above (e.g., conservative fish consumption rate that is higher than the national level consumption rate and includes store-bought fish), the SSL_{HH} are very protective of recreational users who consume fish taken from the Tennessee River.

Inorganic mercury is listed as a CCR Parameter; however, inorganic mercury is converted by biological processes in the aquatic environment to methyl mercury, which then accumulates in biological tissues including fish filet. Mercury speciation analysis was not conducted on fish tissue samples to determine relative amounts of inorganic and methyl (organic) mercury. Rather, only total mercury was measured, which was protectively evaluated as methyl mercury in the HHRA. The fish SSL_{HH} assumes human exposure from fish consumption is to methyl mercury rather than inorganic mercury because methyl mercury has a higher toxicity than inorganic mercury, as noted in Section 5.2. Fish tissue data and comparisons to SSL_{HH} are provided in Table 4-5.

Thallium was not detected in fish filet tissue samples collected from the Tennessee River adjacent to the WBF Plant; however, the reporting limits in fish tissue samples are greater than the screening level for thallium by less than an order of magnitude. The oral toxicity value (USEPA 2012b) used to derive the thallium fish filet screening value is a screening provisional chronic oral reference dose (RfD) derived using an uncertainty factor of 3000 due to critical limitations in the chosen toxicity study because of a lack of epidemiological data in humans and toxicity studies on laboratory animals. In 2009, USEPA concluded that the available toxicity data were insufficient to derive a toxicity value for thallium (USEPA 2009b). In 2012, USEPA derived a screening provisional oral RfD without an updated literature search based on a study which found an increase in alopecia (i.e., hair loss) in rats. Although thallium is toxic to humans at high doses, and alopecia is a symptom of thallium toxicity, the observed alopecia was not linked to histopathological effects or measures of neurotoxicity, and the significance of an increase in alopecia for the study is unclear (USEPA 2012b). As a result of the conservatism built into the thallium oral toxicity value used to derive the thallium fish filet screening level and the low magnitude of non-detect reporting limits above this screening level, thallium was not identified as a COPC in fish filet tissue for the Tennessee River.

5.1.2 Exposure Assumptions

The exposure parameters used in the HHRA and the specific sources and rationale for these parameters are presented in Table 5-2. The sources for the exposure parameters used in the HHRA include:

- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)* (USEPA 1989a)
- *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA 2002)
- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004)
- *Exposure Factors Handbook: 2011 Edition* (USEPA 2011)



- *Compilation and Review of Data on Relative Bioavailability of Arsenic in Soil* (USEPA 2012a)
- *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors* (USEPA 2014a)
- *Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations* (NHANES 2003-2010) (USEPA 2014b)
- *Region 4 Human Health Risk Assessment Supplemental Guidance* (USEPA 2018a)
- *Preliminary Remediation Goals (PRGs) for Radionuclides* (USEPA 2021).

5.1.3 Exposure Point Concentrations

The EPC describes the level of a COPC in CCR material or fish filet to which a receptor is potentially exposed (USEPA 1989a). The EPC serves as the basis for quantifying pathway-specific exposure doses. When there were five or more detected results, EPCs for measured media were the lower of the upper confidence limit (UCL) on the mean concentration or the maximum detected concentration. When there were less than 10 total samples with less than five detected results, the selected EPCs for measured media were the maximum concentrations. If there were 10 or more samples with less than five detected results, EPCs for measured media were the lower of the maximum detected concentration or the median concentrations. For datasets with low detection frequencies, the median may provide a better estimate of the population measure of central tendency (USEPA 2022a). Distributions and recommended UCLs on the mean concentrations were calculated and selected using USEPA's ProUCL software version 5.2 (USEPA 2022a). ProUCL typically recommends a 95% UCL. For datasets with small sample sizes or high result variability, ProUCL may recommend a UCL on the mean associated with a higher confidence level. Measured data used in the EPC derivation for COPCs in each medium are described below.

CCR Material: EPCs for COPCs identified in CCR material (Section 5.1.1.3.1) were derived for each CCR unit listed in Section 3.1.1 (i.e., the CCR units were evaluated separately), as summarized in Appendix C.2.

- CCR material data collected from all sampling depths in the Ash Pond and Slag Disposal Area were included in the CCR material dataset to establish EPCs for these CCR units.
- EPCs were only calculated for COPCs in CCR material from a given unit if the maximum detected concentration in samples collected from that CCR unit was above the respective screening level presented in Table 4-1.

Fish Filet: EPCs were derived for COPCs in the Tennessee River using fish filet tissue data collected from locations adjacent to the WBF Plant CCR units.

- EPCs were only derived for COPCs in fish filet tissue if the maximum detected concentration in fish collected from locations adjacent to the WBF Plant CCR units was above the respective screening level presented in Table 4-5. As a result, an EPC was not derived for copper because



the maximum concentration (0.53 milligrams [mg] per kilogram [kg] - ww[mg/kg-ww]) detected in adjacent Tennessee River is below the respective screening level (7 mg/kg-ww).

The selected EPCs and data summaries are included in Appendix C.2. The ProUCL outputs, including the recommended 95% UCL on the mean concentration, are provided in Appendix C.3.

5.1.3.1 Arsenic in Fish Tissue

The EPCs for arsenic in fish filets are based on total arsenic concentrations measured in fish tissue, and the toxicity values used in the risk calculations are based on inorganic arsenic (USEPA 2024). However, as described in the *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A), arsenic in fish tissue is predominately in the form of relatively low toxicity organic arsenic compounds, instead of the more toxic inorganic forms (USEPA 2000b). As further described in Appendix A, studies have shown that about 10% or less of the total arsenic in fish filet tissue is in the inorganic form (Schoof and Yager 2007). Therefore, an adjustment factor of 0.1, or 10%, was applied to the total arsenic EPCs in the risk calculations for a recreational user – consumer of locally-caught sport fish to adjust for the % of arsenic present in the inorganic form (see Appendix D.1).

5.1.4 Estimation of Exposure Dose for Chemicals

Exposure doses were estimated using the EPCs described in Section 5.1.3 for onsite workers potentially exposed to COPCs in CCR material and for recreational user – consumers of locally-caught sport fish potentially exposed to COPCs in fish filets. For carcinogens, exposure was averaged over a 70-year lifetime; for noncarcinogens, exposure was averaged over the period of exposure (i.e., the exposure duration). When evaluating potential carcinogenic exposure for recreational user – consumers of locally-caught sport fish, intakes were age-adjusted to account for exposure as an adult, adolescent, and child within a combined 26-year exposure duration for these receptors over a 70-year lifetime. Noncarcinogenic exposure and hazard estimates for recreational user – consumers of locally-caught sport fish were evaluated for the most sensitive recreational receptor (i.e., a child). Exposure is generally higher per unit of body weight for a child than an adult due to physiological and behavioral differences. This is reflected in the exposure assumptions used in the exposure dose calculations (Table 5-2). For example, fish ingestion rates per unit of body weight are assumed to be higher for children than adults. The equations used to estimate exposure doses for all receptors with potentially complete pathways are provided in Appendix D.1.

5.2 TOXICITY ASSESSMENT

The human health toxicity assessment process described herein is in accordance with USEPA guidance (USEPA 1989a). Toxicity assessment is the process of using existing toxicity information from human or animal studies to identify potential health risks at various dose levels in exposed populations and generally consists of two steps: (1) hazard identification and (2) dose-response assessment (USEPA 1989a).



Hazard identification is a qualitative evaluation of whether exposure to a stressor is likely to cause adverse health effects in humans. A key component of hazard identification involves evaluating the WOE regarding a chemical's potential to cause adverse human health effects.

The dose-response assessment step of the HHRA process involves characterizing the relationship between the absorbed dose of a chemical agent and the magnitude or likelihood of adverse health effects (USEPA 1989a). For chemicals that are known or suspected to cause cancer, the dose-response assessment defines the relationship between dose of the risk agent and probability of inducing carcinogenic effects in humans or animal species of interest. For systemic toxicants, or chemicals that give rise to toxic endpoints other than cancer and gene mutations (i.e., noncarcinogenic effects), the dose-response assessment determines a threshold value below which the adverse noncarcinogenic effects are not expected in the general population, including sensitive subgroups.

These two steps of the toxicity assessment have been completed by the agencies that publish toxicity values, and a high-level summary of the methods used are presented in Sections 5.2.1 and 5.2.2. The published toxicity values used in this HHRA, as described in Section 5.2.3, were derived by the agencies as part of the dose-response assessment steps. These toxicity values (which describe the bodily response to a daily dose) together with the estimated exposures to the COPC (i.e., estimated dose to individuals) are used in the risk characterization step to estimate the likelihood of adverse effects occurring.

5.2.1 Carcinogenic Dose-Response Assessment Methodology

It has been demonstrated that exposure to some chemicals can result in cancer. The USEPA assumes that a relatively small number of molecular events can elicit changes in a cell, ultimately resulting in uncontrolled cell proliferation and cancer. This is referred to as the non-threshold or "one hit" theory of chemical carcinogenesis. The USEPA uses a two-part evaluation to calculate potential carcinogenic effects of COPCs: (1) assigning a WOE classification, and (2) calculating a cancer slope factor (CSF) or a unit risk factor (URF) (USEPA 1989a).

The system for assigning a WOE classification is based on USEPA guidelines (USEPA 1986 and 2005). It describes the likelihood that a chemical is a human carcinogen based on the supporting evidence of carcinogenicity in human and animal studies. This WOE classification system for carcinogenicity also follows the 1986 or 2005 USEPA guidelines, depending on when the dose-response assessment was completed for each chemical. Although some carcinogens have a mutagenic mode of action, none of the carcinogenic COPCs are classified as mutagens by the USEPA.

The USEPA only derives CSFs and URFs for chemicals that they have determined to be carcinogenic or to have carcinogenic potential.

5.2.2 Noncarcinogenic Dose-Response Assessment Methodology

Substances that produce adverse noncarcinogenic effects are generally thought to have a threshold dose below which the adverse effect is not likely to be observed over the period of exposure (USEPA 1989a). Chemical doses that are expected to result in no adverse effects to humans are referred to by USEPA as

RfDs, and air concentrations that would not result in adverse effects are termed reference concentrations (RfCs). A chronic RfD or RfC is used to evaluate potential noncarcinogenic hazards associated with long-term chemical exposures while sub-chronic RfDs or RfCs are used to evaluate exposures over shorter time periods.

Exposures that are less than the RfD or RfC are not likely to be associated with adverse health effects. As the frequency and level of exposures exceeding the RfD or RfC increases, the likelihood for adverse effects also increases.

5.2.3 Selection of Toxicity Values for the Human Health Risk Assessment

Toxicity values for quantitative risk evaluation were obtained from the following sources cited in USEPA's RSL Tables (USEPA 2024), in general order of preference:

- Integrated Risk Information System (IRIS) Database
- Provisional Peer Reviewed Toxicity Values (PPRTVs)
- Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles
- California Environmental Protection Agency (CalEPA) Toxicity Values
- PPRTV Appendix Screening Toxicity Values
- Health Effects Assessment Summary Tables.

For radium-226 and radium-228 specifically, default slope factors from the PRG calculator (USEPA 2021) were used to calculate PRGs and risks.

Inorganic mercury is listed as a CCR Parameter, and the toxicity factor for the mercuric forms were used to estimate noncancer hazard estimates for exposure to non-biological media (sediment and CCR material). However, inorganic mercury is converted to methyl mercury by biological processes in the aquatic environment, which then accumulates in biological tissues including fish filet. Analytical results for fish filet were reported as total mercury because fish tissue samples were not speciated by inorganic and methyl mercury. It is assumed that human exposure from fish consumption is to methyl mercury rather than inorganic mercury. Therefore, the chronic RfD for methyl mercury (which is lower than the RfD for inorganic mercury) was conservatively used to estimate noncancer hazard estimates for consumption of locally caught fish. The toxicity values are presented in Table 5-3.

Chronic RfDs and RfCs were used to estimate HQs for scenarios associated with an assumed exposure duration of more than seven years (i.e., recreational user – consumers of locally-caught sport fish, with an assumed total exposure duration of 26 years [Table 5-2]). Subchronic RfDs and RfCs, where available, were used for scenarios associated with an assumed exposure duration of between two weeks and seven years (i.e., onsite workers with an assumed exposure duration of one year [Table 5-2]). A subchronic RfD and subchronic RfC are not available for arsenic, so the chronic RfD and RfC were used to estimate HQs for an onsite worker potentially exposed to arsenic in CCR material.



In addition to toxicity values, Table 5-3 presents the target organ (TO) or organ system associated with the critical effect for each noncancer RfD and RfC. The potentially impacted TOs vary among COPCs; when multiple COPCs potentially impact the same TO, the effects are generally considered to be additive (USEPA 1989a). Noncancer TO analysis is described further in Section 5.3.1.

5.2.4 Dermal Toxicity Values

Although USEPA has developed toxicity criteria for the oral and inhalation routes of exposure, toxicity criteria for the dermal route of exposure have not been developed. USEPA has guidance for extrapolating oral toxicity criteria to the dermal route in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004). This USEPA guidance states that the adjustment of the oral toxicity factor for dermal exposures is necessary only when the oral-gastrointestinal absorption efficiency of a constituent is less than 50% (due to the variability inherent in absorption studies). Adjustment of oral toxicity criteria to derive dermal RfDs and CSFs was conducted as follows:

$$\text{Dermal RfD} = \text{Oral RfD} \times \text{ABS}_{GI}$$

$$\text{Dermal CSF} = \frac{\text{Oral CSF}}{\text{ABS}_{GI}}$$

Where:

ABS_{GI} = oral absorption efficiency

CSF = cancer slope factor

RfD = reference dose

For COPCs lacking an oral-gastrointestinal absorption efficiency value, the oral absorption efficiency is assumed to be 100%, and the oral RfD or CSF is used to estimate toxicity via the dermal route.

5.3 RISK CHARACTERIZATION

Risk characterization consists of two major components: risk estimation and risk description. Risk estimation combines results of the exposure assessment and toxicity assessment to derive a quantitative evaluation of potential risks to human receptors. For the risk estimation component, calculated exposure doses for each COPC identified for each medium were used to estimate COPC-specific and cumulative cancer risks, as well as noncancer HQs and HI estimates. The risk description component provides information important for interpreting the risk estimates. As highlighted in Section 2.2 and provided in the document titled *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A), these components were captured through a WOE approach using multiple LOEs.

5.3.1 Methods for Estimating Cancer Risk and Noncancer Hazard for Chemicals

The pathway-specific incremental lifetime cancer risks (ILCRs) from exposure to carcinogenic COPCs in each medium were estimated using the following general equation (USEPA 1989a and 2009a):

$$\text{ILCR (unitless)} = \text{Dose (or Concentration)} \times \text{CSF (or URF)}$$

Where:

ILCR	=	Incremental lifetime cancer risk (unitless)
CSF	=	Cancer slope factor $(\text{mg/kg-day})^{-1}$
URF	=	Unit risk factor (micrograms [µg] per cubic meters [m^3] [$\mu g/m^3$])$^{-1}$
Dose	=	Exposure dose (mg/kg-day)
Concentration	=	Exposure concentration ($\mu g/m^3$)

The HQ is the ratio of the potential exposure to a substance and the level at which no adverse noncarcinogenic effects are expected. Pathway-specific HQs for COPCs in each medium were estimated using the following general equation (USEPA 1989a and 2009a):

$$\text{HQ (unitless)} = \frac{\text{Dose (or Concentration)}}{\text{RfD (or RfC)}}$$

Where:

HQ	=	Hazard quotient (unitless)
Dose	=	Exposure dose (mg/kg-day)
Concentration	=	Exposure concentration (mg/m^3)
RfD	=	Reference dose (mg/kg-day)
RfC	=	Reference concentration (mg/m^3)

A COPC-specific HQ is derived by summing pathway-specific HQs. An HQ greater than 1 indicates that the estimated exposure for that COPC may not be protective of noncarcinogenic health effects. An HQ equal to or less than 1 suggests that noncarcinogenic health effects should not occur. To account for potential cumulative impacts from exposure to multiple COPCs, COPC-specific ILCR and HQ estimates were summed to produce cumulative ILCR and HI estimates, respectively. The methodology for selecting COPCs accounts for cumulative cancer risks and noncancer hazards from multiple exposure pathways. Screening levels for COPC identification are sufficiently protective (screening levels for cancer effects and noncancer effects are defined at 10^{-6} and 0.1, respectively) to confirm that constituents not identified as COPCs would not significantly contribute to cumulative effects from multiple exposures. As described in Appendix A, the State of Tennessee currently considers a cumulative excess lifetime cancer risk estimate



of 1 x 10^{-5} and a noncancer cumulative HI of 1 as the acceptable cancer risk criterion and noncancer threshold, respectively, for making risk management decisions concerning a site (TDEC 2019).

If an HI estimate is greater than 1, it is generally appropriate to derive separate HIs for each TO or organ system potentially impacted by a COPC (i.e., TO-specific HIs [TO HIs]) (USEPA 1989a). This is because the toxicological effects associated with exposure to multiple COPCs may not be additive. As with the HQ, a TO HI equal to or less than 1 suggests that noncarcinogenic health effects should not occur. TO HIs were estimated by summing the HQs for COPCs that affect the same TO/system listed in Table 5-3. If a COPC is associated with critical effects in multiple TO/systems, the HQ for that COPC is included in the TO HI for each impacted TO/system. The maximum TO HI for all potentially impacted TOs/systems is presented as the final TO HI.

5.3.2 Methods for Estimating Risks for Radionuclides

Carcinogenic risk estimates for radionuclide COPCs were derived as the ratio of the EPC for each COPC to the respective PRG multiplied by the target carcinogenic risk level using the equation below. An example of the method used to calculate cancer risks for radionuclide COPCs is provided in Appendix D.1.

$$\text{ILCR} = \frac{\text{EPC}}{\text{PRG}} \times \text{TR}$$

Where:

ILCR	= Incremental lifetime cancer risk (unitless)
EPC	= exposure point concentration (picocuries [pCi] per g [pCi/g])
PRG	= human health risk-based screening level for cancer effects (pCi/g)
TR	= target cancer risk of 1 x 10^{-6} (unitless)

5.3.3 Risk Estimation Results

A summary of cancer risk and noncancer hazard estimates for human receptors potentially exposed to chemical COPCs is presented in Table 5-4. As indicated in Table 5-4 and discussed in further detail below, cumulative cancer risk estimates for each receptor and medium evaluated were less than TDEC's acceptable cancer risk criterion of 1 x 10^{-5}. Cumulative noncancer hazard estimates were not greater than TDEC's acceptable threshold of 1, except for the HI for a recreational user – consumer of locally-caught sport fish from the Tennessee River adjacent to the WBF Plant and the HI for an onsite worker exposed to chemical COPCs in CCR material within the Ash Pond. A summary of cancer risk estimates for human receptors potentially exposed to radionuclide COPCs is presented in Table 5-5. Detailed cancer risk and noncancer hazard calculations for chemicals and radionuclides are presented in Appendices D.2 and D.3, respectively. A WOE evaluation of other LOEs in addition to quantitative results is provided in Section 5.3.4 for receptors with cumulative cancer risk or noncancer hazard estimates above TDEC's acceptable cancer risk criterion or noncancer threshold.

5.3.3.1 Onsite Worker

A summary of the cumulative ILCR and HI estimates for an onsite worker exposed to chemical and radionuclide COPCs in CCR material within the Ash Pond and Slag Disposal Area is provided in the table below.

Onsite Worker CCR Unit	Cumulative ILCR (Chemical)	Cumulative ILCR (Radionuclide)	HI
Ash Pond	6E-07	n/a	**2**
Slag Disposal Area	4E-07	5E-07	1

Note: n/a - not applicable. **Bold** indicates cumulative ILCR or HI estimates greater than $1x10^{-5}$ or 1, respectively.

The cumulative ILCR and HI estimates for an onsite worker exposed to chemical COPCs in CCR material within the Ash Pond are 6×10^{-7} and 2, respectively (Table 5-6). The cumulative ILCR is less than TDEC's acceptable cancer risk criterion of 1×10^{-5}. The HI of 2 is primarily attributable to arsenic (HQ = 1.2) and thallium (HQ = 0.49). As arsenic and thallium share a common target organ ("skin"), the maximum TO HI is also 2, which is greater than TDEC's noncancer threshold of 1. A cumulative ILCR estimate for an onsite worker exposed to radionuclide COPCs in CCR material within the Ash Pond was not calculated because the maximum detected levels in samples collected from this CCR unit were less than the respective screening levels presented in Table 4-1.

The cumulative ILCR and HI estimates for an onsite worker exposed to chemical COPCs in CCR material within the Slag Disposal Area are 4×10^{-7} and 1, respectively (Table 5-6). The cumulative ILCR is less than TDEC's acceptable cancer risk criterion and the HI is equal to the noncancer threshold. The cumulative ILCR estimate for an onsite worker exposed to radionuclide COPCs in CCR material within the Slag Disposal Area is 5×10^{-7} (Table 5-5), which is less than TDEC's acceptable cancer risk criterion.

The cumulative ILCR from exposure to chemical and radionuclide COPCs in CCR material within the Slag Disposal Area is 9×10^{-7}, which is lower than TDEC's acceptable risk criterion. There are uncertainties associated with summing cumulative ILCRs for chemical and radionuclide COPCs because potential interaction and synergies are still poorly understood between chemicals and radionuclides (Health Canada 2023). In addition, the toxicity data which form the basis of chemical and radiological risk assessments also differ (i.e., typically based on laboratory experiments for chemicals and human epidemiology for radionuclides).

5.3.3.2 Recreational User – Consumer of Locally-Caught Sport Fish

The cumulative ILCR and HI estimates for a recreational user – consumer of locally-caught sport fish exposed to chemical COPCs in fish harvested from the Tennessee River adjacent to the WBF Plant are 3×10^{-6} and 2, respectively, as presented in Table 5-7 and summarized in the table below. The cumulative ILCR is less than TDEC's acceptable cancer risk criterion of 1×10^{-5}. The HI of 2 is driven by a single COPC, mercury (i.e., total mercury evaluated as methyl mercury as described in Section 5.2.3), so the maximum TO HI is also 2, which is greater than TDEC's noncancer threshold of 1.



Recreational User - Consumer of Locally-Caught Sport Fish	Cumulative ILCR (Chemical)	HI
Adjacent Tennessee River	3E-06	**2**

Note: Bold indicates cumulative ILCR or HI estimates greater than $1x10^{-5}$ or 1, respectively.

5.3.4 Weight of Evidence

This HHRA uses a WOE approach to evaluate potential risks to human receptors from exposure to COPCs. The WOE approach is consistent with USEPA guidance for conducting risk assessments (USEPA 1989a and 2000a) and is based on the concept that a determination of health risk should go beyond solely calculating numerical risk estimates and should include both quantitative and qualitative evidence linking contaminant exposures to the likelihood of an adverse health effect. It is the combined results of multiple LOEs rather than any single result that are used to determine if risk is present at a level that warrants further evaluation or consideration of corrective measures.

The WOE evaluation for the WBF Plant HHRA was performed in accordance with *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A) and is based on integration of quantitative and qualitative LOEs. Quantitative LOEs include: 1) comparing concentrations of CCR Parameters measured at the WBF Plant to medium-specific and receptor-specific human health screening levels, and 2) calculating cancer risk and noncancer HI (for the human health assessment). Qualitative LOEs include: 1) the use of published information on CCR material and CCR Parameters, 2) results of EIs conducted at the WBF Plant, and 3) findings from the environmental sampling and HHERAs conducted as part of the KRP.

As described in Section 5.3.3, cumulative ILCR estimates for all receptors and media evaluated in the HHRA were less than TDEC's acceptable cancer risk criterion of 1×10^{-5}. Cumulative noncancer hazard estimates did not exceed TDEC's acceptable hazard threshold of 1, except for the HIs for an onsite worker exposed to chemical COPCs in CCR material within the Ash Pond and a recreational user – consumer of locally-caught sport fish from the Tennessee River. A TO HI of 2 was estimated for these exposure scenarios.

The TO HI of 2 for an onsite worker exposed to chemical COPCs in CCR material within the Ash Pond is primarily attributable to arsenic (HQ = 1.2) and thallium (HQ = 0.49). The HQ for arsenic was calculated using the chronic RfD and RfC because a subchronic oral RfD and inhalation RfC are not available. As noted in Section 5.4.2, using the chronic RfD and RfC in the calculation of the HQ for an onsite worker exposed to arsenic in CCR material results in a protective overestimate of the noncancer hazard. The HQ for thallium was calculated with a provisional subchronic oral RfD derived using an uncertainty factor of 1000 due to critical limitations in the chosen toxicity study (see Section 5.1.1). Although "skin" is listed as a target organ for noncancer health effects for both inorganic arsenic and thallium, the toxicity database indicates the effects and HI are not likely to be additive. Chronic exposure to inorganic arsenic in drinking water is associated with a spectrum of adverse health effects in human populations living in geographic regions with naturally high levels of arsenic. The basis of the RfD for arsenic is hyperpigmentation,



keratosis and possible vascular complications. Keratotic lesions (thickening of the skin) form on the palms of the hands and soles of the feet and may become cancerous (USEPA 1991).

As described in Section 5.1.1., the provisional oral RfD for thallium is based on a study which found an increase in alopecia (i.e., hair loss) in rats (USEPA 2012b). In the key study, rats were administered doses of thallium sulfate by gavage over 90 days. The Point of Departure for deriving the provisional RfD was a dose associated with atrophy of the hair follicles and alopecia. USEPA noted deficiencies in the toxicology database for thallium in general, and in the key study selected as the basis for deriving the provisional RfD (alopecia was reported in control and treated animals). Exposure to high levels of thallium produces a spectrum of adverse effects in humans, including hair loss. However, alopecia and keratosis are not comparable effects, and assuming the HQs for arsenic and thallium are additive is not supported by the toxicology and health effects database.

In addition, risks to onsite workers were calculated assuming no health and safety protocols were used to control or mitigate exposure. When standard health and safety protocols (e.g., wearing of protective clothing) are used during future maintenance activities, potential risks to onsite workers are expected to be lower than estimated. Furthermore, if substantive repairs are necessary, a site-specific health and safety plan specifying procedures to protect onsite workers would be required.

The TO HI of 2 for a recreational user – consumer of locally-caught sport fish from the Tennessee River is attributable to mercury. Inorganic mercury is one of the CCR Parameters listed in Appendix III and Appendix IV of the CCR Rule. In the environment, inorganic mercury can be methylated by microorganisms to methyl mercury, which can accumulate in the tissues of organisms including fish (ATSDR 1999). Consumption of fish containing methyl mercury is one of the primary sources of non-occupational human exposure to methyl mercury. TDEC previously established two advisory levels based on total mercury (which was evaluated as methyl mercury) in fish tissues: (1) a “precautionary advisory” of 0.3 parts per million (ppm) (0.3 mg/kg) average concentration, which advises pregnant or nursing mothers, plus children, to avoid any consumption of fish and all other persons to limit consumption to one or two fish meals per month, and (2) a “do not consume advisory” of 1.0 ppm (1.0 mg/kg) average concentration, which advises all persons to avoid fish consumption in any amount (Denton 2007). The EPC for mercury for a recreational user – consumer of locally-caught sport fish from the Tennessee River is 0.280 mg/kg-ww (Table 5-7), which is less than the “precautionary advisory” for methyl mercury in fish tissues.

In addition, a study conducted by TDEC to evaluate the potential bioaccumulation of metals in native game fish in Tennessee streams in coal mining regions found that mercury concentrations in fish filets were highest in fish collected from reference areas followed by fish collected downstream of inactive coalfields (Arnwine et al. 2014). Results of this TDEC study suggest that mercury is a naturally occurring regional contaminant in Tennessee and is also related to historical coal mining and other activities. The similarity in concentrations of mercury (total) detected in fish among Tennessee River reaches is consistent with the results of the TDEC study (Appendix E.7 of Appendix C.1.1). This indicates that mercury in fish tissue from the Tennessee River near the WBF Plant is likely unrelated to the TDEC Order CCR units at the WBF Plant.



Finally, the HI of 2 for a recreational user – consumption of locally-caught sport fish was calculated using a child fish intake rate of 8.7 g-ww/day, which is the age-adjusted 95th percentile fish consumption rate for children one to less than six years old (Table 20a of USEPA 2014b). The adult fish intake rate is 32.7 g-ww/day and is based on the 95th percentile fish consumption rate for the inland south region of the United States (Table 9b of USEPA 2014b), which is higher than the fish consumption rate of 22 g-ww/day used by USEPA (2015) to develop human health ambient water quality criteria under Section 304(b) of the Clean Water Act. The adolescent fish intake rate is the age-adjusted 95th percentile fish consumption rate for six to less than 16 years old (12.8 g-ww/day) (Table 20a; USEPA 2014b). The USEPA's national level fish consumption rates for development of human health ambient water quality criteria are 90th percentile values derived using data from the NHANES, 2003-2010 (USEPA 2014b). It should be noted that these fish consumption rates are based on total freshwater and estuarine finfish and shellfish consumption and include consumption of both locally-caught and store-bought fish. Thus, the fish consumption rates used in this HHRA overestimate locally-caught consumption rates and contribute to likely overestimation of human health risks associated with fish consumption.

In summary, two exposure scenarios, an onsite worker engaged in maintenance activities at the Ash Pond and the recreational user – consumer of locally-caught sport fish from the Tennessee River, were associated with a risk estimate above an acceptable risk threshold in the WBF Plant HHRA; a TO HI of 2 was estimated for these exposure scenarios. The TO HI of 2 for an onsite worker exposed to chemical COPCs in CCR material within the Ash Pond is primarily attributable to arsenic (HQ = 1.2) and thallium (HQ = 0.49). Implementing standard health and safety protocols during maintenance activities is expected to lower the potential risks. The estimated HI of 2 for a recreational user – consumer of locally-caught sport fish from the Tennessee River is attributable to mercury (i.e., total mercury evaluated as methyl mercury) in fish from the Tennessee River. Mercury (total) was detected in fish filet samples collected from the Tennessee River at concentrations above the SSL_{HH}; however, mercury is a regional contaminant and detected concentrations of mercury (total) in fish filet samples are likely attributed to sources other than the TDEC Order CCR units at the WBF Plant. Although mercury (total) was associated with a TO HI above 1 for the recreational user – consumer of locally-caught sport fish, the TO HI calculations were based on a protective fish intake rate. Based on the above, mercury is not proposed for further evaluation for the Tennessee River.

Based on the HHRA findings, risk estimates, and WOE consideration, there are no unacceptable risks to offsite human receptors potentially exposed to CCR Parameters associated with the WBF Plant CCR units as measured in surface stream water and fish tissue samples collected from the Tennessee River. Estimated risks to the onsite worker potentially exposed to CCR material within the Ash Pond is greater than the noncancer threshold of 1; however, implementing standard health and safety protocols during potential maintenance activities is expected to lower the potential risks. A summary of the HHRA results is provided in Section 7.1.

5.4 UNCERTAINTY ANALYSIS

Uncertainties are inherent in the risk assessment process and arise from limitations in the available information, analysis methods, and assumptions used in the assessment. Sources of uncertainty may include chemical characterization information and limitations in the available data, assessment of



potential exposures, and modeling of uptake and toxicity. To assist interpretation of the risk assessment results presented in this HHRA, the primary sources of uncertainty in each step of the HHRA are described in the following subsections.

5.4.1 Exposure Assessment

Uncertainties associated with exposure assessment include identification of COPCs, derivation of medium-specific EPCs, and calculation of exposure doses using upper bound exposure assumptions.

- Protective methods and assumptions were used in selecting COPCs, such as comparison of maximum CCR Parameter concentrations to SSL_{HH} values based on a target cancer risk and HQ of 1 x 10^{-6} and 0.1, respectively; screening CCR material at all sample depths; use of potable surface stream water SSL_{HH} values to select COPCs for a recreational user – swimmer; and inclusion of detected CCR Parameters without screening levels and non-detect CCR Parameters with a maximum reporting limit above the SSL_{HH} for further evaluation as potential COPCs. These multiple protective assumptions and methods reduce to a very low level of uncertainty that human health risks are underestimated by screening out CCR Parameters from the risk assessment.

- Uncertainties are associated with the availability of new toxicity criteria published by USEPA (2024) for several CCR Parameters since the development of SSL_{HH} in 2021. The approved SSL_{HH} were developed using protective assumptions (e.g., target HQ of 0.1, PEF), and as a result, there are low uncertainties associated with these CCR Parameters and the overall conclusions of the HHRA are not expected to be impacted.

- A recreational user – consumer of locally-caught sport fish may be potentially exposed to surface stream water if the same receptor participates in swimming. However, contributions from exposure to COPCs in surface stream water are insignificant when compared to ingestion of COPCs in fish tissue. As a result, there is a low uncertainty associated with underestimating total cumulative risks and hazard for a recreational user – consumer of locally-caught sport fish.

- Thallium was not detected in fish filet tissue samples collected from the Tennessee River and was excluded as a COPC even though sample reporting limits for thallium in fish filet tissue samples (0.012 to 0.013 mg/kg-ww) were above the SSL_{HH} of 0.0018 mg/kg-ww (Table 4-5). Although thallium may be present in fish tissue at concentrations below the reporting limit but above the SSL_{HH}, the uncertainty associated with not including thallium as a COPC for fish tissue from the Tennessee River in the HHRA is low due to the protective nature of the SSL_{HH} (i.e., calculated using an oral RfD derived using a high safety factor of 3000 and a target HQ of 0.1). Furthermore, the maximum reporting limit for thallium in fish tissue samples (0.013 mg/kg-ww) would not exceed an SSL_{HH} based on a target HQ of 1 (0.018 mg/kg-ww).

- In environmental media at the WBF Plant the only detected constituents lacking screening levels were the essential mineral ions calcium, chloride, and sulfate. Because these constituents are not toxic to humans, or only toxic at extremely high doses, which have not been observed at the WBF Plant, there is low uncertainty associated with not including these CCR Parameters as COPCs.



- Concentrations of CCR Parameters may vary across depths within the CCR units. There is low uncertainty in the COPCs identified because the COPCs were identified for the CCR units by screening the maximum detected concentration of each CCR Parameter across all sampled depths. EPCs based on data across all sampling depths were conservatively used to calculate exposure doses because there are no distinct segregated layers within the CCR units.

- There is variability associated with data collected from the Tennessee River adjacent to the WBF Plant. Contributions of CCR Parameters to surface stream water and sediment and subsequent uptake by biota is affected by several factors including river flow, sediment deposition rates and patterns, and biota habitat use. Fish filet data used in the HHRA also include variability across species. As a result, the use of medium-specific EPCs to quantify exposures (rather than distributions) result in uncertainty in the exposure dose estimates. However, the EPCs are most likely overestimated because in most instances, the 95% UCL of the mean concentrations or maximum detected concentrations were conservatively used to quantify exposure doses and risk estimates.

- Toxicity values are generally derived from laboratory studies where readily absorbed forms of constituents are used; under site-specific environmental conditions, the chemical form of the constituent may be less bioavailable. However, the magnitude of the relative bioavailability for most COPCs is not known and is therefore a source of uncertainty in the exposure dose estimates. In this HHRA, the absorbed dose was assumed to be 100% of the exposure dose for all COPCs, except for arsenic. For arsenic in CCR material, the oral dose was adjusted by a relative bioavailability factor of 0.6 as recommended by USEPA (2012a). For other COPCs, the assumption that 100% of the exposure dose is absorbed likely overestimates human health risks.

- Exposure assumptions such as exposure frequency, body weight, or ingestion rates vary among human receptors making them a source of uncertainty in the exposure estimates. Standard default values for exposure factors that are upper-bound estimates were used in this HHRA. This approach results in overestimates rather than underestimates of risk and hazard.

5.4.2 Toxicity Assessment

Uncertainties associated with toxicity assessment are related to a lack of subchronic toxicity values for evaluating short-duration onsite worker exposures, a lack of dermal toxicity values, and assumptions used to derive cancer-based toxicity values.

- Noncancer hazard estimates for onsite workers exposed to CCR material were calculated using subchronic RfDs, where available. A subchronic oral RfD and subchronic inhalation RfC are not available for arsenic. As a result, the noncancer hazard estimate for arsenic was calculated using the chronic RfD and RfC (Appendix D.1, Section 2.2.2). The subchronic toxicity values used to evaluate onsite workers are higher than the corresponding chronic toxicity values. Although there is uncertainty in using a chronic toxicity value to evaluate a subchronic exposure scenario, evaluation of CCR Parameters using chronic toxicity values where subchronic values are not available results in a protective overestimate of noncancer hazard.



- Cancer risk estimates presented in this HHRA were modeled using CSFs developed by the USEPA, when available. USEPA uses the linearized multistage (LMS) mathematical model to extrapolate animal toxicological data to human health toxicity values for carcinogens. The LMS model assumes that there is no dose threshold below which carcinogenic risk occurs. The uncertainty in the LMS approach is that for chemicals having a threshold, it extrapolates the dose-response curve far below the experimental dose range to where a dose carries virtually no risk (Bogdanffy et al. 2001). In addition, the LMS model also can result in conservative carcinogenic potency assumptions because: (1) any exaggerations in the extrapolation that can be produced by some high dose responses (if they occur) are generally neglected; (2) UCLs on the actual response observed in the animal study are used rather than the actual response, resulting in upper bound low dose extrapolations that can overestimate risk; and (3) non genotoxic chemicals (i.e., threshold carcinogens) are modeled in the same manner as highly genotoxic chemicals. Thus, the toxicity values (i.e., CSFs) are designed to yield conservative estimates of cancer risk, and to be protective of the overall population.

- RfDs typically have uncertainty factors of 100 to 1,000 incorporated into their development. These factors account for the potential of humans to be more sensitive to a chemical than the laboratory animal, for some humans to be more sensitive to the chemical than the general population, and for chronic exposure durations when the toxicity experiments were conducted over shorter durations, etc. Thus, toxicity values are designed to be protective of the overall population.

- Dermal toxicity criteria are not available from USEPA. Typically, a simple route to-route (oral-to-dermal) extrapolation is assumed such that the available oral toxicity criteria (RfD and CSF) are used to quantify potential effects associated with dermal exposure. However, as noted in the USEPA *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004), depending upon the COPC being evaluated, there is uncertainty and underestimation of risk and hazard to human health associated with this approach because the oral toxicity criteria are based on an administered dose and not an absorbed dose. In general, USEPA guidance recommends an adjustment of the oral toxicity criteria to convert an administered dose to an absorbed dose (USEPA 2004). The adjustment accounts for the absorption efficiency of the constituent in the "critical study" that is the basis of the oral toxicity criterion. If the oral absorption in the critical study is 100%, then the absorbed dose is equivalent to the administered dose and no adjustment is necessary. If the oral absorption of a constituent in the critical study is poor (i.e., less than 50%), then the absorbed dose is much smaller than the administered dose. Adjustments to the oral toxicity criteria were made for cadmium and vanadium. Adjustments were not made for other COPCs evaluated in the HHRA.

5.4.3 Risk Characterization

The different sources of uncertainty described above are incorporated into the risk estimate through a combination of conservative assumptions. These are propagated through the exposure and risk calculations, resulting in estimated risks presented in this HHRA that are most likely upper bound estimates (or overestimation) of risk. In addition to this uncertainty analysis, supporting qualitative LOEs were provided in Section 5.3.4 to further put quantitative risk estimates into context. As a result, the risk assessment is very unlikely to underestimate human health risk, which leads to high confidence in the HHRA conclusions.



6.0 ECOLOGICAL RISK ASSESSMENT

The ERA evaluated potential ecological risks assuming the concentrations and distribution of CCR Parameters in abiotic and biotic media (described in the EAR) represent current and future conditions following final closure of the CCR units at the WBF Plant. The ERA process was used to evaluate potential hazards to ecological receptors potentially exposed to CCR Parameters in surface stream water, sediment, or biota. Results of this ERA were used in the CARA Plan to evaluate whether corrective measures are needed for the protection of human and ecological receptors.

The ERA methodology described herein is based on the following USEPA guidance documents:

- *Interim Ecological Soil Screening Level (Eco-SSL) Documents* (USEPA 2022b)
- *Region 4 Ecological Risk Assessment Supplemental Guidance* (USEPA 2018b)
- *Weight of Evidence in Ecological Assessment* (USEPA 2016)
- *The Role of Screening-Level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments* (USEPA 2001)
- *Risk Characterization* (USEPA 2000a)
- *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (USEPA 1999a)
- *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Peer Review Draft* (USEPA 1999b)
- *Guidelines for Ecological Risk Assessment* (USEPA 1998)
- *Interim Final Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997)
- *Framework for Ecological Risk Assessment* (USEPA 1992c)
- *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual, Interim Final* (USEPA 1989b).

The general framework for conducting ERAs is provided in USEPA's *Framework for Ecological Risk Assessment* (USEPA 1992c). Consistent with this guidance, the ERA consists of the following primary steps:

- Problem formulation
- Exposure assessment
- Effects assessment

- Risk characterization
- Uncertainty analysis.

The methods and procedures used to perform the problem formulation and risk characterization steps are described in the following subsections.

6.1 PROBLEM FORMULATION

Problem formulation is a process for generating and evaluating preliminary hypotheses by developing an ecological CSM. The ecological CSM includes information on CCR Parameter sources, ecological habitats, exposure media and potential receptors, and possible exposure pathways between CCR Parameters and ecological receptors.

6.1.1 Conceptual Site Model for the Ecological Risk Assessment

The ecological CSM for the WBF Plant (Exhibit 6-1) presents the potential ecological receptors and exposure pathways through which those receptors could be exposed to CCR Parameters. The ecological CSM includes the identification of COPECs (if present) and describes the relationships between CCR Parameter, release mechanisms to environmental media, and routes of exposure to potential ecological receptors.

6.1.1.1 Release Mechanisms

A description of release mechanisms of CCR Parameters is provided in Section 5.1.1.1. None of the release mechanisms described in Section 5.1.1.1 are expected to result in substantial transfer of CCR Parameters to soil. Consequently, there is no pathway for potential exposure of terrestrial ecological receptors to CCR Parameters either through direct contact or dietary transfer due to ingestion of terrestrial plants. However, dissolved and soluble CCR Parameters could potentially be released to groundwater with subsequent movement to the Tennessee River, which provides habitat for riparian and aquatic wildlife.

6.1.1.2 Chemicals of Potential Ecological Concern

COPECs are those CCR Parameters that are carried through the ecological risk quantification process. The selected COPEC screening levels and comparisons of data for each waterbody to these screening levels for CCR Parameters in surface stream water and sediment are presented in Tables 4-3 and 4-5. Derivation of the COPEC screening levels is described in the *Proposed Screening Levels for Sample Results in the EAR* technical memorandum (Appendix B.1, Attachment A). For CCR Parameters with hardness dependent screening levels (i.e., cadmium, chromium, lead, copper, nickel, silver, and zinc), data for the dissolved fractions of these CCR Parameters in surface stream water were compared to their respective EAR screening levels that were based on dissolved fractions. For other CCR Parameters, data for both total and dissolved fractions in surface stream water were compared to their respective EAR screening levels.

The following criteria were applied to identify COPECs for further evaluation in the ERA:



1. If a CCR Parameter was not detected in surface stream water or sediment, and the maximum reporting limits in surface stream water and sediment were equal to or below the respective screening levels, the CCR Parameter was not identified as a COPEC.

2. If a CCR Parameter was detected in surface stream water or sediment and the maximum detected concentrations in surface stream water and sediment were equal to or below the respective screening levels, the CCR Parameter was not identified as a COPEC.

3. If calcium, chloride, fluoride and/or sulfate were detected in surface stream water or sediment, these CCR Parameters were not identified as COPECs. These CCR Parameters are not evaluated in the ERA because they are essential mineral ions and only toxic at levels considerably higher than typical environmental concentrations.

4. If a CCR Parameter was detected in surface stream water or sediment and no respective screening levels were available, then the CCR Parameter was further evaluated to determine whether it should be identified as a COPEC.

    - Boron was not identified as a COPEC in the Tennessee River because it was non-detect in surface stream water samples and detected concentrations in sediment samples from adjacent and downstream transects in the Tennessee River are similar (Attachment E.6-B in Appendix E.6 of Appendix C.1), indicating minimal variability in sediment concentrations between reaches. In addition, boron was not detected in fish tissue or clam tissue samples (Appendices J.3 and J.6, respectively, of the WBF Plant EAR).

    - Lithium was not identified as a COPEC in the Tennessee River because it was not detected in surface stream water samples, and detected concentrations in sediment samples from adjacent and downstream transects in the Tennessee River were similar (Attachment E.6-B in Appendix E.6 of Appendix C.1), indicating minimal variability in sediment concentrations between reaches. In addition, lithium was detected in one upstream whole fish tissue sample but non-detect in fish tissue samples from adjacent and downstream transects in the Tennessee River and lithium concentrations in clam tissue samples from adjacent and downstream transects in the Tennessee River have minimal variability between reaches (Appendices J.3 and J.6, respectively, of the WBF Plant EAR).

5. If a CCR Parameter was not detected in surface stream water or sediment and the maximum reporting limits in surface stream water or sediment were greater than the respective screening levels, the CCR Parameter was further evaluated to determine whether it should be identified as a COPEC.

6. If a CCR Parameter was detected in surface stream water or sediment and the maximum detected concentrations in either surface stream water or sediment were greater than the respective screening levels, the CCR Parameter was identified as a COPEC.

7. If mercury or selenium was detected in surface stream water or sediment, these CCR Parameters were further evaluated by comparing detected concentrations in sampled media from upstream reaches with those from adjacent and downstream reaches to determine whether they should be



identified as COPECs for avian and mammalian surrogate receptors due to bioaccumulation potential of these CCR Parameters.

- Mercury
    - Not identified as a COPEC in the Tennessee River because there is no evidence of increased bioaccumulation. Mercury was not detected in surface stream water or clam tissue samples and was detected below screening levels in sediment. There was minimal variability in detected mercury concentrations in whole fish tissue samples between sampling reaches (Appendix E.7 of Appendix C.1).
- Selenium
    - Not identified as a COPEC in the Tennessee River because there was no evidence of increased bioaccumulation. Selenium was not detected in surface stream water samples and was detected below screening levels in sediment. There was minimal variability in detected selenium concentrations in clam tissue and fish tissue samples between sampling reaches (Appendix J.3 of the WBF Plant EAR and Appendix E.7 of Appendix C.1, respectively).

No COPECs were identified for further quantitative evaluation in the ERA, as presented in Table 6-1. As such, this finding, as well as additional qualitative LOE, will be used to evaluate whether concentrations of CCR Parameters in media to which a receptor is potentially exposed to for the WBF Plant are protective of ecological health.

6.1.1.3 Avian and Mammalian Species of Conservation Concern

As described in Section 3.2.5.3, a review of the TVA Natural Heritage Database in November 2023 indicated that of the wildlife currently or historically listed by the USFWS or TDEC as being of conservation concern, only two avian species with exposure to aquatic and riparian media currently occur or have been known to occur within a three-mile radius of the WBF Plant. These are the bald eagle and the osprey (TVA 2023).

Bald Eagle: Although the bald eagle was removed from the federal list of threatened and endangered species in 2007, it is still protected by the Bald and Golden Eagle Protection Act, the Migratory Bird Treaty Act, and the Lacey Act. Bald eagles are typically found near large, open bodies of water such as rivers, lakes, and reservoirs and are known to nest on cliffs or large trees near water. Suitable foraging habitat exists in the vicinity of the WBF Plant (e.g., in the Tennessee River, or along the Tennessee River shoreline) for the bald eagle.

Earlier reviews indicated that bald eagles were reported within five miles of the WBN Plant (TVA 2007a). Bald eagles nest on Chickamauga and Watts Bar Reservoirs approximately 1.8 and 4.7 miles, respectively, from the WBN Plant and forage over the Tennessee River in the vicinity (TVA 2007a).

Osprey: The osprey, also called sea hawk, river hawk, and fish hawk, is a diurnal, fish-eating bird of prey. The osprey is piscivorous, with fish making up 99% of its diet. It is a large raptor reaching more than 60

centimeters (24 inches) in length and 180 centimeters (71 inches) across the wings. The osprey tolerates a wide variety of habitats, nesting, and breeding in any location near a body of water providing an adequate food supply. Suitable foraging habitat exists in the vicinity of the WBF Plant (e.g., in the Tennessee River, or along the Tennessee River shoreline) for the osprey.

6.1.1.4 Ecological Receptor Selection

For the ERA, it was not necessary or feasible to individually assess each receptor that may potentially inhabit, breed, or forage at or in the vicinity of the WBF Plant. Instead, the potential for adverse effects was evaluated for a subset of receptors (i.e., surrogate species) representing the various feeding guilds and ecological communities that may be exposed to CCR Parameters. The ecological receptors assessed in the ERA were chosen by focusing on receptors that are:

- Indigenous to the area and could potentially be exposed to CCR Parameters
- Representative of the various feeding guilds and trophic levels present at or near the WBF Plant (e.g., aquatic carnivore, riparian herbivore, riparian insectivore)
- Representative of species classified as rare, threatened, or endangered (i.e., species of conservation concern).

The selection of receptors was informed, in part, by information from the TVA Natural Heritage Database, investigations conducted at the WBF Plant (Section 3.2.5.3), and peer-reviewed scientific publications related to CCR Parameters in the environment.

As described in Section 3.2.5, areas within the WBF Plant near buildings, former CCR units, and former metal cleaning pond do not provide suitable terrestrial habitat for ecological receptors. As a result, the ERA focuses on aquatic/riparian receptors who utilize the habitat available in the Tennessee River. These receptors may be exposed to CCR Parameters via direct contact or ingestion of surface stream water or sediment, or via food chain uptake from dietary items (e.g., aquatic plants, aquatic insects, and fish) that have accumulated CCR Parameters due to direct contact with surface stream water or sediment. The selected surrogate species for piscivorous birds is representative of potential exposure to the bald eagle. The bald eagle is an opportunistic feeder; while fish is the primary food source, bald eagle can also prey on riparian and terrestrial birds and mammals. Since potential exposure to CCR Parameters is limited to the Tennessee River, evaluation of a piscivorous bird, like osprey, that feeds exclusively on fish is protective of the bald eagle. The ecological receptor groups that were assessed in the ERA, the surrogate ecological receptors that were used to represent these various groups where applicable, and the basis for their selection, are presented in Table 6-2 and summarized below:

- Freshwater aquatic life:
    - Benthic invertebrates – benthic invertebrate communities
    - Primary producers – aquatic plant communities
    - Fish – fish communities.



- Amphibians – amphibian communities
- Reptiles – reptile communities
- Aquatic and riparian-feeding birds:
    - Herbivorous birds – wood duck (*Aix sponsa*)
    - Omnivorous birds – mallard duck
    - Insectivorous birds – killdeer (*Charadrius vociferus*)
    - Piscivorous birds – great blue heron/osprey.
- Aquatic and riparian-feeding mammals:
    - Herbivorous mammals – muskrat
    - Omnivorous mammals – raccoon
    - Piscivorous mammals – mink (*Neovison vison*).
- Aerial-feeding birds and mammals:
    - Insectivorous birds – tree swallow (*Tachycineta bicolor*)
    - Insectivorous mammals – gray bat.

The selected ecological receptors listed above and shown in Table 6-2 are representative of other species occupying a similar position in the food web. These ecological receptors assessed in the ERA are expected to adequately represent the diversity of fauna and aquatic and riparian vegetation at or near the WBF Plant. Descriptions of the avian and mammalian ecological receptors evaluated in the ERA are provided below.

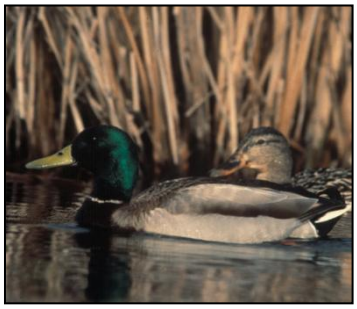
Wood Duck



The wood duck is a colorful species of waterfowl. It is common in the United States and lives near lakes and slow-moving rivers bordered by trees or other tall vegetation (California Department of Fish and Wildlife 2021). The average body weight of the wood duck is 0.658 kg (Cornell Lab of Ornithology 2021a). The foraging range of the wood duck is an estimated 612 acres. This estimate was based on the average breeding female and male home ranges (Verner et al. 1980 and Zeiner et al. 1990). Wood ducks are primarily herbivorous (Zeiner et al. 1990, Landers et al. 1977 and USDA 2021), but laying females consume a higher proportion of invertebrates. For the present assessment, the terrestrial components of the wood duck's diet (i.e., terrestrial invertebrates and terrestrial vegetation) are assumed to be composed of aquatic food items (i.e., aquatic invertebrates and aquatic vegetation). Wood ducks consume 0.0392 kg of dry weight food (or 0.122 kg of

ww food) per day (calculated using Equations 61 and 62 in Nagy [2001]) and 0.0446 liters (L) of water per day (calculated using Equation 3-15 in USEPA [1993]). The wood duck is estimated to incidentally ingest 0.00431 kg per day of dry sediment (Beyer et al. 1994).

Mallard Duck



The mallard is the most abundant dabbling duck species in North America. It prefers areas that provide cover from predators such as grassland with tall and dense vegetation and nests near woodland lakes, streams, and marshes (USEPA 1993). The average body weight of an adult mallard is 1.17 kg (USEPA 1993). The foraging range of the mallard duck is an estimated 274 acres. This estimate was based on the average home range of laying females (USEPA 1993). Mallards feed by dabbling and filtering through sediments. For the present assessment, the diet of a mallard is based on individuals living in south central North Dakota and includes aquatic invertebrates and aquatic vegetation (USEPA 1993). The mallard consumes 0.0562 kg of dry weight food (or 0.176 kg ww food) per day (calculated using Equations 61 and 62 in Nagy [2001]), and 0.0655 L of water per day (calculated using Equation 3-15 in USEPA [1993]). The mallard is estimated to incidentally ingest 0.00185 kg per day of dry sediment (Beyer et al. 1994).

Killdeer



The killdeer is a shorebird that commonly inhabits sandbars, mudflats, and grazed fields (Cornell Lab of Ornithology 2021b). The average body weight of a killdeer is 0.102 kg (Cornell Lab of Ornithology 2021b). The foraging range of the killdeer is an estimated 10.4 acres. This estimate was based on the average home ranges of pre-nesting, nesting and post-nesting females and males (Plissner et al. 2000). They feed primarily on earthworms, snails, crayfish, grasshoppers, beetles, and aquatic insect larvae (Cornell Lab of Ornithology 2021b). For the present assessment, the diet of a killdeer is based on individuals living in North Dakota and includes terrestrial and aquatic invertebrates (Fair et al. 1995), and the terrestrial components of the killdeer's diet (i.e., terrestrial invertebrates) are assumed to be composed of aquatic food items (i.e., aquatic invertebrates). Killdeers consume 0.0183 kg of dry weight food (or 0.0671 kg of ww food) per day (calculated using Equations 39 and 40 in Nagy [2001]) and 0.0128 L of water per day (calculated using Equation 3-15 in USEPA [1993]). The killdeer is estimated to incidentally ingest 0.00190 kg per day of dry sediment, based on the fraction of soil in the American woodcock's diet presented in Beyer et al. (1994). The American woodcock is considered a suitable surrogate for the killdeer given the similar life history traits (e.g., diet, size).

Great Blue Heron



The great blue heron is a large (i.e., greater than one meter tall) wading bird that feeds primarily on aquatic animals (USEPA 1993). They primarily inhabit aquatic and marine areas, spending most of their time foraging for fish in shallow waters of lakes, rivers, streams, or estuarine and sheltered coastal areas. Great blue herons tend to nest in dense colonies (heronries) close to foraging grounds (USEPA 1993). The foraging range of the great blue heron is an estimated 1.93 miles. This estimate was based on the average foraging distances of breeding adults within South Dakota rivers and streams (USEPA 1993). The average body weight of an adult great blue heron is 2.31 kg (USEPA 1993). For the present assessment, the diet of a great blue heron is based on individuals living in lower Michigan and includes aquatic invertebrates, fish, reptile/amphibians and birds/mammals. The great blue heron consumes 0.144 kg of dry weight food (or 0.526 kg ww food) per day (calculated using Equations 63 and 64 in Nagy [2001]), and 0.103 L of water per day (calculated using Equation 3-15 in USEPA [1993]). As a piscivore, sediment ingestion for the great blue heron is likely negligible (Sample and Suter 1994). However, the great blue heron is conservatively estimated to incidentally ingest 0.00288 kg per day of dry sediment. The sediment ingestion rate was estimated using the minimum fraction of soil in diet (i.e., 2%) reported in Beyer et al. (1994).

Osprey



The osprey is a large bird of prey that feeds primarily on fish (USEPA 1993). Osprey are found primarily in marine environments in the United States, but also inhabit large inland rivers, lakes, and reservoirs. The average body weight of an adult osprey is 1.60 kg (USEPA 1993). Ospreys build large stick nests in the tops of tall trees or artificial structures (USEPA 1993). The foraging range of the osprey is an estimated 2,240 acres. This estimate was based on the average foraging radius of adult males within Minnesota lakes (USEPA 1993). They are adapted for hovering over the water and dive feet-first, seizing fish with their talons (USEPA 1993). For the present assessment, the diet of the osprey is assumed to be composed of fish. The osprey consumes 0.113 kg of dry weight food (or 0.412 kg ww food) per day (calculated using Equations 63 and 64 in Nagy [2001]), and 0.0808 L of water per day (calculated using Equation 3-15 in USEPA [1993]). Incidental ingestion of sediment by the osprey is assumed to be negligible.

Muskrat



The muskrat is an aquatic rodent that is common throughout most of the United States. They live along the banks of freshwater creeks, streams, lakes, marshes, and ponds (USEPA 1993). The average body weight of a muskrat is 1.17 kg (USEPA 1993). The foraging range of the muskrat is an estimated 0.330 acres. This estimate was based on the average of available home ranges (USEPA 1993). Muskrats are primarily herbivorous and feed at night on aquatic vegetation growing near their dens. They may also consume crayfish, mollusks, fish, frogs, turtles, and young birds (USEPA 1993). For the present assessment, the muskrat's diet is assumed to be composed entirely of aquatic vegetation. Muskrats consume 0.0787 kg of dry weight food (or 0.263 kg of ww food) per day (calculated using Equations 11 and 12 in Nagy [2001]) and 0.114 L of water per day (calculated using Equation 3-17 in USEPA [1993]). The muskrat was estimated to incidentally ingest 0.00740 kg per day of dry sediment. The muskrat's sediment ingestion rate is based on the fraction of soil in the raccoon's diet presented in Beyer et al. (1994). The raccoon is considered a suitable surrogate for the muskrat given the similar life history traits (e.g., diet, size).

Raccoon



The raccoon is the most abundant mid-sized omnivore in North America and is found throughout the United States (USEPA 1993). The average body weight of an adult raccoon is 5.84 kg (USEPA 1993). The foraging range of the raccoon is an estimated 385 acres. This estimate was based on the average home ranges of adult females and males within Michigan riparian habitats (USEPA 1993). Raccoons are found near aquatic habitat but are also common in residential areas and farmland (USEPA 1993). The raccoon is an opportunistic feeder and consumes animals, plants, garbage, and carrion. For the present assessment, the diet of raccoons is based on individuals living in Tennessee and includes terrestrial invertebrates, aquatic invertebrates, terrestrial vegetation, fish, reptile/amphibians, small mammals and birds and other/unspecified (USEPA 1993). However, the terrestrial components of the raccoon's diet (i.e., terrestrial invertebrates, terrestrial vegetation and small mammals and birds) are assumed to be composed of aquatic food items (i.e., aquatic invertebrates, aquatic vegetation and small mammals and birds). The other/unspecified component of the raccoon's diet was split amongst aquatic food items. Raccoons consume 0.155 kg of dry weight food (or 0.482 kg of ww food) per day (calculated using Equations 33 and 34 in Nagy [2001]) and 0.485 L of water per day (calculated using Equation 3-17 in USEPA [1993]). The raccoon is estimated to incidentally ingest 0.0146 kg per day of dry sediment (Beyer et al. 1994).

Mink



The American mink is a member of the weasel family and is the most abundant and widely distributed carnivorous mammal in North America (USEPA 1993). Minks are active year-round and occupy aquatic habitats such as rivers, streams, lakes, ditches, swamps, marshes, and backwater areas (USEPA 1993). The average body weight of an adult mink is 1.02 kg (USEPA 1993). The foraging range of the mink is an estimated 34.8 acres. This estimate was based on the average home ranges of adult females within Montana riverine habitats (USEPA 1993). For the present assessment, the diet of minks is based on individuals living near streams and rivers in Michigan and includes aquatic invertebrates, vegetation, fish, reptile/amphibians, birds/mammals and other/unspecified. Muskrats are an important food source for minks. For the present assessment, the terrestrial components of the mink's diet (i.e., vegetation, and small mammals and birds) are assumed to be composed of aquatic food items (i.e., aquatic vegetation, small mammals and birds). The other/unspecified component of the mink's diet was split amongst aquatic food items. Minks consume 0.0494 kg of dry weight food (or 0.167 kg of ww food) per day (calculated using Equations 25 and 26 in Nagy [2001]) and 0.101 L of water per day (calculated using Equation 3-17 in USEPA [1993]). The ingestion of sediment is likely negligible for the mink. However, the mink is conservatively estimated to incidentally ingest 0.000642 kg per day of dry sediment. The sediment ingestion rate is based on the fraction of soil in the mink's diet presented in Sample and Suter (1994).

Tree Swallow



The tree swallow is a small migratory songbird. Tree swallows breed in open habitats such as fields and wetlands throughout North America, usually adjacent to water (Cornell Lab of Ornithology 2021c). Tree swallows form large migratory and wintering flocks and often nest close together. The average body weight of adult tree swallow is 0.0205 kg (Cornell Lab of Ornithology 2021c). Although tree swallows often nest near water bodies and wetlands, their diet exhibits considerable variability with regard to the proportion of insects consumed that are terrestrial or aquatic. A study conducted in the vicinity of the Kingston Fossil Plant (Beck et al. 2013) has shown that while the tree swallow's diet of insects with an aquatic larval stage was 67% of their total diet when averaged across the study area, the percentage varied between 28 to 75% for different colonies. The study concluded these differences may be attributable to habitat characteristics and seasonal variation. The foraging range of the tree swallow is an estimated 31.1 acres. This estimate was based on the observed foraging distances of individuals from their nests (McCarty and Winkler 1999, Dunn and Hannon 1992, and Quinney and Ankney 1985). Tree swallows feed on aerial insects caught during acrobatic flight (Cornell Lab of Ornithology 2021c). For the present assessment, the tree swallow's diet was assumed to be composed of invertebrates. The terrestrial components of the tree swallow's diet (i.e., terrestrial invertebrates) is assumed to be composed of aquatic food items (i.e., aquatic invertebrates). The tree swallow consumes 0.0116 kg of dry weight food (or 0.0352 kg ww food) per day

(Nagy 2001), and 0.00436 L of water per day (calculated using Equation 3-15 in USEPA [1993]). Incidental ingestion of sediment by the tree swallow is assumed to be negligible.

Gray Bat



The gray bat is endangered in the United States (USFWS 2022). Gray bats reside in caves located along rivers in the summer and hibernate in deep vertical caves over winter (USFWS 2022). Approximately 95% of the gray bat population hibernates in eight caves located in southeastern United States. The average body weight of a gray bat is 0.00950 kg (TNBWG 2021). The foraging range of the gray bat is an estimated 7.3 miles (LaVal et al. 1977). This estimate was based on the average distance from banding (i.e., cave and stream) of individuals. Gray bats eat a variety of flying aquatic and terrestrial insects present along rivers or lakes (USFWS 2022). Mayflies are an important food item for gray bats (TNBWG 2021). For the present assessment, the gray bat's diet was assumed to be composed of invertebrates. The terrestrial components of the gray bat's diet (i.e., terrestrial invertebrates) are assumed to be composed of aquatic food items (i.e., aquatic invertebrates). Gray bats consume 0.00165 kg of dry weight food (or 0.00529 kg of ww food) per day (calculated using Equations 7 and 8 in Nagy [2001]) and 0.00150 L of water per day (calculated using Equation 3-17 in USEPA [1993]). Incidental ingestion of sediment by the grey bat is assumed to be negligible.

6.1.1.5 Exposure Pathways and Routes of Exposure

Exposure pathways identified in the CSM for the WBF Plant (Exhibit 6-1) are classified as:

- Potentially complete
- Potentially complete but contribution to exposure is negligible
- Incomplete.

An exposure pathway is complete when there is potential for a receptor to be exposed to an exposure medium that may contain COPECs through an identified exposure route. The ecological receptor groups, potential exposure media, and the classification of the potential exposure pathways for the WBF Plant ecological CSM are presented in Table 6-3. A graphical presentation of the ecological CSM is presented in Exhibit 6-1, and the complete exposure pathways are summarized below.

In general, freshwater aquatic life (i.e., benthic invertebrates, aquatic plants and fish communities) can be exposed to CCR Parameters within the environmental media that they inhabit. Direct contact and ingestion of CCR Parameters from surface stream water and sediment can occur, and some CCR Parameters in these media can bioaccumulate in aquatic life via food chain uptake. Amphibians and reptiles can also be exposed to CCR Parameters through ingestion and food chain uptake, as well as from dermal contact with, and ingestion of sediment and surface stream water. For mammals and birds, their life histories dictate the primary exposure pathways. For example, consumption of vegetation, fish, and invertebrates makes up the primary complete exposure pathways for mammalian and avian herbivores, piscivores, and insectivores, respectively.

6.1.2 Assessment Endpoints

Assessment endpoints define the focus of the ERA. As defined in USEPA's *Guidelines for Ecological Risk Assessment* (USEPA 1998), an assessment endpoint is an explicit expression of the environmental value that is to be protected (e.g., growth, survival, and reproduction of a specific species population). Thus, assessment endpoints focus the ERA on the guilds or communities that might be affected by exposure to CCR Parameters in impacted media. The assessment endpoints for this ERA are shown in Table 6-2. The assessment endpoints are population scale adverse effects to various receptors. No COPECs were identified for the WBF Plant (Section 6.1.1) and the ERA risk characterization (Section 6.2) is qualitative in nature. As a result, this ERA does not define measurement endpoints for quantitative estimation of effect.

6.2 RISK CHARACTERIZATION METHODS

Risk characterization consists of two major components: risk estimation and risk description. No COPECs were identified for the WBF Plant (Section 6.1.1), and as a result, the risk characterization for the ERA does not include risk estimation. Rather, the risk description component is qualitative in nature and a WOE approach is used to characterize risks and potential impacts of CCR Parameters on the selected assessment endpoints. As highlighted in Section 2.2 and provided in the document titled *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A), these components were captured through a WOE approach using multiple LOEs.

6.2.1 Weight of Evidence Framework

This ERA uses a WOE approach to evaluate potential risks to ecological communities and receptors from exposure to CCR Parameters. The WOE approach is consistent with USEPA guidance for conducting ERAs (USEPA 2000a) and is based on the concept that a determination of ecological risk should go beyond solely calculating numerical risk estimates and should include evidence and analysis demonstrating or refuting a causal link between stressor and response (e.g., USEPA 1992c, 1997, 1998, 1999a, and 2000a). It is the combined results of multiple LOEs rather than any single result that are used to determine if risk is present at a level that warrants further evaluation or consideration of corrective measures.

The WOE evaluation for the WBF Plant ERA was performed in accordance with *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A)

6.3 WEIGHT OF EVIDENCE EVALUATION

The assessment endpoints include the protection of abundance and diversity of community receptors (i.e., benthic invertebrate, aquatic vegetation, fish, and aquatic/riparian feeding amphibian and reptile communities); and protection of populations of avian and mammalian receptors (i.e., aquatic/riparian feeding birds, aquatic/riparian feeding mammals, and aerial-feeding birds and mammals), by limiting acute and chronic effects from exposure to site-related exposure (Section 6.1.2 and Table 6-2).



6.3.1 Tennessee River

No COPECs were identified for the Tennessee River (Section 6.1.1.2, Table 6-1). As a result, no quantitative evaluations were conducted for community or avian and mammalian receptors.

Benthic Invertebrate Communities

No COPECs were identified for the Tennessee River. CCR Parameter concentrations in sediment samples from the Tennessee River are less than the sediment screening values (Table 4-4). Benthic invertebrate community RBI results for the Tennessee River as depicted in Exhibit 4-4 showed adjacent and downstream sampling locations as having 'Excellent' biological integrity, while upstream communities scored comparably much lower (Section 4.1.4.2). TTR and HBI (Exhibits 4-6 and 4-7, respectively) in addition to RBI indicate benthic communities within adjacent and downstream areas of the Tennessee River appear to be healthy, rich, and sensitive and demonstrate more favorable ecological conditions than upstream locations in the reservoir above Watts Bar Dam. These LOEs indicate that there are no unacceptable risks to benthic invertebrate communities in the Tennessee River related to the WBF Plant CCR units.

Aquatic Vegetation Communities

No COPECs were identified for the Tennessee River. Because CCR Parameter concentrations in sediment samples from the Tennessee River are less than the sediment screening values (Table 4-4), it is concluded that there are no unacceptable risks to aquatic vegetation.

Fish Communities

No COPECs were identified for the Tennessee River. CCR Parameter concentrations in surface stream water samples collected from the Tennessee River are less than surface water screening values (Table 4-3). RFAI scores were reviewed from historical NPDES biological monitoring studies. RFAI results showed that a balanced indigenous population is currently being demonstrated in Chickamauga Reservoir headwater region downstream from the WBF Plant. TVA's RFAI assessment data has consistently indicated that Chickamauga Reservoir headwater region fish assemblages downstream from the WBN Plant remain similar over time (TVA 2018a). Results of the 1970s and 2000s impingement monitoring also concluded that no fish species were impinged at those facilities in sufficient numbers to impact Watts Bar and Chickamauga Reservoir fish communities (TVA 1975, 2007b, 2011b, and 2017b). These LOEs indicate that there are no unacceptable risks to the fish community in the Tennessee River related to exposures to the WBF Plant CCR units.

Aquatic/Riparian Feeding Amphibians and Reptiles

No COPECs were identified for the Tennessee River. Because CCR Parameter concentrations in surface stream water samples collected from the Tennessee River are less than surface water screening values (Table 4-3), it is concluded that there are no unacceptable risks to amphibian and reptile communities within the Tennessee River.



Aquatic/Riparian Feeding Birds, Aquatic/Riparian Feeding Mammals and Aerial Feeding Birds and Mammals

No COPECs were identified for the Tennessee River. CCR Parameter concentrations in surface stream water and sediment samples collected from the Tennessee River are less than surface water and sediment screening values (Tables 4-3 and 4-4, respectively). As such, there are no unacceptable risks to aquatic/riparian feeding bird, aquatic/riparian feeding mammal and aerial feeding birds and mammal populations at the Tennessee River related to exposures to the WBF Plant CCR units.

6.4 INTERPRETATION OF RISK

This ERA included multiple LOEs in a WOE evaluation (Section 6.3) of potential ecological risks to community receptors and avian and mammalian receptor populations from exposure to CCR Parameters measured in environmental media samples collected from the Tennessee River. The interpretation of results is as follows.

6.4.1 Tennessee River

CCR Parameter concentrations in surface stream water and sediment samples collected during the investigations described herein from the Tennessee River are less than screening values. No COPECs were identified for the Tennessee River (Table 6-1); as a result, no quantitative evaluations were conducted for community receptors or avian and mammalian receptors. Benthic invertebrate community sampling was conducted in upstream, adjacent, and downstream locations of the Tennessee River in proximity to the WBF Plant CCR units. The benthic invertebrate community TTR, HBI and RBI results indicate that benthic communities within adjacent and downstream areas appear to be healthy, rich, and sensitive, and they demonstrate more favorable ecological conditions than upstream locations in the reservoir above Watts Bar Dam. RFAI scores from historical NPDES biological monitoring studies showed that a balanced indigenous population of fish is currently being demonstrated in Chickamauga Reservoir.

Based on the WOE presented in Section 6.3 and summarized above, the overall interpretation is that there are no unacceptable risks to abundance and diversity in community receptors and populations of avian and mammalian receptors inhabiting or using the Tennessee River resulting from the WBF Plant CCR units.

6.5 UNCERTAINTY ANALYSIS

Uncertainties are inherent in the risk assessment process and arise from limitations in the available information, analysis methods, and assumptions used in the assessment. Sources of uncertainty may include chemical characterization information and limitations in the available data, assessment of potential exposures, and modeling of uptake and toxicity. To assist interpretation of the risk assessment results presented in this ERA, the primary sources of uncertainty in the problem formulation of the ERA are described in the following subsection. The different sources of uncertainty described below were incorporated into the ERA. Because the COPEC selection process err on the conservative side (i.e., environmentally protective), the uncertainty associated with the conclusion that there are no unacceptable risks to the abundance and diversity in ecological receptors related to the WBF Plant CCR-units is low.



6.5.1 Problem Formulation Uncertainties

Uncertainties associated with the problem formulation include identification of COPECs and selection of ecological receptors, as described below:

- The process used to select COPECs in surface stream water and sediment for evaluation of risks to ecological receptors may introduce a degree of uncertainty in the ERA. Conservative methods and assumptions were used to select COPECs, if present. These include identifying CCR Parameters as COPECs if maximum detected concentrations of CCR Parameters in any medium exceeded respective conservative screening levels. These conservative screening levels were derived as described in the *Proposed Screening Levels for Sample Results in the EAR* technical memorandum (Appendix B.1, Attachment A) and are protective of freshwater aquatic life. CCR Parameters without applicable screening levels and mercury and selenium that were detected below screening levels were also further evaluated to determine whether they should be identified as COPECs. Uncertainty associated with not including CCR Parameters which have the potential to cause unacceptable risks as COPECs is low due to the conservative COPECs selection process.

- Selection of ecological receptors (and surrogate species) for risk evaluation may be a source of uncertainty. Ecological receptors were chosen by focusing on organisms indigenous to the area and representative of different feeding guilds, as well as species of conservation concern. The selection of receptors was informed, in part, by information from the TVA Natural Heritage Database, investigations conducted at the WBF Plant and as part of the KRP, and peer-reviewed scientific publications related to CCR Parameters in the environment. The selected ecological receptors are representative of other species occupying similar positions in the food web. Using these criteria, the ecological receptors assessed in the ERA should provide an adequate representation of the diversity of the fauna and aquatic and riparian vegetation at and near the WBF Plant. Consequentially, uncertainty related to the selection of ecological receptors at the WBF Plant is likely to be low.

- CCR Parameters occur naturally in soil, rock, streambed sediment, surface stream water, groundwater, and biological tissues. Anthropogenic sources of CCR Parameters are not limited to combustion of coal and management of CCR material. Other common sources of metals found in streambed sediment include lumber pilings and docks treated with chromated copper arsenate, metal pigments and lead in paints used on outdoor structures such as bridges, antifouling marine paint containing copper, discharges from industrial sources, and regional coal and mineral mining. Because CCR Parameters are widely distributed in the environmental media sampled during the EI, it is possible that concentrations of CCR Parameters used in COPEC screening include contribution from sources other than the CCR units.



7.0 SUMMARY

The findings of the HHRA and ERA for the WBF Plant are summarized In Sections 7.1 and Section 7.2 below, respectively. Confidence in the findings of the HHERA is supported by the use of multiple LOEs in a WOE approach and by incorporation of protective assumptions for and approaches to important uncertainties in the assessments.

7.1 HUMAN HEALTH RISK ASSESSMENT

The HHRA process was used to evaluate potential carcinogenic risks and noncarcinogenic hazards to onsite human receptors potentially exposed to CCR material, and to offsite human receptors potentially exposed to CCR Parameters in groundwater, surface stream water, and fish tissue. No wells or springs potentially used for domestic or business purposes were identified in the water use survey. No seasonally exposed sediment locations adjacent or downstream of the WBF Plant were identified.

The human receptors identified in the HHRA (and the primary exposure media for each) are as follows:

- Onsite worker (exposed to CCR material)
- Recreational user – swimmer (exposed to surface stream water)
- Recreational user – consumer of locally-caught sport fish (exposed to fish tissue)
- Offsite resident (use of surface stream water for domestic water supply).

A summary of the HHRA findings is that:

- No COPCs were identified for surface stream water in the Tennessee River. As a result, risks to recreational user – swimmers or for use of surface stream water for domestic water supply were not further evaluated in the HHRA
- No wells or springs potentially used for domestic or business purposes were identified in the water use survey; thus, ingestion of groundwater is not a complete pathway for offsite residents
- Cumulative ILCR estimates for identified human receptors and media evaluated in the HHRA were below TDEC's acceptable cancer risk criterion of 1×10^{-5}
- Cumulative noncancer hazard estimates were not greater than TDEC's acceptable hazard threshold of 1, except for an estimated HI of 2 for an onsite worker exposed to chemical COPCs in CCR material within the Ash Pond and a recreational user – consumer of locally-caught sport fish from the Tennessee River. The HI of 2 for an onsite worker exposed to chemical COPCs in CCR material within the Ash Pond is primarily attributable to arsenic (HQ = 1.2) and thallium (HQ = 0.49). Implementing standard health and safety protocols (e.g., wearing protective clothing) during maintenance activities is expected to lower the potential risks. The estimated HI of 2 for a recreational user – consumer of locally-caught sport fish from the Tennessee River is

attributable to mercury (total mercury evaluated as methyl mercury) in fish filet. However, LOEs indicate that the levels of mercury in sport fish are consistent with offsite regional sources, thus are not associated with CCR management at the WBF Plant.

- The overall WOE concluded that there are no unacceptable risks to offsite human receptors potentially exposed to CCR Parameters associated with the WBF Plant CCR units as measured in surface stream water and fish filet tissue samples collected from the Tennessee River. While estimated risks to the onsite worker potentially exposed to CCR material within the Ash Pond is greater than the noncancer threshold of 1, implementing standard health and safety protocols is expected to lower the potential risks.

7.2 ECOLOGICAL RISK ASSESSMENT

The ERA process was used to evaluate the potential hazards to aquatic ecological community receptors and to populations of avian and mammalian receptors from exposure to CCR Parameters measured in environmental media samples collected from the Tennessee River.

The general assessment endpoint for this ERA is protection of the abundance and diversity of community receptors and populations of avian and mammalian receptors in the Tennessee River by limiting acute and chronic effects from exposure to site-related exposure. Specific assessment endpoints were identified and evaluated for these ecological community receptors (i.e., benthic invertebrate, aquatic vegetation, fish, and aquatic/riparian feeding amphibian and reptile communities); and populations of aquatic/riparian feeding birds, aquatic/riparian feeding mammals, and aerial-feeding birds and mammals.

The results are summarized below.

Tennessee River

No COPECs were identified for the Tennessee River; as a result, no quantitative evaluations were conducted for community receptors or avian and mammalian receptors. The benthic invertebrate community TTR, HBI and RBI results indicate that benthic communities within adjacent and downstream areas appear to be healthy, rich, and sensitive, and they demonstrate more favorable ecological conditions than upstream locations in the reservoir above Watts Bar Dam. RFAI results showed that a balanced indigenous population is currently being demonstrated in Chickamauga Reservoir headwater region downstream from the WBF Plant.

Based on the WOE and summary above, the overall WOE interpretation is that there are no unacceptable risks to abundance and diversity in community receptors or populations of avian and mammalian receptors inhabiting or using the Tennessee River related to the WBF Plant CCR units.

7.3 NEXT STEPS

In accordance with the TDEC Order, TVA is submitting the HHERA with the CARA Plan. TVA has further evaluated the risk assessment findings in the CARA Plan to assess whether corrective measures are needed. If needed, the CARA Plan specifies the actions TVA plans to take at the CCR units, the basis of those actions, and incorporate any other operational changes planned or in progress by TVA.



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TABLES

TABLE 4-1 – CCR Material Data Summary and Comparisons to Human Health Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening	
CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Screening Level [b]	Maximum Detected Concentration > Screening Level
			%	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	
Antimony	21	20	95.2	0.0819	0.0819	0.104	6.71	2.27	13	No
Arsenic	21	21	100	n/a	n/a	5.81	258	105	5.9	**Yes**
Barium	21	21	100	n/a	n/a	69.4	337	202	2,200	No
Beryllium	21	21	100	n/a	n/a	0.411	6.06	2.69	12	No
Boron	21	21	100	n/a	n/a	2.01	300	66.0	4,500	No
Cadmium	21	20	95.2	0.0224	0.0224	0.0283	5.64	1.64	5.4	**Yes**
Calcium	21	21	100	n/a	n/a	387	27,600	6,350	-	n/a
Chloride	21	6	28.6	4.15	5.95	6.17	30.8	12.1	-	n/a
Chromium	21	21	100	n/a	n/a	4.58	75.8	42.8	3,100	No
Cobalt	21	21	100	n/a	n/a	7.67	20.9	13.0	12	**Yes**
Copper	21	21	100	n/a	n/a	16.7	111	42.2	1,400	No
Fluoride	21	16	76.2	0.730	0.934	1.11	6.8	3.78	1,200	No
Lead	21	21	100	n/a	n/a	5.06	92.6	37.6	130	No
Lithium	21	21	100	n/a	n/a	3.29	39.2	26.7	68	No
Mercury	21	18	85.7	0.0156	0.140	0.0209	1.13	0.416	50	No
Molybdenum	21	21	100	n/a	n/a	0.489	16.3	8.28	800	No
Nickel	21	21	100	n/a	n/a	15.3	57.8	32.3	110	No
Radium-226	21	21	100	n/a	n/a	0.634	6.69	3.12	6.5	**Yes**
Radium-228	21	20	95.2	0.399	0.399	1.23	3.29	2.13	6.5	No
Selenium	21	20	95.2	0.81	0.812	1.06	11.5	5.60	170	No
Silver	21	18	85.7	0.0299	0.0357	0.0309	0.243	0.130	170	No
Sulfate	21	21	100	n/a	n/a	23.3	1,580	428	-	n/a
Thallium	21	21	100	n/a	n/a	0.243	10.9	4.40	1.4	**Yes**
Vanadium	21	21	100	n/a	n/a	7.55	226	77.1	55	**Yes**
Zinc	21	21	100	n/a	n/a	6.95	423	133	10,000	No

Notes:

Bold	maximum detected concentration > screening level for detected CCR Parameter
-	not available
%	percent
>	greater than
CCR	coal combustion residuals
mg/kg	milligrams per kilogram
n/a	not applicable
pCi/g	picocuries per gram (radium-226 and radium-228 only)
SSL_{HH}	receptor-specific screening levels for human health

[a] Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a CCR Parameter is less than 100%.

[b] Screening levels are equal to the soil SSL_{HH} for an onsite worker based on a target carcinogenic risk and hazard quotient of $1x10^{-6}$ and 0.1, respectively (Appendix B.1).

TABLE 4-2 – Surface Stream Water Data Summary and Comparisons to Human Health Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening	
Surface Stream/ CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Screening Level [b]	Maximum Detected Concentration > Screening Level
			%	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	
Tennessee River										
Antimony, total	79	4	5.06	0.378	0.378	0.394	0.585	0.491	6	No
Antimony, dissolved	79	2	2.53	0.378	0.633	0.378	0.467	0.423	6	No
Arsenic, total	79	79	100	n/a	n/a	0.445	0.927	0.627	10	No
Arsenic, dissolved	79	70	88.6	0.512	0.768	0.376	0.844	0.554	10	No
Barium, total	79	79	100	n/a	n/a	24.3	46.6	28.4	2,000	No
Barium, dissolved	79	79	100	n/a	n/a	21.6	29.6	26.0	2,000	No
Beryllium, total	79	16	20.3	0.155	0.907	0.170	0.846	0.385	4	No
Beryllium, dissolved	79	10	12.7	0.155	0.327	0.169	0.321	0.249	4	No
Boron, total	79	12	15.2	30.3	39.5	34.5	168	68.7	4,000	No
Boron, dissolved	79	9	11.4	30.3	54.9	31.9	81.2	50.1	4,000	No
Cadmium, total	79	2	2.53	0.125	0.125	0.152	0.153	0.153	5	No
Cadmium, dissolved	79	1	1.27	0.125	0.125	0.130	0.130	0.130	5	No
Calcium, total	79	79	100	n/a	n/a	20,600	24,700	22,600	-	n/a
Calcium, dissolved	79	79	100	n/a	n/a	20,500	24,800	22,500	-	n/a
Chloride	79	79	100	n/a	n/a	3,980	6,620	5,180	250,000	No
Chromium, total	79	10	12.7	1.53	6.61	1.84	11.9	3.17	100	No
Chromium, dissolved	79	10	12.7	1.53	5.20	1.67	2.14	1.94	100	No
Cobalt, total	79	76	96.2	0.139	0.151	0.0870	0.272	0.144	6	No
Cobalt, dissolved	79	20	25.3	0.0750	0.0750	0.0850	0.143	0.103	6	No
Copper, total	79	76	96.2	1.15	1.48	0.657	2.45	1.11	1,300	No
Copper, dissolved	79	46	58.2	0.627	1.46	0.700	2.20	1.03	1,300	No
Fluoride	79	71	89.9	51.5	62.2	52.3	82.4	61.1	4,000	No
Lead, total	79	62	78.5	0.128	0.218	0.128	0.375	0.185	5	No
Lead, dissolved	79	3	3.80	0.128	0.128	0.138	0.184	0.159	5	No
Lithium, total	79	13	16.5	3.14	3.39	3.18	4.89	3.86	40	No
Lithium, dissolved	79	10	12.7	3.14	3.39	3.15	5.20	3.89	40	No
Mercury, total	79	0	0	0.101	0.101	n/a	n/a	n/a	2	No
Mercury, dissolved	79	0	0	0.101	0.101	n/a	n/a	n/a	2	No
Molybdenum, total	79	0	0	0.610	0.610	n/a	n/a	n/a	100	No
Molybdenum, dissolved	79	1	1.27	0.610	0.610	0.703	0.703	0.703	100	No
Nickel, total	79	43	54.4	0.312	1.86	0.323	0.620	0.431	100	No
Nickel, dissolved	79	14	17.7	0.312	1.75	0.339	0.441	0.374	100	No
Radium-226	79	0	0	0.0600	0.271	n/a	n/a	n/a	5	No
Radium-228	79	5	6.33	0.361	1.03	0.465	0.623	0.564	5	No

TABLE 4-2 – Surface Stream Water Data Summary and Comparisons to Human Health Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening	
Surface Stream/ CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Screening Level [b]	Maximum Detected Concentration > Screening Level
			%	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	
Selenium, total	79	0	0	1.51	2.62	n/a	n/a	n/a	50	No
Selenium, dissolved	79	0	0	1.51	2.62	n/a	n/a	n/a	50	No
Silver, total	79	1	1.27	0.121	0.177	0.270	0.270	0.270	100	No
Silver, dissolved	79	0	0	0.121	0.177	n/a	n/a	n/a	100	No
Sulfate	79	79	100	n/a	n/a	8,160	11,800	9,730	250,000	No
Thallium, total	79	6	7.59	0.128	0.148	0.152	0.437	0.240	2	No
Thallium, dissolved	79	3	3.80	0.128	0.280	0.151	0.457	0.278	2	No
Vanadium, total	79	52	65.8	0.955	2.24	1.05	2.40	1.46	86	No
Vanadium, dissolved	79	54	68.4	0.899	1.88	0.899	2.16	1.29	86	No
Zinc, total	79	24	30.4	3.22	3.22	3.33	9.55	5.01	2,000	No
Zinc, dissolved	79	5	6.33	3.22	3.22	3.59	5.65	4.59	2,000	No

Notes:

-	not available
%	percent
>	greater than
CCR	coal combustion residuals
n/a	not applicable
pCi/L	picocuries per liter (radium-226 and radium-228 only)
µg/L	micrograms per liter

[a] Data summary includes sample locations adjacent to and downstream of the Watts Bar Fossil Plant; sample locations upstream of the Watts Bar Fossil Plant were excluded. Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a CCR Parameter is less than 100%.

[b] Screening levels are equal to the human health surface water screening levels presented in *Proposed Screening Levels for Sample Results in Environmental Assessment Report (EAR)* (Appendix B.1, Attachment A).

TABLE 4-3 – Surface Stream Water Data Summary and Comparisons to Ecological Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening			
Surface Stream/ CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Chronic Screening Level [b]	Acute Screening Level [b]	Maximum Detected Concentration > Chronic Screening Level [c]	Maximum Detected Concentration > Acute Screening Level [c]
			%	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L		
Tennessee River												
Antimony, total	79	4	5.06	0.378	0.378	0.394	0.585	0.491	190	900	No	No
Antimony, dissolved	79	2	2.53	0.378	0.633	0.378	0.467	0.423	-	-	n/a	n/a
Arsenic, total	79	79	100	n/a	n/a	0.445	0.927	0.627	150	340	No	No
Arsenic, dissolved	79	70	89	0.512	0.768	0.376	0.844	0.554	150	340	No	No
Barium, total	79	79	100	n/a	n/a	24.3	46.6	28.4	220	2,000	No	No
Barium, dissolved	79	79	100	n/a	n/a	21.6	29.6	26.0	-	-	n/a	n/a
Beryllium, total	79	16	20.3	0.155	0.907	0.170	0.846	0.385	11	93	No	No
Beryllium, dissolved	79	10	12.7	0.155	0.327	0.169	0.321	0.249	-	-	n/a	n/a
Boron, total	79	12	15.2	30.3	39.5	34.5	168	68.7	7,200	34,000	No	No
Boron, dissolved	79	9	11.4	30.3	54.9	31.9	81.2	50.1	-	-	n/a	n/a
Cadmium, total	79	2	2.53	0.125	0.125	0.152	0.153	0.153	0.628	1.44	n/a	n/a
Cadmium, dissolved	79	1	1.27	0.125	0.125	0.130	0.130	0.130	0.579	1.38	No	No
Calcium, total	79	79	100	n/a	n/a	20,600	24,700	22,600	116,000	-	No	n/a
Calcium, dissolved	79	79	100	n/a	n/a	20,500	24,800	22,500	-	-	n/a	n/a
Chloride	79	79	100	n/a	n/a	3,980	6,620	5,180	230,000	860,000	No	No
Chromium, total	79	10	12.7	1.53	6.61	1.84	11.9	3.17	68.1	1,425	n/a	n/a
Chromium, dissolved	79	10	12.7	1.53	5.20	1.67	2.14	1.94	58.6	450	No	No
Cobalt, total	79	76	96.2	0.139	0.151	0.0870	0.272	0.144	19	120	No	No
Cobalt, dissolved	79	20	25.3	0.0750	0.0750	0.0850	0.143	0.103	-	-	n/a	n/a
Copper, total	79	76	96.2	1.15	1.48	0.657	2.45	1.11	7.30	10.7	n/a	n/a
Copper, dissolved	79	46	58.2	0.627	1.46	0.700	2.20	1.03	7.00	10.2	No	No
Fluoride	79	71	89.9	51.5	62.2	52.3	82.4	61.1	2,700	9,800	No	No
Lead, total	79	62	78.5	0.128	0.218	0.128	0.375	0.185	2.21	56.6	n/a	n/a
Lead, dissolved	79	3	3.80	0.128	0.128	0.138	0.184	0.159	1.84	47.2	No	No
Lithium, total	79	13	16.5	3.14	3.39	3.18	4.89	3.86	440	910	No	No
Lithium, dissolved	79	10	12.7	3.14	3.39	3.15	5.20	3.89	-	-	n/a	n/a
Mercury, total	79	0	0	0.101	0.101	n/a	n/a	n/a	0.77	1.4	No	No
Mercury, dissolved	79	0	0	0.101	0.101	n/a	n/a	n/a	0.77	1.4	No	No
Molybdenum, total	79	0	0	0.610	0.610	n/a	n/a	n/a	800	7,200	No	No
Molybdenum, dissolved	79	1	1.27	0.610	0.610	0.703	0.703	0.703	-	-	n/a	n/a
Nickel, total	79	43	54.4	0.312	1.86	0.323	0.620	0.431	40.9	368	n/a	n/a
Nickel, dissolved	79	14	17.7	0.312	1.75	0.339	0.441	0.374	40.8	367	No	No

TABLE 4-3 – Surface Stream Water Data Summary and Comparisons to Ecological Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening			
Surface Stream/ CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Chronic Screening Level [b]	Acute Screening Level [b]	Maximum Detected Concentration > Chronic Screening Level [c]	Maximum Detected Concentration > Acute Screening Level [c]
			%	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L	µg/L or pCi/L		
Radium-226	79	0	0	0.0600	0.271	n/a	n/a	n/a	3	3	No	No
Radium-228	79	5	6.33	0.361	1.03	0.465	0.623	0.564	3	3	No	No
Selenium, total	79	0	0	1.51	2.62	n/a	n/a	n/a	3.1	20	No	No
Selenium, dissolved	79	0	0	1.51	2.62	n/a	n/a	n/a	-	-	No	No
Silver, total	79	1	1.27	0.121	0.177	0.270	0.270	0.270	-	2.31	n/a	n/a
Silver, dissolved	79	0	0	0.121	0.177	n/a	n/a	n/a	-	1.96	No	No
Sulfate	79	79	100	n/a	n/a	8,160	11,800	9,730	-	-	n/a	n/a
Thallium, total	79	6	7.59	0.128	0.148	0.152	0.437	0.240	6	54	No	No
Thallium, dissolved	79	3	3.80	0.128	0.280	0.151	0.457	0.278	-	-	n/a	n/a
Vanadium, total	79	52	65.8	0.955	2.24	1.05	2.40	1.46	27	79	No	No
Vanadium, dissolved	79	54	68.4	0.899	1.88	0.899	2.16	1.29	-	-	n/a	n/a
Zinc, total	79	24	30.4	3.22	3.22	3.33	9.55	5.01	94	94	n/a	n/a
Zinc, dissolved	79	5	6.33	3.22	3.22	3.59	5.65	4.59	93	92	No	No

Notes:

-	not available
%	percent
>	greater than
CCR	coal combustion residuals
n/a	not applicable
pCi/L	picocuries per liter (radium-226 and radium-228 only)
µg/L	micrograms per liter

[a] Data summary includes sample locations adjacent to and downstream of the Watts Bar Fossil Plant; sample locations upstream of the Watts Bar Fossil Plant were excluded. Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a CCR Parameter is less than 100%.

[b] Screening levels are based on acute and chronic surface stream water screening values presented in *Proposed Screening Levels for Sample Results in Environmental Assessment Report (EAR)* (Appendix B.1, Attachment A).

[c] CCR Parameters with hardness-dependent screening criteria (i.e., cadmium, chromium, copper, lead, nickel, silver and zinc) are only compared to dissolved fraction screening criteria.

TABLE 4-4 – Sediment Data Summary and Comparisons to Ecological Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening			
Surface Stream/ CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Chronic Screening Level [b]	Acute Screening Level [b]	Maximum Detected Concentration > Chronic Screening Level	Maximum Detected Concentration > Acute Screening Level
			%	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g		
Tennessee River												
Antimony	7	6	86	0.0465	0.0465	0.0498	0.159	0.0933	2	25	No	No
Arsenic	7	7	100	n/a	n/a	1.34	4.59	2.50	9.8	33	No	No
Barium	7	7	100	n/a	n/a	43.3	108	80.9	240	22,925	No	No
Beryllium	7	7	100	n/a	n/a	0.309	1.09	0.714	1.2	42	No	No
Boron	7	7	100	n/a	n/a	1.03	2.89	1.82	-	-	n/a	n/a
Cadmium	7	7	100	n/a	n/a	0.0743	0.423	0.177	1	5	No	No
Calcium	7	7	100	n/a	n/a	1,090	9,500	3,080	-	-	n/a	n/a
Chloride	7	0	0	5.42	6.19	n/a	n/a	n/a	-	-	No	No
Chromium	7	7	100	n/a	n/a	7.43	17.9	13.3	43.4	111	No	No
Cobalt	7	7	100	n/a	n/a	4.63	11.3	8.08	50	-	No	n/a
Copper	7	7	100	n/a	n/a	4.52	30.3	11.6	31.6	149	No	No
Fluoride	7	5	71.4	0.952	1.00	0.950	1.47	1.24	-	-	n/a	n/a
Lead	7	7	100	n/a	n/a	5.82	21.2	11.1	35.8	128	No	No
Lithium	7	7	100	n/a	n/a	5.52	16.9	10.20	-	-	n/a	n/a
Mercury	7	6	85.7	0.0102	0.0102	0.0116	0.0790	0.0339	0.18	1.1	No	No
Molybdenum	7	7	100	n/a	n/a	0.163	0.572	0.366	38	69,760	No	No
Nickel	7	7	100	n/a	n/a	5.80	14.3	10.6	22.7	48.6	No	No
Radium-226	7	7	100	n/a	n/a	0.657	1.38	1.09	90	90	No	No
Radium-228	7	7	100	n/a	n/a	1.00	1.65	1.37	90	90	No	No
Selenium	7	7	100	n/a	n/a	0.430	1.12	0.819	2	2.9	No	No
Silver	7	4	57.1	0.0195	0.0216	0.0232	0.0409	0.0293	1	2.2	No	No
Sulfate	7	7	100	n/a	n/a	25.4	65.1	44.3	-	-	n/a	n/a
Thallium	7	7	100	n/a	n/a	0.0887	0.215	0.152	1.2	10	No	No
Vanadium	7	7	100	n/a	n/a	8.54	26.1	16.7	66	564	No	No
Zinc	7	7	100	n/a	n/a	33.9	98.6	57.9	121	459	No	No

TABLE 4-4 – Sediment Data Summary and Comparisons to Ecological Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening			
Surface Stream/ CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Chronic Screening Level [b]	Acute Screening Level [b]	Maximum Detected Concentration > Chronic Screening Level	Maximum Detected Concentration > Acute Screening Level
			%	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g		

Notes:

-	not available
%	percent
>	greater than
CCR	coal combustion residuals
mg/kg	milligrams per kilogram
n/a	not applicable
pCi/g	picocuries per gram (radium-226 and radium-228 only)

[a] Data summary includes sample locations adjacent to and downstream of the Watts Bar Fossil Plant; sample locations upstream of the Watts Bar Fossil Plant were excluded. Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a CCR Parameter is less than 100%.

[b] Screening levels are based on acute and chronic freshwater sediment screening values presented in *Proposed Screening Levels for Sample Results in Environmental Assessment Report (EAR)* (Appendix B.1, Attachment A).

TABLE 4-5 – Fish Filet Data Summary and Comparisons to Human Health Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening	
Surface Stream/ Fish Tissue CCR Parameters	**Number of Samples**	**Number of Detections**	**Detection Frequency**	**Minimum Reporting Limit for Non-Detects**	**Maximum Reporting Limit for Non-Detects**	**Minimum Detected Concentration**	**Maximum Detected Concentration**	**Mean Concentration for Detected Results**	**Screening Level [b]**	**Maximum Detected Concentration > Screening Level**
			%	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	
Tennessee River										
Antimony	8	0	0	0.019	0.021	n/a	n/a	n/a	0.072	No
Arsenic	8	8	100	n/a	n/a	0.062	0.17	0.114	0.0047	**Yes**
Barium	8	3	37.5	0.028	0.030	0.035	0.061	0.0467	36	No
Beryllium	8	0	0	0.031	0.033	n/a	n/a	n/a	0.36	No
Boron	8	0	0	0.65	0.70	n/a	n/a	n/a	36	No
Cadmium	8	2	25.0	0.010	0.011	0.024	0.028	0.0260	0.18	No
Calcium	8	8	100	n/a	n/a	75.5	475	266	-	n/a
Chromium	8	0	0	0.082	0.088	n/a	n/a	n/a	270	No
Cobalt	8	0	0	0.018	0.019	n/a	n/a	n/a	0.054	No
Copper	8	4	50.0	0.26	0.28	0.48	10.8	3.10	7.2	**Yes**
Lead	8	0	0	0.028	0.030	n/a	n/a	n/a	-	No
Lithium	8	0	0	0.020	0.021	n/a	n/a	n/a	0.36	No
Mercury	8	7	87.5	0.0072	0.0072	0.029	0.28	0.120	0.018	**Yes**
Molybdenum	8	0	0	0.033	0.036	n/a	n/a	n/a	0.90	No
Nickel	8	3	37.5	0.038	0.041	0.043	0.24	0.117	3.6	No
Selenium	8	8	100	n/a	n/a	0.15	0.37	0.260	0.90	No
Silver	8	0	0	0.010	0.011	n/a	n/a	n/a	0.90	No
Thallium	8	0	0	0.012	0.013	n/a	n/a	n/a	0.0018	***No***
Vanadium	8	0	0	0.031	0.033	n/a	n/a	n/a	0.90	No
Zinc	8	8	100	n/a	n/a	4.1	6.6	5.63	54	No

Notes:

Bold	maximum detected concentration > screening level for detected CCR Parameter
Bold Italic	maximum reporting limit > screening level for non-detect CCR Parameter
-	not available
%	percent
>	greater than
CCR	coal combustion residuals
mg/kg-ww	milligrams per kilogram wet weight
n/a	not applicable
SSL_{HH}	receptor-specific screening levels for human health

TABLE 4-5 – Fish Filet Data Summary and Comparisons to Human Health Screening Levels
Watts Bar Fossil Plant

	Data Summary [a]								Screening	
Surface Stream/ Fish Tissue CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Screening Level [b]	Maximum Detected Concentration > Screening Level
			%	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	

[a] Data summary includes sample locations adjacent to and downstream of the Watts Bar Fossil Plant; sample locations upstream of the Watts Bar Fossil Plant were excluded. Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a CCR Parameter is less than 100%. Chloride, fluoride, sulfate, Radium-226, and Radium-228 were not analyzed in fish tissues as indicated in the Environmental Investigation Plan.

[b] Screening levels are equal to the fish SSL_{HH} for a consumer of locally-caught sport fish based on a target carcinogenic risk and hazard quotient of $1x10^{-6}$ and 0.1, respectively (Appendix B.1). Mercury SSL_{HH} for consumer of locally-caught sport fish were calculated using the chronic reference dose for methyl mercury.

TABLE 5-1 – COPCs Identified for the HHRA
Watts Bar Fossil Plant

	CCR Material	Surface Stream Water	Fish Tissue
		Recreational User - Swimmer	Recreational User - Consumer of Locally-Caught Sport Fish
CCR Parameter [a]	Onsite Worker	Tennessee River	Tennessee River
Antimony			
Arsenic	✓		✓
Barium			
Beryllium			
Boron			
Cadmium	✓		
Calcium	--	--	--
Chloride	--		
Chromium			
Cobalt	✓		
Copper			✓
Fluoride			
Lead			
Lithium			
Mercury			✓
Molybdenum			
Nickel			
Radium-226	✓		
Radium-228			
Selenium			
Silver			
Sulfate	--		
Thallium	✓		
Vanadium	✓		
Zinc			

Notes:

Groundwater exposure pathways associated with onsite and offsite use of groundwater and springs as a drinking water source were not considered complete, and therefore, there are no COPCs for groundwater.

	not detected or was detected below respective screening levels
--	detected but not selected as a COPC because it is naturally occurring and has a low risk potential (refer to Section 5.1.1.3)
✓	denotes a COPC
CCR	coal combustion residuals
COPC	constituent of potential concern
HHRA	human health risk assessment

[a] A CCR Parameter detected above its respective screening level is identified as a COPC unless otherwise noted. For surface stream water, sample results for both dissolved and total fractions are used to identify COPCs. Detected CCR Parameters without screening levels were conservatively selected as COPCs unless otherwise noted.

TABLE 5-2 - Exposure Assumptions Used in the Human Health Risk Assessment
Watts Bar Fossil Plant

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
CCR Material	Onsite Worker	Adult	Ingestion	IR_{CCR}	Ingestion Rate of CCR Material	mg/day	330	n/a	n/a	Soil ingestion rate for a construction worker (USEPA 2002)
				EF_w	Exposure Frequency	days/year	20	n/a	n/a	5 days a week for 4 weeks (Site-specific assumption)
				CF	Conversion Factor	kg/mg	1E-06	n/a	n/a	n/a
				ED_w	Exposure Duration	years	1	n/a	n/a	Exposure duration for a construction worker (USEPA 2002)
				RBA	Relative Bioavailability Factor	unitless	0.6 (Arsenic) 1 (Other chemicals)	n/a	n/a	Default (USEPA 2012a)
				BW_w	Body Weight	kg	80	n/a	n/a	Adult worker body weight (USEPA 2014a)
				AT_{NCw}	Averaging Time (noncancer)	days	28	n/a	n/a	7 days/week for 4 weeks
				AT_C	Averaging Time (cancer)	days	25,550	n/a	n/a	Lifetime (70 years) x 365 days/year (USEPA 1989a)
			Dermal	CF	Conversion Factor	kg/mg	1E-06	n/a	n/a	n/a
				AF_w	Adherence factor of CCR Material to skin	mg/cm^2-event	0.3	n/a	n/a	Default adherence factors for a construction worker (USEPA 2002)
				ABS	Dermal absorption fraction	unitless	Chemical Specific	n/a	n/a	USEPA 2004
				SA_w	Skin surface area available for contact	cm^2	3,527	n/a	n/a	Worker skin surface area (USEPA 2014a).
				EF_w	Exposure Frequency	days/year	20	n/a	n/a	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	years	1	n/a	n/a	Exposure duration for a construction worker (USEPA 2002)
				BW_w	Body Weight	kg	80	n/a	n/a	Adult worker body weight (USEPA 2014a)
				AT_{NCw}	Averaging Time (noncancer)	days	28	n/a	n/a	7 days/week for 4 weeks
				AT_C	Averaging Time (cancer)	days	25,550	n/a	n/a	Lifetime (70 years) x 365 days/year (USEPA 1989a)
			Inhalation	CF	Conversion Factor	mg/µg	1E-03	n/a	n/a	n/a
				IRA	Inhalation Rate for Radionuclide	m^3/day	60	n/a	n/a	USEPA 2021
				ET_w	Exposure Time	hours/day	8	n/a	n/a	Worker air exposure time (USEPA 2014a)
				PEF	Particulate Emission Factor	m^3/kg	1.36E+09	n/a	n/a	Default outdoor worker PEF (USEPA 2002)
				EF_w	Exposure Frequency	days/year	20	n/a	n/a	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	years	1	n/a	n/a	Exposure duration for a construction worker (USEPA 2002)
				AT_{NCw}	Averaging Time (noncancer)	days	28	n/a	n/a	7 days/week for 4 weeks
				AT_C	Averaging Time (cancer)	days	25,550	n/a	n/a	Lifetime (70 years) x 365 days/year (USEPA 1989a)
			External Exposure	EF_w	Exposure Frequency	days/year	20	n/a	n/a	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	years	1	n/a	n/a	Exposure duration for a construction worker (USEPA 2002)
				ACF	Site Area for Area Correction Factor	acres	0.5	n/a	n/a	USEPA 2021
				GSF	Clean Soil Thickness for Gamma Shielding Factor	cm	0.0	n/a	n/a	USEPA 2021
				ET_o	Exposure Time - Outdoor	unitless	8	n/a	n/a	Worker soil exposure time (USEPA 2014a)

TABLE 5-2 - Exposure Assumptions Used in the Human Health Risk Assessment
Watts Bar Fossil Plant

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
Fish	Recreational User - Consumer of Locally-Caught Sport Fish	Adult/ Adolescent/ Child	Ingestion	CF	Conversion Factor	kg/mg	1E-06	1E-06	1E-06	n/a
				EF_{fish}	Exposure Frequency	days/year	350	350	350	Default exposure frequency for residents (USEPA 2014a)
				IR_{fish}	Fish intake rate	g-ww/day	32.7	12.8	8.7	Adult fish intake rates equal to 95th percentile fish consumption rates for inland south region (Table 9a, USEPA 2014b). Adolescent and child fish intake rates are age-adjusted 95th percentile fish consumption rates for 6 to <16 years old and 1 to <6 years old, respectively (Table 20a, USEPA 2014b).
				ED_{fish}	Exposure Duration	years	10	10	6	Total exposure duration is equal to the default exposure duration for a resident (26 years; USEPA 2014a). Child and adolescent are receptors living adjacent to the river from 0 to <6 years old and 6 to <16 years old, respectively (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26 years) minus the adolescent duration (10 years) and the child duration (6 years).
				BW_{fish}	Body Weight	kg	80	44.3	15	Adult and child body weight equal to the adult and child resident (USEPA 2014a). Adolescent body weight is equal to the weighted average of mean body weights for 6 to <16 years (Table 8-1, USEPA 2011).
				AT_{NCfish}	Averaging Time (noncancer)	days	3,650	3,650	2,190	EDadult/adol/child x 365 days/year (USEPA 1989a)
				AT_C	Averaging Time (cancer)	days	25,550	25,550	25,550	Lifetime (70 years) x 365 days/year (USEPA 1989a)

Notes:

cm	centimeters
cm^2	square centimeters
g-ww/day	grams wet weight per day
kg	kilograms
kg/mg	kilograms per milligram
m^3/day	cubic meters per day
m^3/kg	cubic meters per kilogram
mg/cm^2	milligrams per square centimeters
mg/cm^2-event	milligrams per square centimeters per event
mg/day	milligrams per day
mg/µg	milligrams per microgram
n/a	not applicable

TABLE 5-3 - Toxicity Values Used in the Human Health Risk Assessment
Watts Bar Fossil Plant

COPC	Cancer Slope Factor				IUR		Chronic RfD				Subchronic RfD [a]				Subchronic Inhalation		ABS_{GI} [c]	Target Organ/System Effect [d]
	Oral		Dermal [b]				Oral		Dermal [b]		Oral		Dermal [b]		RfC [a]			
	$(mg/kg\text{-}day)^{-1}$		$(mg/kg\text{-}day)^{-1}$		$(\mu g/m^3)^{-1}$		mg/kg-day		mg/kg-day		mg/kg-day		mg/kg-day		mg/m^3		%	
Arsenic	1.5E+00	I	1.5E+00	R	4.3E-03	I	3.0E-04	I	3.0E-04	R	3.0E-04	cr	3.0E-04	R	1.5E-05	cr	100%	Skin, Blood, Developmental, Neurological, Respiratory
Cadmium (diet)	-	-	-	-	1.8E-03	I	1.0E-04	A	2.5E-06	R	5.0E-04	A	1.3E-05	R	1.0E-05	A	2.5%	Chronic: Urinary / Renal; Subchronic: Musculoskeletal, Urinary / Renal
Cobalt	-	-	-	-	9.0E-03	P	3.0E-04	P	3.0E-04	R	3.0E-03	P	3.0E-03	R	2.0E-05	P	100%	Thyroid, Respiratory
Copper	-	-	-	-	-	-	4.0E-02	H	4.0E-02	R	4.0E-02	cr	4.0E-02	R	-	-	100%	Gastrointestinal
Mercury [e]	-	-	-	-	-	-	3.0E-04	I	2.1E-05	R	3.0E-04	cr	2.1E-05	R	3.0E-04	H	7%	Immune, Urinary, Neurological
Methyl Mercury	-	-	-	-	-	-	1.0E-04	I	-	-	-	-	-	-	-	-	100%	Neurological
Radium-226 [f]	n/a		n/a		n/a		n/a		n/a		n/a		n/a		n/a		n/a	n/a
Thallium	-	-	-	-	-	-	1.0E-05	X	1.0E-05	R	4.0E-05	X	4.0E-05	R	-	-	100%	Skin
Vanadium	-	-	-	-	-	-	5.0E-03	G	1.3E-04	R	1.0E-02	A	2.6E-04	R	1.0E-04	A	2.6%	Chronic: Skin, Respiratory; Subchronic: Blood, Respiratory

Notes:

-	not available	mg/m^3	milligrams per cubic meter
%	percent	$\mu g/m^3$	micrograms per cubic meter
ABS_{GI}	oral absorption efficiency	n/a	not applicable
COPC	constituent of potential concern	PRG	preliminary remediation goal
CSF	cancer slope factor	RfD	reference dose
USEPA	United States Environmental Protection Agency	RfC	reference concentration
IUR	inhalation unit risk	RSL	Regional Screening Levels
mg/kg-day	milligrams per kilogram per day		

Sources Key: A = Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels; C = California Environmental Protection Agency (CalEPA) Toxicity Values; cr = chronic value; G = RSL User's Guide; H = Health Effects Assessment Summary Tables (HEAST); I = Integrated Risk Information System (IRIS) Database; P = Provisional Peer Reviewed Toxicity Values (PPRTVs); R = route extrapolation; X = Screening values in chemical-specific PPRTV Appendices. All sources and toxicity values as cited in the USEPA RSL Tables (USEPA 2024).

[a] Subchronic RfDs and RfCs obtained from USEPA's RSL Tables (USEPA 2024) were used unless otherwise noted in text.

[b] The following equations are used as recommended by the USEPA (2004) to estimate dermal CSFs and RfDs from the ingestion toxicity values when ABS_{GI} is less than 50 percent:

Dermal RfD = Oral RfD x ABS_{GI} and Dermal CSF = Oral CSF/ABS_{GI}.

When ABS_{GI} is greater than 50 percent, the dermal CSF and/or RfD is assumed to be equal to the oral CSF and/or RfD (USEPA 2004).

[c] Values are from USEPA Risk Assessment Guidance for Superfund (RAGS) Part E. Where no specific ABS_{GI} is available, the ABS_{GI} is assumed to be 100 percent (USEPA 2004).

[d] Target organs are for noncancer effects and based on data from the online Risk Assessment Information System (RAIS) chemical toxicity metadata accessed in June 2024 (RAIS 2024b). Where the source of an inhalation RfC or oral RfD is CalEPA, target organs are also based on information from the California Office of Environmental Health Hazard Assessment (OEHHA) chemical database metadata accessed in June 2024 (OEHHA 2024).

[e] Mercuric chloride used as a surrogate

[f] Radionuclides are evaluated using PRGs calculated using the USEPA PRG Calculator for Radionuclides (USEPA 2021; see Appendix D.3). Default slope factors from the calculator were used in the PRG calculations.

TABLE 5-4 - Summary of Human Health Risk Estimates for Chemical COPCs
Watts Bar Fossil Plant

Receptor/Media/Exposure Unit [a]	Cumulative ILCR	Risk Driver [b]	HI	Hazard Driver [b]
Onsite Worker				
CCR Material				
Ash Pond	6E-07	n/a	**2** [d]	n/a
Slag Disposal Area	4E-07	n/a	1	n/a
Recreational User - Consumer of Locally-Caught Sport Fish [c]				
Fish				
Adjacent Tennessee River	3E-06	n/a	**2** [d]	Mercury
State of Tennessee Acceptable Cancer Risk and Noncancer Threshold:	1E-05		1	

Notes:

CCR	coal combustion residuals
COPC	constituent of potential concern
HI	hazard index
ILCR	incremental lifetime cancer risk
n/a	not applicable

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk or noncancer threshold.

[a] Only those media where COPCs were selected and the applicable receptors for those media are presented herein.

[b] "Risk drivers" are those COPCs with an ILCR that is greater than the State of Tennessee acceptable cancer risk of 1E-05. "Hazard drivers" are those constituents with a target organ HI that is greater than the noncancer threshold of 1.

[c] For recreational users, ILCRs are estimated for an age-adjusted composite adult, child, and adolescent and HIs are estimated for the most sensitive receptor (i.e., a child); see Section 5.1.4.

[d] The HI presented herein is equal to the maximum target organ HI because the HI for all COPCs is greater than 1 (see Tables 5-6 and 5-7).

TABLE 5-5 - Summary of Human Health Risk Estimates for Radionuclide COPCs Watts Bar Fossil Plant

Exposure Scenario/Exposure Unit	Cumulative ILCR	Risk Driver [a]
	unitless	
Onsite Worker Exposed to CCR Material		
Slag Disposal Area	5E-07	n/a
State of Tennessee Acceptable Cancer Risk:	1E-05	

Notes:

CCR	coal combustion residuals
COPC	constituent of potential concern
ILCR	incremental lifetime cancer risk
n/a	not applicable

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk.

[a] "Risk drivers" are those COPCs with an ILCR that exceeds the State of Tennessee acceptable cancer risk of $1x10^{-5}$.

TABLE 5-6 - Summary of Risk Estimates for Onsite Workers Exposed to Chemical COPCs in CCR Material
Watts Bar Fossil Plant

Medium/CCR Unit/COPC	EPC[a]	Onsite Worker		
		ILCR	Hazard Quotient	Target Organ for Subchronic Exposure
	mg/kg	unitless	unitless	
CCR Material				
Ash Pond				
Arsenic	1.81E+02	6.1E-07	1.2	Skin, Blood, Developmental, Neurological, Respiratory
Cobalt	1.59E+01	2.7E-11	0.016	Thyroid, Respiratory
Thallium	6.62E+00	n/a	0.49	Skin
Vanadium	9.11E+01	n/a	0.027	Skin, Respiratory
	Cumulative ILCR/HI:	6E-07	**2**	
	Maximum TO HI [b]:	n/a	**2**	
Slag Disposal Area				
Arsenic	1.20E+02	4.0E-07	0.82	Skin, Blood, Developmental, Neurological, Respiratory
Cadmium	2.24E+00	7.7E-13	0.015	Urinary / Renal
Cobalt	1.42E+01	2.5E-11	0.014	Thyroid, Respiratory
Thallium	5.75E+00	n/a	0.42	Skin
Vanadium	1.08E+02	n/a	0.032	Skin, Respiratory
	Cumulative ILCR/HI:	4E-07	1	
State of Tennessee Acceptable Cancer Risk and Noncancer Threshold:		1E-05	1	

Notes:

%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
EPC	exposure point concentration
HI	hazard index
ILCR	incremental lifetime cancer risk
mg/kg	milligrams per kilogram
n/a	not applicable
TO	target organ
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk or noncancer threshold.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

[b] Maximum target organ HIs are shown only when the HI for all COPCs is greater than 1. A target organ HI is the sum of the hazard quotients for COPCs that affect the same target organ.

TABLE 5-7 - Summary of Risk Estimates for a Recreational User - Consumer of Locally-Caught Sport Fish Exposed to Chemical COPCs in Fish Tissue
Watts Bar Fossil Plant

		Recreational User - Consumer of Locally-Caught Sport Fish		
	EPC [a]		Hazard	Target Organ
Surface Stream/COPC	Fish Filet	ILCR [b]	Quotient [c]	for Chronic Exposure
	mg/kg-ww	unitless	unitless	
Adjacent Tennessee River				
Arsenic	1.60E-01	3.4E-06	0.030	Skin, Blood, Developmental, Neurological, Respiratory
Mercury	2.80E-01	n/a	**1.6**	Neurological
	Cumulative ILCR/HI:	3E-06	**2**	
	Maximum TO HI [d]:	n/a	**2**	
State of Tennessee Acceptable Cancer Risk and Noncancer Hazard:		1E-05	1	

Notes:

%	percent
COPC	constituent of potential concern
EPC	exposure point concentration
HI	hazard index
HQ	hazard quotient
ILCR	incremental lifetime cancer risk
mg/kg-ww	milligrams per kilogram wet weight
n/a	not applicable
TO	target organ
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk or noncancer threshold.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

[b] ILCRs are estimated for an age-adjusted composite adult, child, and adolescent, as described in Section 5.1.4.

[c] HQs and HIs are estimated for the most sensitive recreational receptor (i.e., a child), as described in Section 5.1.4.

[d] Maximum target organ HIs are shown only when the HI for all COPCs is greater than 1. A target organ HI is the sum of the hazard quotients for COPCs that affect the same target organ.

TABLE 6-1 – COPECs Identified for the ERA
Watts Bar Fossil Plant

CCR Parameter	Surface Stream Water CCR Parameter > Screening Levels [a] Tennessee River	Sediment CCR Parameter > Screening Levels [a] Tennessee River	CCR Parameter Identified as COPEC by Location [b] Tennessee River
Antimony			○
Arsenic			○
Barium			○
Beryllium			○
Boron			○
Cadmium			○
Calcium			--
Chloride			○
Chromium			○
Cobalt			○
Copper			○
Fluoride			--
Lead			○
Lithium			○
Mercury			○
Molybdenum			○
Nickel			○
Radium-226			○
Radium-228			○
Selenium			○
Silver			○
Sulfate			--
Thallium			○
Vanadium			○
Zinc			○

TABLE 6-1 – COPECs Identified for the ERA
Watts Bar Fossil Plant

CCR Parameter	Surface Stream Water CCR Parameter > Screening Levels [a] Tennessee River	Sediment CCR Parameter > Screening Levels [a] Tennessee River	CCR Parameter Identified as COPEC by Location [b] Tennessee River

Notes:

	not detected or was detected below respective screening levels
	without a screening level
--	detected but not selected as a COPEC because it is naturally occurring and has a low risk potential (refer to Section 6.1.1.2)
○	not identified as a COPEC (refer to Section 6.1.1.2)
CCR	coal combustion residuals
COPEC	constituent of potential ecological concern
ERA	ecological risk assessment

[a] A CCR Parameter detected in surface stream water (i.e., dissolved fraction for hardness-dependent parameters; dissolved or total fraction for other CCR Parameters) and/or sediment above its respective chronic screening levels.

[b] If a CCR Parameter is detected above surface stream water and/or sediment chronic screening levels, then it is identified as a COPEC for evaluation at that surface stream location. If a CCR Parameter is detected but no respective screening levels are available, concentrations evaluated on a parameter-specific basis.

Table 6-2 – Selected Ecological Receptors for the ERA
Watts Bar Fossil Plant

	Receptor Group	Receptor Type	Basis	Surrogate Receptors	Assessment Endpoint
Freshwater Aquatic Life	Benthic Invertebrate	Epifauna	Benthic invertebrates in the Tennessee River could be directly exposed to CCR Parameters in impacted media.	Benthic invertebrate communities	Protect the abundance and diversity of benthic invertebrates in the Tennessee River by limiting acute and chronic effects from site-related exposure.
		Infauna			
	Primary Producer	Phytoplankton	Aquatic/riparian plants in the Tennessee River could be directly exposed to CCR Parameters in impacted media.	Aquatic plant communities	Protect the abundance and diversity of aquatic plants in the Tennessee River by limiting acute and chronic effects from site-related exposure.
		Periphyton			
		Macrophyte			
	Fish	Benthivorous	Fish in the Tennessee River could be directly exposed to CCR Parameters in impacted media and indirectly via the food web.	Fish communities	Protect the abundance and diversity of fish in the Tennessee River by limiting acute and chronic effects from site-related exposure.
		Planktivorous			
		Piscivorous			
	Amphibian	Omnivorous	Amphibians utilizing the Tennessee River could be directly exposed to CCR Parameters in impacted media and indirectly via the food web.	Amphibian communities	Protect the abundance and diversity of amphibians utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.
	Reptile	Omnivorous	Reptiles utilizing the Tennessee River could be directly exposed to CCR Parameters in impacted media and indirectly via the food web.	Reptile communities	Protect the abundance and diversity of reptiles utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.
	Aquatic and Riparian-Feeding Birds	Herbivorous	Herbivorous birds utilizing the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Wood duck	Protect populations of herbivorous birds utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.
		Omnivorous	Omnivorous birds utilizing the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Mallard duck	Protect populations of omnivorous birds utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.
		Insectivorous	Insectivorous birds utilizing the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Killdeer	Protect populations of insectivorous birds utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.
		Piscivorous	Piscivorous birds utilizing the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Great blue heron/Osprey	Protect populations of piscivorous birds utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.

Table 6-2 – Selected Ecological Receptors for the ERA
Watts Bar Fossil Plant

Receptor Group	Receptor Type	Basis	Surrogate Receptors	Assessment Endpoint
Aquatic and Riparian-Feeding Mammals	Herbivorous	Herbivorous mammals utilizing the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Muskrat	Protect populations of herbivorous mammals utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.
	Omnivorous	Omnivorous mammals utilizing the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Raccoon	Protect populations of omnivorous mammals utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.
	Piscivorous	Piscivorous mammals utilizing the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Mink	Protect populations of piscivorous mammals utilizing the Tennessee River by limiting acute and chronic effects from site-related exposure.
Aerial-feeding Birds and Mammals	Insectivorous	Aerial-feeding insectivorous birds feeding over the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Tree swallow	Protect populations of aerial-feeding insectivorous birds feeding over the Tennessee River by limiting acute and chronic effects from site-related exposure.
	Insectivorous	Aerial-feeding insectivorous mammals feeding over the Tennessee River could be exposed to CCR Parameters in impacted media and indirectly via the food web.	Gray bat	Protect populations of aerial-feeding insectivorous mammals feeding over the Tennessee River by limiting acute and chronic effects from site-related exposure.

Notes:

CCR	coal combustion residuals
ERA	ecological risk assessment

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Watts Bar Fossil Plant

Receptor Group		Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Freshwater Aquatic Life	Benthic Invertebrate Communities	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for benthic invertebrate communities. Also, once the geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, benthic invertebrate communities are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, benthic invertebrate communities are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, benthic invertebrate communities are not exposed to seep water.
		Surface stream water	Direct contact	Negligible	Benthic invertebrates could be exposed to CCR Parameters in surface stream water through direct contact, ingestion of surface water and ingestion of algae and bacteria within surface water. However, exposure is expected to be negligible because no COPECs were identified.
			Ingestion	Negligible	
			Food chain uptake	Negligible	
		Sediment	Direct contact	Negligible	Benthic invertebrates live in sediments for most of their lifespan. Therefore, benthic invertebrates could be exposed to CCR Parameters in sediment through direct contact, incidental ingestion of sediment, and ingestion of algae and bacteria within sediment. However, exposure is expected to be negligible because no COPECs were identified.
			Incidental ingestion	Negligible	
			Food chain uptake	Negligible	
		Groundwater and Springs	Direct contact and ingestion	No	Benthic invertebrate communities are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
	Aquatic Plant Communities	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for aquatic plant communities. Also, once the geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, aquatic plant communities are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, aquatic plant communities are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, aquatic plant communities are not exposed to seep water.
		Surface stream water	Direct contact	Negligible	Aquatic plant communities could be exposed to CCR Parameters in surface water via root uptake. However, exposure is expected to be negligible because no COPECs were identified. Ingestion and food chain uptakes are not applicable to plants.
			Ingestion	No	
			Food chain uptake	No	
		Sediment	Direct contact	Negligible	Many aquatic plants live in or are associated with sediments for most of their lifespan. Therefore, aquatic plant communities could be exposed to CCR Parameters in sediment via direct contact with sediment. However, exposure is expected to be negligible because no COPECs were identified. Ingestion and food chain uptakes are not applicable to plants.
			Incidental ingestion	No	
			Food chain uptake	No	
		Groundwater and Springs	Direct contact and ingestion	No	Aquatic plant communities are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
	Fish Communities	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for fish. Also, once the geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, fish are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, fish are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, fish are not exposed to seep water.

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Watts Bar Fossil Plant

Receptor Group		Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Freshwater Aquatic Life	Fish Communities	Surface stream water	Direct contact	Negligible	Surface water provides habitat for fish communities. Therefore, fish could be exposed to CCR Parameters in surface water through direct contact, ingestion of surface stream water, and ingestion of plants or invertebrates exposed to surface stream water. However, exposure is expected to be negligible because no COPECs were identified.
			Ingestion	Negligible	
			Food chain uptake	Negligible	
		Sediment	Direct contact	Negligible	Sediment provides habitat for fish communities. Therefore, fish could be exposed to CCR Parameters in sediment through direct contact, incidental ingestion of sediment, and ingestion of plants or invertebrates exposed to sediment. However, exposure is expected to be negligible because no COPECs were identified.
			Incidental ingestion	Negligible	
			Food chain uptake	Negligible	
		Groundwater and Springs	Direct contact and ingestion	No	Fish are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
Amphibians		CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for amphibians. Also, once the geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, amphibians are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, amphibians are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, amphibians are not exposed to seep water.
		Surface stream water	Direct contact	Negligible	Amphibians could be exposed to CCR Parameters in surface water through direct contact, ingestion of surface stream water, and ingestion of food items exposed to surface stream water. However, exposure is expected to be negligible because no COPECs were identified.
			Ingestion	Negligible	
			Food chain uptake	Negligible	
		Sediment	Direct contact	Negligible	Amphibians could be exposed to CCR Parameters in sediment through direct contact, incidental ingestion of sediment, and ingestion of plants or invertebrates exposed to sediment. However, exposure is expected to be negligible because no COPECs were identified.
			Incidental ingestion	Negligible	
			Food chain uptake	Negligible	
		Groundwater and Springs	Direct contact and ingestion	No	Amphibians are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
Reptiles		CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for reptiles. Also, once the geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, reptiles are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, reptiles are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, reptiles are not exposed to seep water.

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Watts Bar Fossil Plant

Receptor Group	Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Reptiles	Surface stream water	Direct contact	Negligible	Exposure via direct contact with surface stream water is assumed to be a minor exposure pathway for reptiles relative to ingestion of surface stream water and ingestion of food items exposed to surface stream water. In addition, exposure is expected to be negligible because no COPECs were identified.
		Ingestion	Negligible	Reptiles could be exposed to CCR Parameters in surface stream water through ingestion of surface stream water. However, exposure is expected to be negligible because no COPECs were identified.
		Food chain uptake	Negligible	Reptiles could be exposed to CCR Parameters in surface stream water through ingestion of food items exposed to surface water. However, exposure is expected to be negligible because no COPECs were identified.
	Sediment	Direct contact	Negligible	Exposure via direct contact with sediment is assumed to be a minor exposure pathway for reptiles relative to ingestion of sediment and ingestion of foods items exposed to sediment. In addition, exposure is expected to be negligible because no COPECs were identified.
		Incidental ingestion	Negligible	Reptiles could be exposed to CCR Parameters in sediment through incidental ingestion of sediment. However, exposure is expected to be negligible because no COPECs were identified.
		Food chain uptake	Negligible	The diets of reptiles include a proportion of benthic invertebrates and aquatic plants. As such, they could be exposed to CCR Parameters in sediment through food chain uptake. However, exposure is expected to be negligible because no COPECs were identified.
	Groundwater and Springs	Direct contact and ingestion	No	Reptiles are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
Mammals	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for mammals. Also, once the geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, mammals are not exposed to CCR material.
	Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, mammals are not exposed to seep soil.
	Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, mammals are not exposed to seep water.
	Surface stream water	Direct contact	Negligible (No for aerial-feeding mammals)	Exposure to CCR Parameters in surface stream water via direct contact with surface stream water is assumed to be a minor exposure pathway for mammals relative to ingestion of water and ingestion of food items (e.g., fish) from the aquatic environment. In addition, exposure is expected to be negligible because no COPECs were identified. Aerial-feeding mammals are not expected to be dermally exposed to surface water.
		Ingestion	Negligible	Mammals could be exposed to CCR Parameters in surface stream water through ingestion of surface stream water. However, exposure is expected to be negligible because no COPECs were identified.
		Food chain uptake	Negligible	Mammals could be exposed to CCR Parameters in surface stream water through ingestion of food items exposed to surface water. However, exposure is expected to be negligible because no COPECs were identified.

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Watts Bar Fossil Plant

Receptor Group	Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Mammals	Sediment	Direct contact	Negligible (No for aerial-feeding mammals)	Exposure to CCR Parameters in sediment via direct contact with sediment is assumed to be a minor exposure pathway for mammals relative to incidental ingestion of sediment and ingestion of food items (e.g., fish) exposed to sediment. In addition, exposure is expected to be negligible because no COPECs were identified. Aerial-feeding mammals are not expected to be dermally exposed to sediment.
		Incidental ingestion	Negligible (No for aerial-feeding mammals)	Mammals could be exposed to CCR Parameters in sediment through incidental ingestion of sediment. Activities such as grooming and constructing dens (e.g., muskrat) could also result in incidental sediment ingestion. However, exposure is expected to be negligible because no COPECs were identified. Aerial-feeding mammals are not expected to ingest sediment.
		Food chain uptake	Negligible	The diets of some mammals include a proportion of benthic invertebrates and aquatic plants. As such, they could be exposed to CCR Parameters in sediment through food chain uptake. However, exposure is expected to be negligible because no COPECs were identified.
	Groundwater and Springs	Direct contact and ingestion	No	Mammals are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
Birds	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for birds. Also, once the geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, birds are not exposed to CCR material.
	Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, birds are not exposed to seep soil.
	Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the WBF Plant. Therefore, birds are not exposed to seep water.
	Surface stream water	Direct contact	Negligible (No for aerial-feeding birds)	Exposure to CCR Parameters in surface stream water through direct contact with surface stream water is assumed to be a minor exposure pathway for birds relative to ingestion of water and ingestion of food items (e.g., fish) exposed to surface stream water. In addition, exposure is expected to be negligible because no COPECs were identified. Aerial-feeding birds are not expected to be dermally exposed to surface stream water.
		Ingestion	Negligible	Birds could be exposed to CCR Parameters in surface stream water through ingestion of surface stream water. However, exposure is expected to be negligible because no COPECs were identified.
		Food chain uptake	Negligible	Birds could be exposed to CCR Parameters in surface stream water through ingestion of food items exposed to surface stream water. However, exposure is expected to be negligible because no COPECs were identified.

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Watts Bar Fossil Plant

Receptor Group	Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Birds	Sediment	Direct contact	Negligible (No for aerial-feeding birds)	Exposure to CCR Parameters in sediment through direct contact with sediment is assumed to be a minor exposure pathway for birds relative to ingestion of sediment and ingestion of foods items (e.g., fish) exposed to sediment. In addition, exposure is expected to be negligible because no COPECs were identified. Aerial-feeding birds are not expected to be dermally exposed to sediment.
		Incidental ingestion	Negligible (No for aerial-feeding birds)	Birds could be exposed through incidental ingestion of sediment. Activities such as grooming and constructing nests could also result in incidental sediment ingestion. However, exposure is expected to be negligible because no COPECs were identified. Aerial-feeding birds are not expected to ingest sediment.
		Food chain uptake	Negligible	The diets of some birds include a proportion of benthic invertebrates and aquatic plants. As such, they could be exposed to CCR Parameters in sediment through food chain uptake. However, exposure is expected to be negligible because no COPECs were identified.
	Groundwater and Springs	Direct contact and ingestion	No	Birds are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.

Notes:

Negligible	exposure pathway is potentially complete but contribution to exposure is negligible
No	exposure pathway is incomplete
Yes	exposure pathway is potentially complete
CCR	coal combustion residuals
COPEC	constituent of potential ecological concern

EXHIBITS

Exhibit No.
1-1

Title
WBF Plant Overview

Client/Project
Tennessee Valley Authority
Watts Bar Fossil (WBF) Plant TDEC Order

Project Location
Spring City, Tennessee

175668050
Prepared by MB on 2024-03-13
Technical Review by VC on 2024-03-13

0 400 800 1,200 1,600 Feet
1:4,800 (At original document size of 22x34)

Legend

- NPDES Outfalls (Historical)
- Limit of Existing Cover System (Approximate – 2023)
- CCR Unit Area (Approximate)
- Closed Metal Cleaning Pond (Approximate)
- Drainage Improvements Area; Stormwater Pond (Former Ash Pond) (Approximate)
- CCR Material Removed (Approximate)

CCR: Coal combustion residuals
NPDES: National Pollutant Discharge Elimination System

DRAFT

Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Provided by TVA (2023)



Stantec TVA

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Exhibit No.

4-1

Title

WBF Plant CCR Units

Client/Project

Tennessee Valley Authority
Watts Bar Fossil (WBF) Plant TDEC Order

Project Location

Spring City, Tennessee

175668050

Prepared by MB on 2024-03-13
Technical Review by VC on 2024-03-13

0 150 300 450 600 Feet

1:1,800 (At original document size of 22x34)

Legend

- Geotechnical Boring
- Geotechnical Boring with Vibrating Wire Piezometer
- Cone Penetration Test
- Limit of Existing Cover System (Approximate – 2023)
- CCR Unit Area (Approximate)
- Closed Metal Cleaning Pond (Approximate)
- Drainage Improvements Area; Stormwater Pond (Former Ash Pond) (Approximate)
- CCR Material Removed (Approximate)

CCR: Coal combustion residuals

DRAFT

Notes

1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Provided by TVA (2023)
3. Boring locations surveyed by Stantec on June 30, 2021.



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Exhibit No.

4-2

Title

Surface Stream, Sediment and Ecological Investigation Sample Locations and Reaches

Client/Project

Tennessee Valley Authority
Watts Bar Fossil (WBF) Plant TDEC Order

Project Location
Spring City, Tennessee

175668050
Prepared by KB on 2023-12-05

Legend

- Adjacent sediment sample
- Downstream sediment sample
- Adjacent surface water sample
- Downstream surface water sample
- Upstream benthic macroinvertebrate community sampling transect
- Adjacent benthic macroinvertebrate community sampling transect
- Downstream benthic macroinvertebrate community sampling transect
- Upstream Asiatic clam and fish tissue sampling reach
- Adjacent Asiatic clam and fish tissue sampling reach
- Downstream Asiatic clam and fish tissue sampling reach
- Samples east or south of these lines are upstream (Location is approximate)
- Samples west or north of this line are downstream (Location is approximate)
- 2018 Imagery Boundary
- CCR Unit Area (Approximate)

Imagery Provided by: Tuck Mapping (c. 2017); TVA (5/21/2021and 5/12/2022); Bing imagery ©2022 Microsoft Corporation ©2022 Maxar ©CNES (2022) Distribution Airbus DS

CCR: Coal combustion residuals

DRAFT

Stantec

TVA

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Exhibit No.

4-3

Title

Tennessee River - Adjacent and Downstream Sample Locations

Client/Project

Tennessee Valley Authority
Watts Bar Fossil (WBF) Plant TDEC Order

Project Location

Spring City, Tennessee

175668050

Prepared by DMB on 2024-03-13
Technical Review by VC on 2024-03-13

0 1,000 2,000 3,000 4,000 Feet

1:12,000 (At original document size of 22x34)

Legend

- Adjacent Sediment Sampling Location
- Adjacent Surface Stream Sampling Location
- Downstream Sediment Sampling Location
- Downstream Surface Stream Sampling Location
- Limit of Existing Cover System (Approximate – 2023)
- Asiatic Clam Sampling Locations — TRA – Tennessee River Adjacent; TRD – Tennessee River Downstream
- Fish Sampling Reaches — TRA - Tennessee River Adjacent; TRD - Tennessee River Downstream
- CCR Unit Area (Approximate)
- Closed Metal Cleaning Pond (Approximate)
- Drainage Improvements Area; Stormwater Pond (Former Ash Pond) (Approximate)
- CCR Material Removed (Approximate)

CCR: Coal combustion residuals

DRAFT

Notes

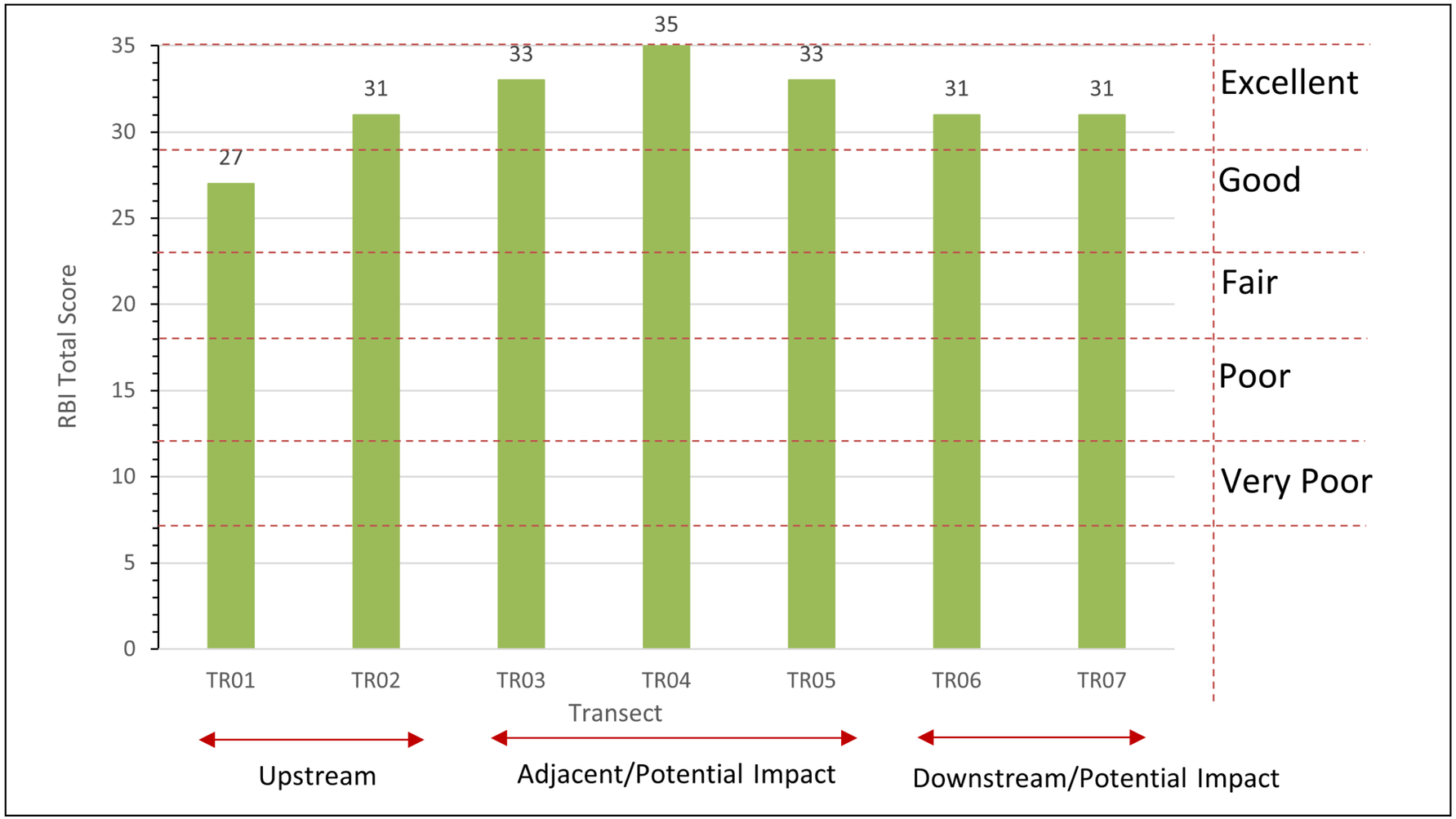
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Provided by TVA (2023) and Esri World Imagery
3. Clusters of sampling points are represented with one label.



Stantec TVA

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Exhibit No.

4-4

Title

Tennessee River 2019 Reservoir Benthic Index Results Summary

Client/Project 175668050

Tennessee Valley Authority
Watts Bar Fossil (WBF) Plant TDEC Order

Project Location

Spring City, Tennessee

Prepared by DMB on 2023-12-05
TR by VC on 2023-12-05
IR Review by RB on 2023-12-05

Notes

1. RBI - Reservoir Biotic Index
2. Red dashed lines represent categorical rating thresholds

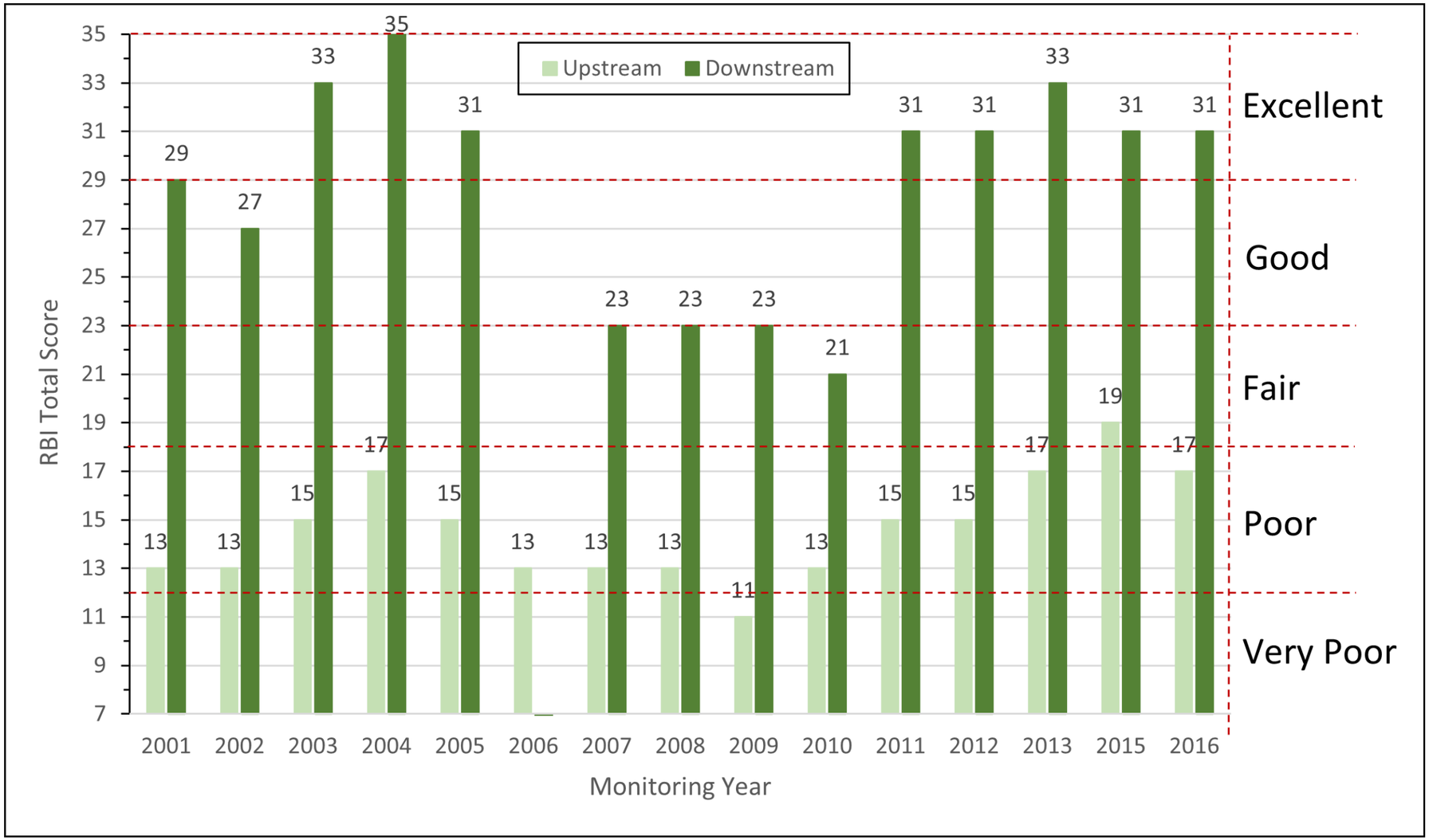


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DRAFT

Exhibit No.

4-5

Title

Tennessee River Historical Average Reservoir Benthic Index Results Summary

Client/Project 175668050

Tennessee Valley Authority
Watts Bar Fossil (WBF) Plant TDEC Order

Project Location
Spring City, Tennessee

Prepared by DMB on 2023-12-05
TR by VC on 2023-12-05
IR Review by RB on 2023-12-05

Notes

1. RBI - Reservoir Biotic Index
2. Red dashed lines represent categorical rating thresholds

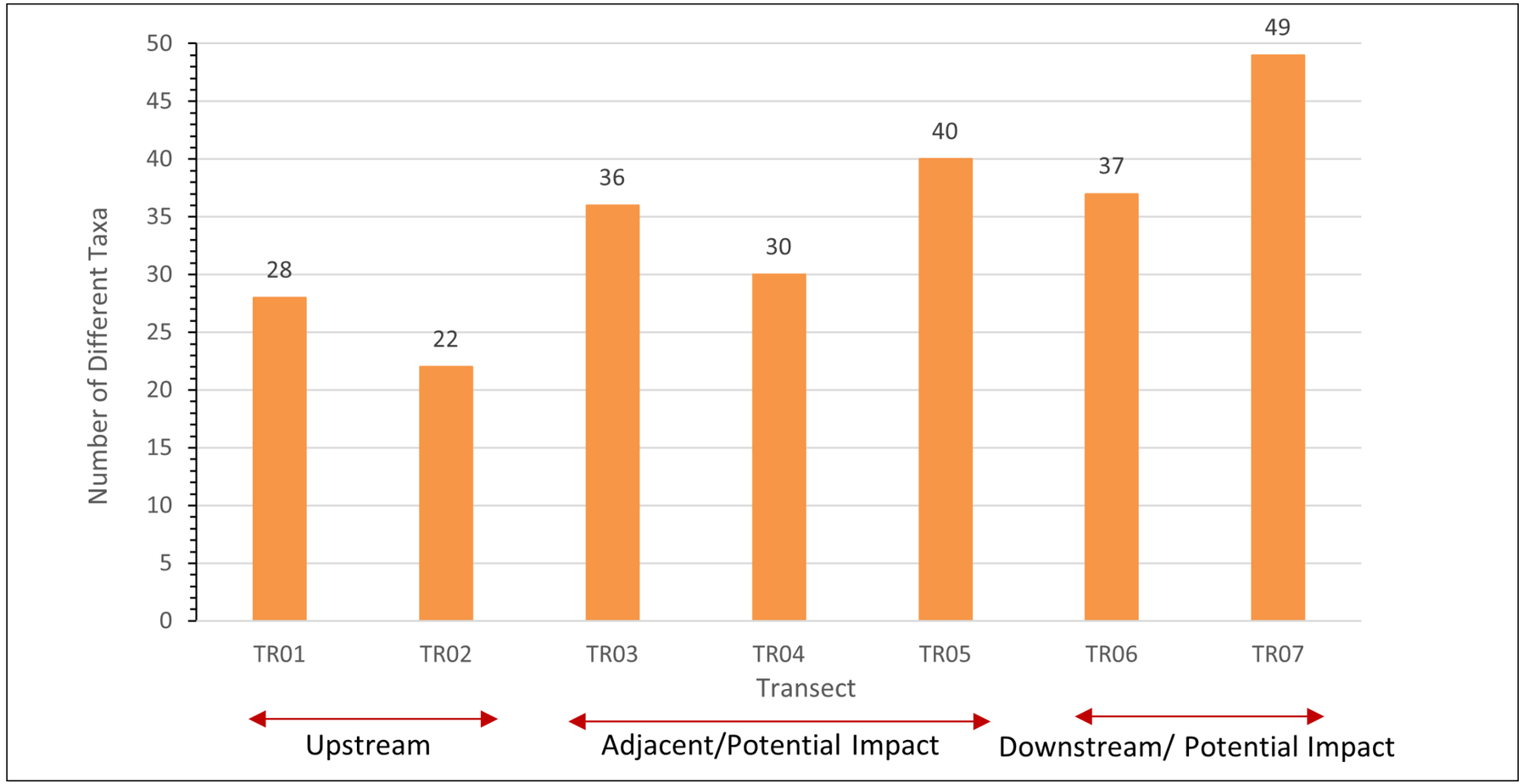


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TVA

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DRAFT

Exhibit No.

4-6

Title

Tennessee River Total Taxa Richness Results Summary 2019

Client/Project 175668050

Tennessee Valley Authority
Watts Bar Fossil (WBF) Plant TDEC Order

Project Location
Spring City, Tennessee

Prepared by DMB on 2023-12-05
TR by VC on 2023-12-05
IR Review by RB on 2023-12-05



Stantec

TVA

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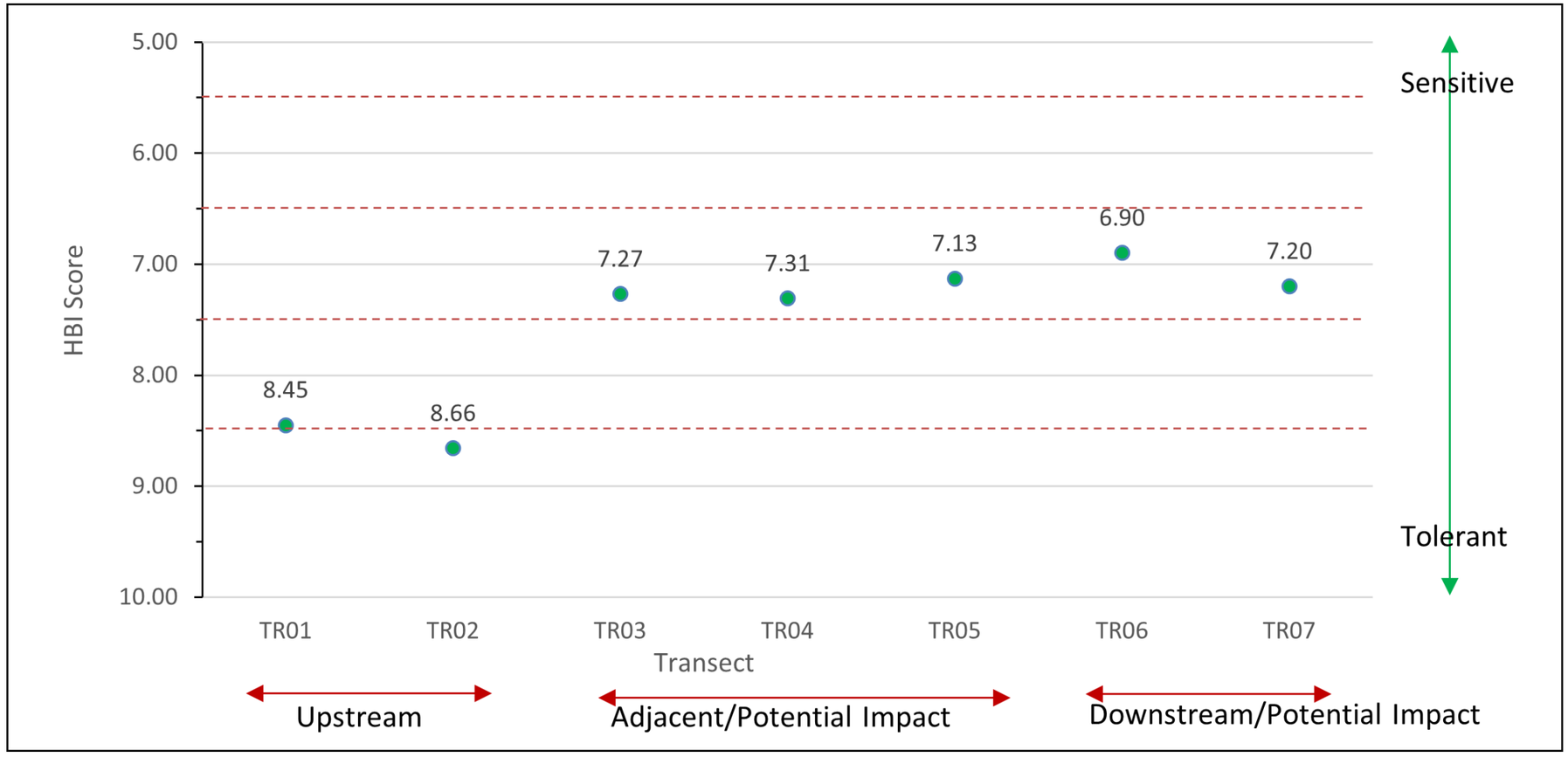


Exhibit No.
4-7

Title
Tennessee River Hilsenhoff Biotic Index Results Summary 2019

Client/Project 175668050
Tennessee Valley Authority
Watts Bar Fossil (WBF) Plant TDEC Order

Project Location
Spring City, Tennessee

Prepared by DMB on 2023-12-05
TR by VC on 2023-12-05
IR Review by RB on 2023-12-05

Notes
1. HBI - Hilsenhoff Biotic Index
2. Red dashed lines represent categorical rating thresholds; category labels are not provided because they are not descriptive for use in reservoir-associated systems such as the Tennessee River.

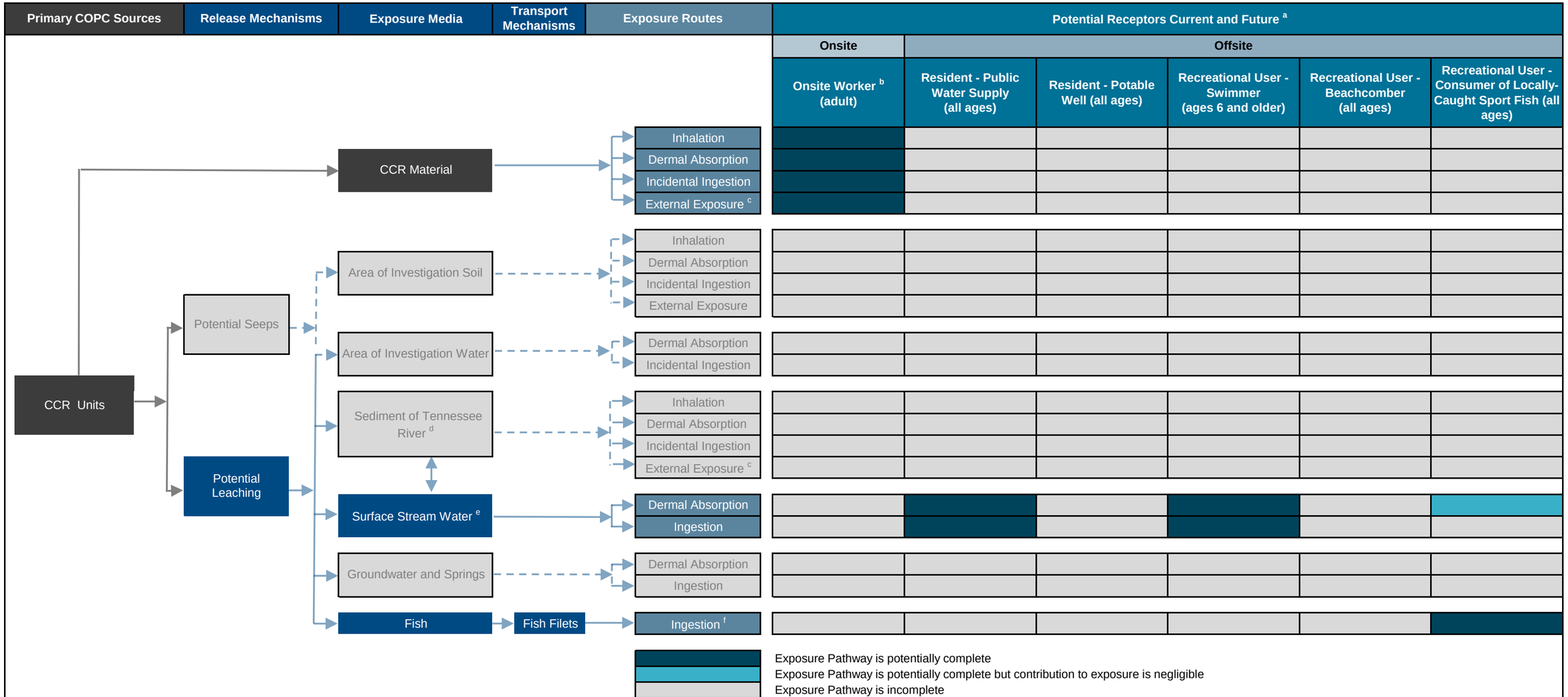


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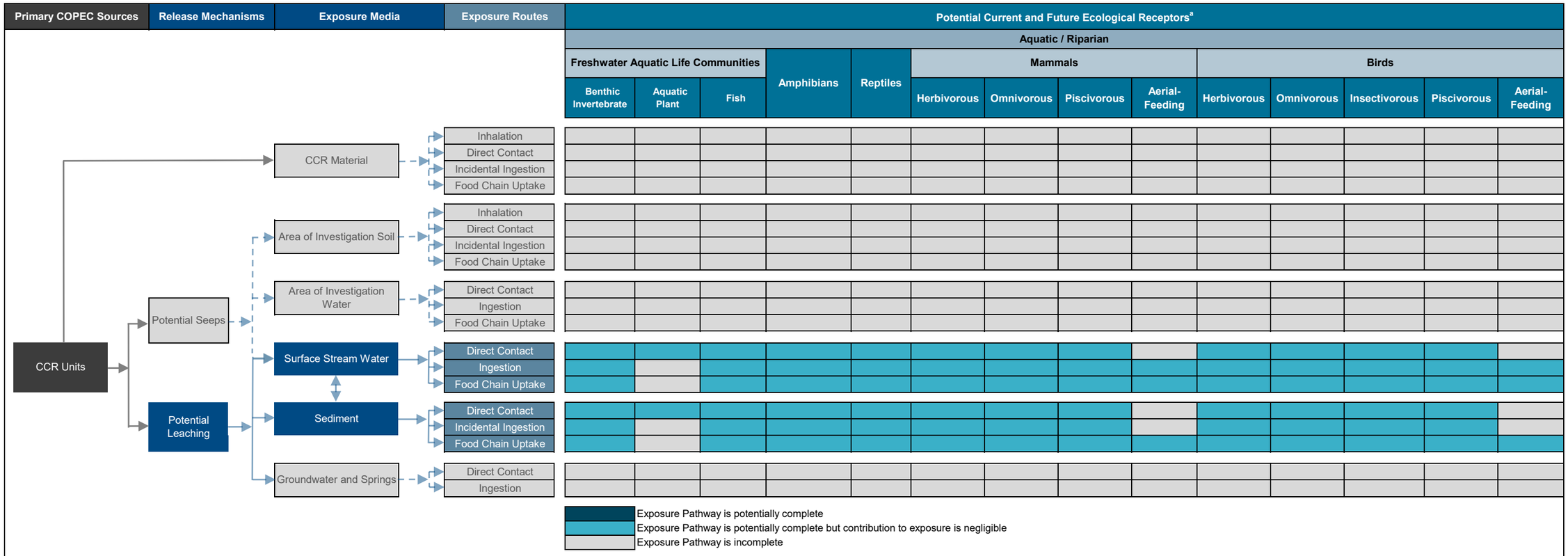
EXHIBIT 5-1
Human Health Risk Assessment Conceptual Site Model
Watts Bar Fossil Plant



Notes:
CCR - Coal combustion residuals
COPC - Constituent of potential concern
CSM - Conceptual site model

[a] The Watts Bar Fossil Plant is expected to continue industrial operations into the future. Rationale for why exposure pathways are incomplete or potentially complete are noted in Section 5.1.1 of the text.
[b] Onsite workers making minor repairs to the CCR units or on dikes that may include limited digging.
[c] External exposure to radiation emanating from radionuclides (radium) in CCR material and sediment.
[d] There is no sediment on the banks of the Tennessee River adjacent to the WBF Plant that is above water during low pool conditions. Submerged sediment is not a complete pathway of exposure for human receptors (USEPA 2018).
[e] Surface stream water in Tennessee River. Quantitative risk/hazard calculations were not performed for the Recreational User - Swimmer because no CCR Parameters were detected at concentrations above surface water screening levels for human health (surface water as domestic water supply).
[f] Consumption of locally-harvested aquatic and riparian biota (e.g., fish, crayfish) is represented by sport fish.

EXHIBIT 6-1
Ecological Risk Assessment Conceptual Site Model
Watts Bar Fossil Plant



Notes:
CCR coal combustion residuals
COPEC constituent of potential ecological concern

[a] Rationale for why exposure pathways are incomplete or potentially complete are noted in Table 6-3.

PHOTOGRAPHS

Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 1

Photo Location:
Ash Pond

Direction:
West

Survey Date:
11/21/2019

Comments:
Looking west at closed Ash Pond in foreground. Nuclear cooling towers in background.



Photograph ID: 2

Photo Location:
Tennessee River

Direction:
North

Survey Date:
11/21/2019

Comments:
Looking north along river bank near location of Ash Pond. Exposed sediment (sandy) at base of rip-rap. Boat ramp acts as a jetty with deposition downriver.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 3

Photo Location:
Tennessee River

Direction:
North

Survey Date:
11/21/2019

Comments:
At boat ramp looking north towards Watts Bar Dam. Note lack of sediment along shoreline.



Photograph ID: 4

Photo Location:
Outfall F02 / Outfall 010

Direction:
West

Survey Date:
11/21/2019

Comments:
Nuclear cooling water outfall structure looking west.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 5

Photo Location:
Former Coal Yard Storage Area

Direction:
South

Survey Date:
11/21/2019

Comments:
Former Coal Yard Storage Area and barren areas with exposed coal residuals.



Photograph ID: 6

Photo Location:
Tennessee River

Direction:
South

Survey Date:
11/21/2019

Comments:
Looking south from public boat ramp on eastern side of Tennessee River river across from Watts Bar Fossil (WBF) Plant.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 7

Photo Location:
Tennessee River

Direction:
North

Survey Date:
11/21/2019

Comments:
Looking north from public boat ramp at Watts Bar Dam.



Photograph ID: 8

Photo Location:
Tennessee River

Direction:
Northwest

Survey Date:
11/21/2019

Comments:
Looking northwest from public beach located upstream of Watts Bar Dam on eastern shore of Tennessee River.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 9

Photo Location:
Watts Bar Dam

Direction:
North

Survey Date:
11/21/2019

Comments:
Looking upstream towards Watts Bar Dam. Historical pier structures in the Tennessee River where coal barges docked and unloaded.



Photograph ID: 10

Photo Location:
Stormwater Pond (Former Ash Pond)

Direction:
Southwest

Survey Date:
11/21/2019

Comments:
Looking southwest at closed Stormwater Pond (Former Ash Pond) in foreground. Nuclear cooling towers in background.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 11

Photo Location:
Tennessee River

Direction:
Northeast

Survey Date:
11/21/2019

Comments:
Looking upstream from location adjacent to the Consolidated and Capped CCR unit. Note rip rap and exposed sediment along the shoreline.



Photograph ID: 12

Photo Location:
Tennessee River Shoreline

Direction:
West

Survey Date:
11/21/2019

Comments:
Standing on the shoreline in previous photo looking back up the slope towards access road between the River and the Consolidated and Capped CCR unit.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 13

Photo Location:
Watts Bar Dam

Direction:
North

Survey Date:
11/21/2019

Comments:
Railings associated with historical coal barge docking area looking upstream towards Watts Bar Dam. The shoreline is very steep in this location.



Photograph ID: 14

Photo Location:
Watts Bar Dam Hydro Electric Facility Entrance

Direction:
Northwest

Survey Date:
11/21/2019

Comments:
Entrance to the Watts Bar Dam Hydro electric facility upstream of the former Watts Bar Fossil Plant and Nuclear Plant.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 15

Photo Location:
Pond South of Former Coal Yard Storage Area

Direction:
Southwest

Survey Date:
11/21/2019

Comments:
Small surface water body south of the Former Coal Yard Storage Area. Looking southwest - field offices associated with the Watts Bar Fossil Plant in the background.



Photograph ID: 16

Photo Location:
TVA's Watts Bar Dam Reservation Park

Direction:
Northwest

Survey Date:
11/21/2019

Comments:
Looking northwest at TVA's Watts Bar Dam Reservation Park located upstream of the Watts Bar Dam.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 17

Photo Location:
Tennessee River

Direction:
Southwest

Survey Date:
11/21/2019

Comments:
Fish survey crew working in reservoir upstream of the Watts Bar Dam - structures in background. Photo taken from the public beach.



Photograph ID: 18

Photo Location:
Former Slag Disposal Area

Direction:
West

Survey Date:
11/21/2019

Comments:
Deer grazing on the former Slag Disposal Area on the morning of the site visit. Access road in foreground continues to perimeter road along the Tennessee River.



Stantec

Photographic Log

Client:	**Tennessee Valley Authority**	**Project:**	**TDEC Order**
Site Name:	**Watts Bar Fossil (WBF) Plant**	**Site Location:**	**Spring City, Tennessee**

Photograph ID: 19

Photo Location:
Watts Bar Nuclear Plant Cooling Towers

Direction:
Southwest

Survey Date:
11/21/2019

Comments:
Looking southwest from the access road next to the Slag Disposal Area towards the Watts Bar Nuclear Plant cooling towers.



Photograph ID: 20

Photo Location:
Tennessee River Shoreline

Direction:
Northeast

Survey Date:
11/21/2019

Comments:
View of shoreline looking northeast from access road - south end of Slag Disposal Area. Note monitoring well in the foreground and small fishing boat center right.



APPENDIX A – MULTIPLE LINES OF EVIDENCE FOR THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS FOR TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION ORDER PLANTS

DRAFT

Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants

October 22, 2021

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

MULTIPLE LINES OF EVIDENCE FOR THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS FOR TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION ORDER PLANTS

Revision Record

Revision	Description	Date
0	Submittal to TDEC	July 23, 2021
1	Addresses August 26, 2021 TDEC Review Comments and Issued for TDEC Review	September 24, 2021
2	Addresses October 12, 2021 TDEC Review Comments and Issued for TDEC Review	October 22, 2021



Sign-off Sheet

This document entitled Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants was prepared by Stantec Consulting Ltd. ("Stantec") for the account of Tennessee Valley Authority (TVA) (the "Client"). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____
Loren D. Knopper, Ph.D., Principal Environmental Health Scientist

Reviewed by _____
Tania G. Noble, M. Eng., Senior Principal Risk Assessment Specialist

Approved by _____
Deborah L. Gray, Ph.D., DABT, Principal Toxicologist

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Executive Summary

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to the Tennessee Valley Authority (TVA) for coal combustion residuals (CCR) compliance pursuant to the provisions of Tennessee's solid waste management and remediation laws. One of the purposes of the TDEC Order is to establish a transparent comprehensive process for the investigation, assessment, and remediation of unacceptable risks resulting from the management and disposal of CCR at seven coal-fired power plants subject to the TDEC Order (TDEC Order plants). Stantec Consulting Services Inc. (Stantec) will be preparing human health and ecological risk assessment (HHERA) reports for six of these TDEC Order plants.

The United States Environmental Protection Agency encourages the use of multiple lines of evidence (LOE) when conducting HHERAs such that a weight of evidence approach is used to characterize risk. The LOE to be used in the HHERA for the TDEC Order plants are quantitative and qualitative in nature. Quantitative LOE will include 1) comparing concentrations of CCR chemical constituents (referred to as Parameters) measured at the TDEC Order plants to medium-specific and receptor-specific human health/ecological screening levels and 2) calculating carcinogenic risk and non-cancer hazard index (for the human health assessment) and hazard quotients (for the ecological assessment). Qualitative LOE will include 1) the use of published information on CCR and CCR Parameters, 2) results of Environmental Investigations (EIs) conducted at each of the TDEC Order plants, and 3) findings from the environmental sampling, biological studies, and human health and ecological risk assessments conducted as part of the Kingston Recovery Project (KRP, also known as the Kingston Ash Recovery Project).

The information available from the KRP is especially useful because it is directly applicable to the TDEC Order plants (e.g., based on similar stressors, receptors, exposure pathways) and well documented. For example, the KRP was based on approximately 20,000 samples of air, water, sediment, CCR material, and biota resulting in more than 500,000 chemical analyses; toxicity testing of both water and sediments (including partial life-cycle tests); field and laboratory studies conducted by TVA staff, consultants, government research agencies, and universities; all of which culminated in approximately 50 papers published in peer-reviewed journals. As such, the KRP has influenced the scope of the EIs, the pathways and receptors to be considered in the TDEC Order HHERAs, and provides information that support a LOE evaluation. Indeed, findings and recommendations stemming from the HHERAs conducted as part of the KRP supported the decision to implement a monitored natural recovery program, which was confirmed through long term monitoring, and influenced the data collection activities for the TDEC Order plant EIs.

The objective of this report is to outline the multiple quantitative and qualitative LOE to be used in the HHERAs such that future CCR management decisions at the TDEC Order plants are informed by an assessment of risk based on the combined results of LOE rather than any single LOE alone.



Abbreviations

BERA	Baseline Ecological Risk Assessment
CCR	coal combustion residuals
CCR constituents	constituents serving to form, compose or make up the whole of CCR material
CCR Parameters	constituents listed In Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
COPC	constituents of potential concern
COPEC	constituents of potential ecological concern
EI	environmental investigation
EPA	United States Environmental Protection Agency
ERA	ecological risk assessment
HHERA	human health and ecological risk assessment
HHRA	human health risk assessment
HQ	hazard quotient
KIF	Kingston Fossil Plant
KRP	Kingston Recovery Project
LOE	lines of evidence
SLERA	screening level ecological risk assessment
SSL_{HH}	human health screening levels
TDEC	Tennessee Department of Environment and Conservation
TDEC Order	(TDEC) Commissioner's Order No. OGC15-0177
TDEC Order plants	TVA coal-fired power plants subject to the TDEC Order
TDH	Tennessee Department of Health
TVA	Tennessee Valley Authority

1.0 INTRODUCTION

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to the Tennessee Valley Authority (TVA) for coal combustion residuals (CCR) compliance pursuant to the provisions of Tennessee's solid waste management and remediation laws. The TDEC Order has two purposes. First, the TDEC Order is intended to establish a transparent comprehensive process for the investigation, assessment, and remediation of unacceptable risks resulting from the management and disposal of CCR at seven coal-fired power plants subject to the TDEC Order, namely the Allen Fossil Plant, Bull Run Fossil Plant, Cumberland Fossil Plant, John Sevier Fossil Plant, Johnsonville Fossil Plant, Kingston Fossil Plant, and Watts Bar Fossil Plant (collectively, the TDEC Order plants). Second, the TDEC Order is intended to establish the process whereby TDEC will oversee TVA's implementation of the 2015 United States Environmental Protection Agency Final CCR Rule to insure coordination and compliance with Tennessee laws and regulations that govern the management and disposal of CCR (TDEC 2015).

As stipulated in the TDEC Order, the Corrective Action/Risk Assessment Plan specifies the actions (i.e., corrective measures) TVA plans to take at each of the TDEC Order plants and the basis for those actions. In addition to other regulatory criteria, the need for, and extent of, corrective measures will be informed by whether the presence of CCR consitiutents in environmental media at the TDEC Order plants presents unacceptable risks to human health and the environment.

1.1 OBJECTIVE

Stantec Consulting Services Inc. (Stantec) will be preparing human health and ecological risk assessment (HHERA) reports for six of the TDEC Order plants (not for the Allen Fossil Plant). The objective of the HHERAs is to provide quantitative and qualitative statements of potential risks to human and ecological receptors from exposures to CCR Parameters in environmental media at the TDEC Order plants to inform future CCR management decisions. When conducting risk assessment, the United States Environmental Protection Agency (EPA) encourages the use of multiple lines of evidence (LOE) such that a weight of evidence approach can be used to characterize risk (e.g., EPA 2000a). In their guidance, EPA also makes clear that determining unacceptable risk should go beyond solely calculating numerical risk estimates and should include evidence and analysis demonstrating or refuting a causal link between stressor and response (e.g., EPA 1992, 1997, 1998, 1999 and 2000b). It is the combined results of these LOE rather than any single line of evidence that are used to determine if risk is present at a level that warrants further evaluation or consideration of remedial options.

Accordingly, the objective of this report is to outline the multiple LOE to be used in the HHERAs such that future CCR management decisions at the TDEC Order plants are informed by an assessment of risk based on the combined results of LOE rather than any single LOE alone.

1.2 QUANTITATIVE AND QUALITATIVE LINES OF EVIDENCE

The LOE to be used in the HHERA for the TDEC Order plants are both quantitative and qualitative in nature. Quantitative LOE will include 1) comparing concentrations of CCR Parameters measured at the TDEC Order plants to medium-specific and receptor-specific human health/ecological screening levels and 2) calculating carcinogenic risk and non-cancer hazard index (for the human health assessment) and hazard quotients (for the ecological assessment). Qualitative LOE will include 1) the use of published information on CCR and CCR Parameters, 2) results of Environmental Investigations (EIs) conducted at each of the TDEC Order plants, and 3) findings from the environmental sampling, biological studies, and human health and ecological risk assessments conducted as part of the Kingston Recovery Project (KRP, also known as the Kingston Ash Recovery Project).

In brief, the KRP took place after the 2008 structural failure at TVA's Kingston Fossil (KIF) Plant that resulted in the release of approximately 5.4 million cubic yards (cy) of sluiced ash (CCR material) into the adjacent Swan Pond Embayment with transport into the Emory, Clinch, and Tennessee River system. The information available from the KRP is especially useful because it is directly applicable to the TDEC Order plants (e.g., based on similar stressors, receptors, exposure pathways) and well documented. For example, the KRP was based on approximately 20,000 samples of air, water, sediment, CCR material, and biota resulting in more than 500,000 chemical analyses; toxicity testing of both water and sediments (including partial life-cycle tests); field and laboratory studies conducted by TVA staff, consultants, government research agencies, and universities; all of which culminated in approximately 50 papers published in peer-reviewed journals. As such, the KRP has influenced the scope of the EIs, the pathways and receptors to be considered in the TDEC Order HHERAs, and provides information that support a LOE evaluation. Indeed, findings and recommendations stemming from the HHERAs conducted as part of the KRP supported the decision to implement a monitored natural recovery program, which was confirmed through long term monitoring, and influenced the data collection activities for the TDEC Order plant EIs.

1.3 REPORT ORGANIZATION

This report is organized into the following sections:

- **Section 2 - Human Health and Ecological Risk Assessment for the TDEC Order Plants:** A summary of available TDEC Order Plant datasets and receptor-exposure pathway interactions
- **Section 3 - Lines of Evidence to Be Used in the Human Health and Ecological Risk Assessments:** A description of the quantitative and qualitative LOE to be used in the HHERAs for the TDEC Order plants
- **Section 4 - Conclusions:** A summary of the report
- **Section 5 - References:** Lists the reference documents cited in this report
- **Appendices:** Provides published information on primary CCR constituents



2.0 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT FOR THE TDEC ORDER PLANTS

2.1 DATASETS

Analytical results from the EIs conducted at the TDEC Order plants are the primary datasets for evaluating potential human and ecological exposures and risks. Quantitative estimates of exposures and risks will be based on the concentrations for the following CCR constituents listed in Appendices III and IV of the Federal CCR Rule, Title 40 of the Code of Federal Regulations Part 257 (40 CFR 257):

- Antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium (total), cobalt, fluoride, lead, lithium, mercury (inorganic), molybdenum, pH, radium 226 & 228, selenium, sulfate, thallium, and total dissolved solids

and five metals included in Appendix 1 of TN Rule 0400-11-01-04 that are not listed in 40 CFR 257:

- Copper, nickel, silver, vanadium, and zinc.

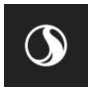
The term “CCR Parameters” is used for these specific constituents for the purpose of the EI and HHERA conducted under the TDEC Order.

As part of the EI, these CCR Parameters were analyzed in CCR material, soils from areas of interest (collected as part of seep investigations), surface stream water, sediment, mayfly tissue, and fish tissues. Onsite groundwater is not a source of potable water or other human contact uses for the TDEC Order plants; therefore, on-site groundwater data will not be used to estimate human exposure risks (with the possible exception of the Allen Fossil Plant in Memphis, Tennessee). Details of the investigations can be found in the Environmental Investigation Plans for each TDEC Order plant and can be found on-line at https://www.tva.com/environment/environmental-stewardship/tdec-order-on-coal-combustion-residuals.

While offsite groundwater data were not collected as part of the EI, domestic use of offsite groundwater is still a potentially complete exposure pathway. Domestic use includes, but is not limited to human consumption. Based on the outcome of water use surveys, samples of groundwater from private wells and springs that could act as a domestic source will be analyzed for CCR Parameters. Analytical results from private domestic sources may be supplemented with modeled data, which will be used as a line of evidence to assess the potential of CCR Parameter movement from onsite to offsite locations of domestic water use.

2.2 HUMAN HEALTH AND ECOLOGICAL RECEPTORS AND EXPOSURE PATHWAYS

The seven coal-fired power plants subject to the TDEC Order are similar in several ways. They were constructed during an approximately 20-year period between the early 1950s and mid-1970s. The environmental settings are similar across the fleet and all are located on large rivers that are sources of



public drinking water supplies and widely used for boating and water sports, fishing, and shoreline activities. CCR Parameters potentially released from the CCR management units could be transported to nearby surface streams and rivers where human and ecological exposure might occur.

Given the commonalities among the TDEC Order plants and their adjacent land uses, for the purposes of the HHRA, human receptors have been grouped as onsite and offsite receptors – people who may be present on or near the CCR management units, and people who may be present on surrounding properties or who use adjacent water bodies for recreation, respectively. Consistent with the approach taken in the KRP, these receptors will be grouped by their primary activities to assess risk, specifically:

- Onsite Workers – Workers who may have contact with CCR material, or CCR Parameters in seep soils and seep water while engaged in short-term excavation projects
- Offsite Residential Users of Surface Stream Water – Local residents whose drinking water is supplied by public drinking water utilities using surface streams downstream from these power plants as their source water
- Offsite Residential Users of Groundwater – Nearby residents who use private wells and springs for drinking water
- Offsite Recreational Users – Swimmers who may be in direct contact with CCR Parameters in surface stream water
- Offsite Recreational Users – Beachcombers who may be in direct contact with CCR Parameters in seasonally exposed sediment
- Offsite Recreational Users – Consumers who may be exposed to CCR Parameters through ingestion of locally-caught fish.

For the purposes of the ERA and consistent with the approach in the KRP, risks to the following groups of ecological receptors from exposure to CCR Parameters will be assessed:

- Benthic Invertebrate Communities – In contact with surface stream sediments and pore water
- Aquatic Plant Communities – In contact with surface stream sediments, pore water, and surface water
- Fish Communities – In contact with surface stream water and sediments (demersal fish only)
- Amphibians and Reptiles – In contact with surface stream water and bank sediments
- Aquatic and Riparian Mammals and Birds – In contact with surface stream water and bank sediments and consume benthic invertebrates, aquatic plants, and forage fish.

3.0 LINES OF EVIDENCE TO BE USED IN THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

As noted above, the EPA encourages the use of LOE in HHERA such that a weight of evidence approach can be used to characterize risk (e.g., EPA 2000a). The multiple LOE to be used in the HHERA for the TDEC Order plants are quantitative and qualitative in nature.

- Quantitative LOE will include 1) comparing concentrations of CCR Parameters measured at the TDEC Order plants to medium-specific and receptor-specific human health/ecological screening levels and 2) calculating carcinogenic risk and non-cancer hazard index (for the human health assessment) and hazard quotients (for the ecological assessment). Details of these LOE are provided in **Section 3.1.**

- Qualitative LOE will include 1) the use of published information on CCR and CCR Parameters, 2) findings from EIs conducted at each of the TDEC Order plants, and 3) findings from the environmental sampling, biological studies, and human health and ecological risk assessments conducted as part of the KRP. Details of these LOE are provided in **Section 3.2.**

A summary of the key studies conducted for the KRP, their major findings, the LOE used in those studies, and a discussion of the application of the findings and LOE to the TDEC Order HHERAs are provided in **Table 1**. The information available from the KRP is especially useful because it is directly applicable to the TDEC Order plants (e.g., based on similar stressors, receptors, exposure pathways) and well documented.

3.1 QUANTITATIVE LINES OF EVIDENCE

3.1.1 Screening Levels

3.1.1.1 Human Health Screening Levels

Concentrations of CCR Parameters measured in CCR material, soil, sediment and fish tissue will be compared to medium-specific and receptor-specific human health screening levels (SSL_{HH}). The methods used to derive SSL_{HH} for CCR material, soil, sediment and fish tissue are described in *Proposed Receptor-Specific Screening Levels for Human Health (SSL_{HH})* (Stantec 2021). Offsite surface stream water is also evaluated as a potential medium of concern for the HHRA because surface stream waters are used as sources of public drinking water supplies and for recreational activities (e.g., swimming). State of Tennessee and EPA water quality criteria and standards for domestic water supply are available and will be used to screen CCR Parameters in surface stream water used for both domestic water supply and human recreational activities (Stantec 2021). CCR Parameters with media concentrations higher than SSL_{HH} for CCR material, soil, sediment or fish tissue, or generic human health screening levels for surface stream water will be identified as constituents of potential concern (COPCs) for further evaluation in the HHRA.

Lines of Evidence to Be Used in the Human Health and Ecological Risk Assessments

The potential movement of CCR Parameters in onsite groundwater to offsite locations where there may be private domestic wells or springs will be addressed by water use surveys and offsite water analysis. Should the use survey indicate that groundwater is used for human consumption, the intent is to sample water from wells/taps and analyze for CCR Parameters. The measured concentrations will then be screened against EPA drinking water standards and Tennessee Groundwater Protection Standards consistent with the Federal CCR Rule. Groundwater modeling may also be used as a line of evidence to assess the potential of CCR Parameter movement from onsite to offsite locations of domestic water use (i.e., modeled data will be compared to measured data).

3.1.1.2 Ecological Screening Criteria

Concentrations of CCR Parameters in abiotic media (i.e., stream surface water and sediment) will be compared to media-based ecological screening criteria in the ERA. CCR Parameters with media concentrations higher than ecological screening criteria will be identified as constituents of potential ecological concern (COPECs) for further evaluation in the ERA. Because media-based ecological screening criteria (e.g., sediment screening benchmarks) are generally based on the potential for impacts to lower trophic level receptors (e.g., benthic macroinvertebrates), they may not be adequately protective of higher trophic level receptors (e.g., birds or mammals). This is particularly relevant for bioaccumulating constituents that may increase in concentration through successive stages of the food chain. Therefore, to be protective of aquatic-dependent birds and mammals, COPEC selection will be based on multiple media-based ecological screening criteria. Concentrations of CCR Parameters in surface stream water and sediment will be compared to ecological screening criteria for each of these media; a given CCR Parameter with concentrations that are higher than an abiotic screening criterion will be identified as a COPEC for further evaluation in the ERA. In addition, CCR Parameters that are known to bioaccumulate (i.e., mercury and selenium) will be identified as COPEC for higher trophic levels if present in sediment or surface water.

Food chain modeling based on an oral dose approach will be used to estimate exposures to COPECs in surface stream water, sediment and biological (i.e., mayfly and fish) tissues for avian and mammalian receptors. Exposure doses calculated for each COPEC and ingestion exposure pathway (i.e., ingestion of food, water and sediment) will be compared to effects-related endpoints to estimate potential hazards. COPEC concentrations in biological (mayfly and fish) tissues will be evaluated in the ERA for potential risks to benthic macroinvertebrate and fish communities, respectively, through comparison to critical body residues. For CCR Parameters that are known to bioaccumulate, fish tissue concentrations from multiple species and trophic levels in the food web (i.e., bluegill, channel catfish, redear sunfish, gizzard shad and largemouth bass), will be compared to critical body residue values.

3.1.2 Hazard Thresholds, Hazard Index and Hazard Quotients

CCR Parameters identified during the screening process as COPCs and COPECs will be further quantitatively evaluated by calculating hazard thresholds, hazard indices or hazard quotients as applicable. The EPA considers a carcinogenic risk between 1×10^{-6} and 1×10^{-4} and a non-cancer hazard index of one as the points of departure for risk management decisions about potential human health

concerns at a contaminated site (EPA 1991). However, the upper boundary of the risk management range is not a discrete line at 1 x 10^{-4}, although the EPA generally uses 1 x 10^{-4} in risk management decisions. A specific risk estimate slightly higher than 1x10^{-4} may be considered acceptable if justified based on site-specific conditions (EPA 1991). The State of Tennessee (TDEC 2016) refers to the EPA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process and Risk Assessment Guidance for Superfund. The regulatory target for acceptable excess lifetime cancer risk in Tennessee is 1 x 10^{-5} (TDEC 2019). Since the Tennessee risk assessment process is consistent with CERCLA, the risk assessments being evaluated as part of the TDEC Order will assume that regulatory program targets for acceptable excess lifetime cancer risk and non-cancer hazard index for protection of human health are 1x10^{-5} and 1.0, respectively.

Hazard quotients (HQs) for birds and mammals will be calculated based on no observed adverse effect levels and lowest observed effects levels. The EPA considers that when HQ calculated based on no observed adverse effect levels are less than or equal to one, adverse effects on representative ecological receptors are not likely (EPA 1997). When ecological HQs are greater than one, adverse effects on representative ecological receptors are possible, but interpretation of HQs greater than one should include a weight of evidence evaluation including, but not limited to, consideration of the potentially affected receptor(s), the nature of the stressor(s), ecological effects information, toxicological relevance to population effects and the likelihood and duration of exposure.

3.2 QUALITATIVE LINES OF EVIDENCE

3.2.1 Published Information on Primary CCR Parameters in Fish

Consumption of locally-caught fish is an important pathway of exposure to contaminants for human and ecological receptors. Fish take up naturally-occurring metals/metalloids from their environment and incorporate some of them into their tissues. The toxicities of metals depend on their chemical forms and valence states, important characteristics that may not be represented by the toxicity factors used to estimate cancer risk and non-cancer hazard from total metals concentrations in environmental or biological media. Section 4.3.1 of the USEPA *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1. Fish Sampling and Analysis* (EPA 2000b) provides a discussion of metals in edible portions of fish. Of the CCR Parameters, EPA listed inorganic arsenic, cadmium, selenium, and methyl mercury as priority target analytes for fish tissue sampling programs.

In the KRP Baseline Ecological Risk Assessment (BERA; Arcadis 2012), arsenic and selenium in stream sediment were identified as the primary hazard drivers for ecological receptors (benthic macroinvertebrates). The KRP Baseline HHRA determined that arsenic in edible fish tissue was primarily organic arsenic, which has very low toxicity. Thus arsenic in fish tissue was not a risk driver for human health. Information on these CCR Parameters that is relevant to interpreting fish tissue analytical results collected during the TDEC Order EIs is summarized in **Appendix A**.

3.2.2 Ecological Sources of Information and Assessment Methods

The following sources of information and methods of assessment will be used to evaluate potential ecological exposures and hazards.

Benthic Invertebrate Communities: Concentrations of COPECs measured in samples of sediment and surface stream water from locations upstream, adjacent, and downstream of the TDEC Order plants will be compared to published ecological screening values, literature-derived toxicity values, and concentrations used in toxicity tests in the KRP studies. Concentrations of COPECs measured in the tissues of mayfly nymphs and adults will be compared spatially (upstream, adjacent, and downstream) by sample transects in nearby surface water bodies, and to critical body residues derived from the literature. TVA's benthic community indices will be compared spatially (upstream, adjacent, and downstream) and to historical benthic community indices derived as part of TVA's reservoir vital signs monitoring program.

Aquatic Plant Communities: Effects of potential releases of CCR constituents on aquatic plants in water bodies in close proximity to the TDEC Order plants will be inferred by comparing concentrations of COPECs in surface stream water and sediment to literature-derived screening levels and by evaluating possible spatial differences among upstream, adjacent, and downstream locations.

Fish Communities: Concentrations of COPECs measured in samples of sediment and surface stream water from locations upstream, adjacent, and downstream of the TDEC Order plants will be compared to published ecological screening values, literature-derived toxicity values, and concentrations observed in toxicity test samples from the KRP studies. Concentrations of COPECs measured in tissues of fish collected from sampling transects upstream, adjacent, and downstream will be compared to critical body residues derived from the literature and to findings from the KRP studies. In addition, TVA fish community assessments conducted at each plant over extended periods of time will constitute another line of evidence for assessing risks to fish communities from plant operations.

Amphibians and Reptiles: Effects of potential releases of CCR Parameters on amphibians and reptiles in the riparian habitat adjacent to the TDEC Order plants will be inferred by comparing COPEC concentrations in sediment and surface stream water to literature-derived screening levels and results of KRP biological investigations.

Mammals and Birds: There are three general classifications of mammals and birds based on feeding habits: herbivores, omnivores, and carnivores/piscivores. Food chain modeling based on an oral dose approach will be used to estimate exposures of these receptors to COPECs in surface stream water, sediment and biological (i.e., mayfly and fish) tissues. Exposure doses calculated for each COPEC and ingestion exposure pathway (i.e., ingestion of food, water and sediment) will be compared to literature-derived toxicity reference values to estimate potential hazards (refer to **Section 3.1.2**).



3.2.3 Environmental Investigations and Assessments Conducted for the Kingston Recovery Project

Following the CCR release from the KIF Plant in December 2008, TVA in partnership with federal and state agencies conducted numerous environmental sampling investigations, biological studies, and HHERAs to evaluate potential effects of the release on human and ecological receptors. Investigations were conducted immediately following the release as part of the Time-Critical Action to remove CCR material from the river system and adjacent properties, and additional sampling and assessment studies were conducted as part of the Non-Time-Critical Action after dredging of CCR material from the Emory River. The Baseline HHRA (Jacobs 2012) and BERA (Arcadis 2012) were conducted as part of the Non-Time Critical Removal Action for the River System, and represent conditions and potential risks to receptors from residual CCR that could not be removed or otherwise was not removed from the river sediments.The extensive information generated during the KRP between 2009 and 2014, were summarized by EPA in the Project Completion Fact Sheet (EPA 2014) and included results reported from each of the following:

- Approximately, 20,000 samples of air, water, sediment, CCR material, and biota resulting in more than 500,000 chemical analyses
- Toxicity testing conducted on water and sediments, including partial life-cycle tests of a duration as long as 60 days
- Field and laboratory studies of possible effects on fish and community health and reproduction
- Field biological studies on birds and other wildlife species conducted by TVA staff, consultants, government research agencies, and universities
- Site-specific HHERAs to evaluate potential impacts of the ash release and emergency response/cleanup activities on the surrounding human and ecological communities
- Approximately 50 papers published in peer-reviewed journals.

The KRP serves as a blueprint for the HHRAs and ERAs to be prepared under the TDEC Order. For instance, the HHERAs prepared for the KIF Plant following the December 2008 CCR release were based on multiple LOE, and many of these are also applicable to the TDEC Order HHERAs. The environmental settings adjacent to TDEC Order plants in Tennessee are similar to the settings assessed for the KRP. Regardless of how CCR Parameters have been or may be released into the surrounding environment from the CCR management units at a given plant, nearby surface streams and rivers are the primary locations where human and ecological receptors might be exposed. The major rivers adjacent to the TDEC Order plants are sources of public drinking water supplies and are widely used for boating, water sports, fishing, and shoreline activities. In addition, concentrations of CCR Parameters in samples of environmental media collected as part of the TDEC Order EIs can be compared to the analytical data generated during the KRP to infer risks to human and ecological receptors as LOE in the TDEC Order



HHERAs. Similarly, quantitative estimates of risk and results of biological studies conducted during the KRP may inform as to risks and biological effects that may occur at the TDEC Order plants.

3.2.3.1 Environmental Sampling Investigations

Following the 2008 CCR release at the KIF Plant, TVA conducted sampling of abiotic media and biota in the rivers and coves adjacent to the plant from 2009 to the present. Environmental sampling activities were associated with the dredging period (2009), post-dredging residual CCR period (2010–2011), and long-term monitoring (2013–present). Dredging period sampling was conducted to: (1) assess potential effects from dredging and ash dewatering activities on water column biota and benthic biota; and (2) characterize the toxicity of ash deposits in the KIF Plant river system on benthic biota. Post-dredging sampling was conducted to assess potential toxicity of the CCR remaining in the Clinch and Emory Rivers to benthic biota, fish, and aquatic-dependent ecological receptors (i.e., reptiles, birds, and mammals) after dredging operations ceased. Long-term monitoring of sediments, benthic biota, fish, and aquatic-dependent ecological receptors is continuing to assess the progress of the monitored natural recovery program. Information from reports of these investigations will be used to make inferences about risks at the TDEC Order plants (**Table 1**).

3.2.3.2 Biological Studies

Numerous toxicological and biological studies were conducted during the KRP to evaluate potential impacts of the 2008 CCR release on ecological communities using or inhabiting the rivers and coves adjacent to the KIF Plant. Toxicological evaluations conducted during the KRP included field and laboratory studies on water column and benthic invertebrates during dredging activities and field and laboratory studies on benthic invertebrates and fish during post-dredging and long-term monitoring activities (Sherard et al. 2015). Biological studies conducted during the KRP included field and laboratory assessments of benthic invertebrate communities, aquatic plant communities, fish communities, amphibians and reptiles, and mammals and birds inhabiting the KIF Plant river system. The biological studies included collecting tissue samples from benthic invertebrates, plants, amphibians, reptiles, birds, and mammals for analysis of CCR Parameters to evaluate bioaccumulation potential. In addition, reproductive health and community metrics were evaluated in fish and avian communities. Information from these reports will be used to make inferences about risks at the TDEC Order plants (**Table 1**).

3.2.3.3 Human Health and Ecological Risk Assessments

The Tennessee Department of Health (TDH) Environmental Epidemiology Program, in collaboration with the Agency for Toxic Substances and Disease Registry, evaluated the potential impacts of the December 2008 ash release and emergency response/cleanup activities on the health of the surrounding community (TDH 2010). The TDH used data reported from environmental samples collected and analyzed by the TVA, EPA, and TDEC in the health assessment. TVA's main KRP contractor, Jacobs Engineering, Inc., performed a baseline HHRA for the Non-Time-Critical Removal Actions for the Swan Pond Embayment/Dredge Cell Engineering Evaluation/Cost Analysis (EE/CA) (Jacobs 2010). It evaluated potential cancer risks and non-cancer hazards for human receptors exposed to environmental media impacted by ash west of Dike 2 in the Swan Pond Embayment.



MULTIPLE LINES OF EVIDENCE FOR THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS FOR TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION ORDER PLANTS

Lines of Evidence to Be Used in the Human Health and Ecological Risk Assessments

A second baseline HHRA, the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Human Health Risk Assessment* (Jacobs 2012), evaluated potential cancer risks and non-cancer hazards for human receptors exposed to environmental media impacted by residual ash in the river system (Clinch, Emory, and Tennessee rivers). The HHRA represented conditions in the river system following removal of as much ash as practical and was based on analytical data collected in 2010 and 2011 from surface water, seasonally exposed sediment, and fish tissue (fillet) samples.

Jacobs also performed a screening level ecological risk assessment (SLERA) for the *Non-Time-Critical Removal Actions Swan Pond Embayment/Dredge Cell Engineering Evaluation/Cost Analysis (EE/CA)* (Jacobs 2010) that evaluated the possibility of adverse effects to terrestrial and aquatic receptors from direct contact with ash in the Dredge Cell and Swan Pond Embayment. Results of the SLERA indicated that a more detailed BERA was warranted for the river system to assess ecological risks following completion of the cleanup. The subsequent River System BERA (Arcadis 2012) evaluated potential adverse effects of CCR and CCR Parameters on 17 ecological receptors in the Clinch, Emory, and Tennessee rivers. The BERA assessed maintenance and reproduction of communities or populations of both lower trophic level and upper trophic level aquatic and riparian receptors. Information from these reports will be used to make inferences about risks at the TDEC Order plants (**Table 1**).



4.0 CONCLUSIONS

Due to the protective nature of the methods, exposure assumptions, and toxicity values that are used in HHERAs, the resulting quantitative risk estimates often overestimate risks to human and ecological receptors. The EPA encourages the use of multiple LOE such that a weight of evidence approach can be used to characterize risk. The objective of this report is to outline the multiple quantitative and qualitative LOE to be used in the HHERAs such that future CCR management decisions at the TDEC Order plants are informed by an assessment of risks based on the combined results of LOE rather than any single LOE alone. These include quantitative LOE for human and ecological risk (i.e., the calculation of carcinogenic risk, non-cancer hazard index and ecological hazard quotients), and qualitative LOE (e.g., published information on CCR and CCR constituents, findings from EIs conducted at each of the TDEC Order plants, and findings from the environmental sampling, biological studies, and HHERA conducted as part of the KRP). By using a multiple LOE approach, future CCR management decisions at the TDEC Order plants can be informed by an assessment of risk based on the combined results of LOE rather than any single LOE.

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TABLE

Table 1: Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments

Table 1. Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments Under the TDEC Order

Summary of Key Studies Conducted for the Kingston Recovery Project

Lines of Evidence for the Human Health Risk Assessment

Study Title and Description	Major Findings	Key Lines of Evidence	Application to TDEC Order HHRA
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Human Health Risk Assessment. Jacobs Engineering Group, July 11, 2012. EPA-AO-052. This baseline HHRA evaluated potential cancer risks and noncancer hazards for human receptors exposed to environmental media impacted by residual ash in the river system (Clinch, Emory, and Tennessee Rivers) based on analytical data collected in 2010 and 2011 from surface water, seasonally exposed sediment, and fish tissue (fillet) samples. Abiotic environmental media and fish tissue samples were collected from locations in the Clinch, Emory, and Tennessee Rivers impacted by the 2009 ash release, as well as unimpacted upstream reference (background) segments of the Clinch, Emory, and Little Emory Rivers. Samples of sediment, surface water, and fish tissue collected from each of the river reaches were analyzed for CCR constituents, as well as legacy constituents present in the river system from sources other than coal ash. Arsenic and selenium found in fish tissue were speciated to determine the chemical form. The HHRA evaluated the following receptor exposure scenarios: a resident using surface water for domestic supply, a recreational swimmer, a recreational beachcomber, and a recreational fisher.	Health risks for CCR constituents and legacy constituents did not exceed EPA acceptable risk ranges for residential domestic use of river water or recreational contact (swimmer) with river water. Health risks for CCR constituents and legacy constituents in seasonally exposed sediment did not exceed EPA acceptable risk ranges for recreational contact. Non-ash related legacy constituents PCBs and mercury were the primary contributors to cancer risk and non-cancer hazard for consumption of recreationally caught fish. Arsenic in fish filet was in the organic form (with one exception) and not evaluated (per EPA guidance). Major conclusion - no unacceptable risks to human receptors from concentrations of ash-related constituents remaining in the river system. EPA determined that no further actions were required to protect human health.	Concentrations of CCR constituents in surface water, seasonally exposed sediment, and fish fillet samples collected from reaches of the Emory and Clinch Rivers impacted by ash did not exceed EPA acceptable risk ranges for potentially exposed human receptors (i.e., domestic use of river water, recreational swimmer, beachcomber, and consumers of locally-caught fish).	Concentrations of CCR Parameters in surface stream water, seasonally-exposed sediment, and fish fillets in streams adjacent to TDEC Order plants can be compared to concentrations evaluated in this KRP HHRA. If concentrations at the TDEC Order plant are within the range considered in this KRP HHRA, then risk and hazard for the recreational swimmer, beachcomber, and consumer of locally caught fish are expected to be similar (but not identical) to those reported in the KRP HHRA. Because none of the other TDEC Order plants have released similar volumes of residual CCR material (ash) to adjacent surface water bodies, the post-removal conditions in the KRP river system and associated risks to human receptors documented in the KRP HHRA will be used as a "worst case" benchmark for comparing concentrations of CCR Parameters in surface water, seasonally-exposed sediments, and edible fish tissue collected for the TDEC Order plants.
		Arsenic in edible portions of fish was determined to be in the organic form (e.g. arsenobetaine). Organic arsenic is the most common form in fish and is much less toxic than inorganic arsenic.	The text will be revised as follows: "The assumption that most of the arsenic present in fish fillet tissue is in the organic form is based on EPA guidance (EPA 2000); research conducted by EPA (EPA 1997); state regulatory agencies (e.g., Idaho DEQ 2010; Oregon DEQ 2011); peer-reviewed publications (e.g., Schoof and Yager 2007; Rosemond et al., 2008); and speciation of fish fillet samples collected to support the Baseline Human Health Risk Assessment for the KRP (Jacobs 2012). Arsenic was determined to be in the organic form for most, but not all fillet samples from bluegill, largemouth bass, and channel catfish analyzed for the baseline HHRA. The same types of fish were collected for the TDEC Order investigations from streams with conditions similar to the Clinch, Emory, and Tennessee Rivers associated with the Kingston Fossil Plant. It is therefore reasonable to assume that the types of arsenic in fish fillet tissue collected for the TDEC order would be comparable to the KRP results. Rather than completely excluding arsenic in fish fillet from the TDEC Order human health risk assessments, it will be assumed that inorganic forms of arsenic comprise 10% of the total reported arsenic for quantification of risks to consumers of sport-caught fish. The assumption that, on average, 10% or less of the total arsenic in fish fillet tissue is in the inorganic form is supported by Schoof and Yager (2007), Idaho DEQ (2010), Rosemond et al. (2008), Oregon DEQ (2011), and references provided in Schoof (2014). References: - Idaho Department of Environmental Quality (DEQ). 2010. *Arsenic, Mercury and Selenium in Fish Tissue from Idaho Lakes and Reservoirs* , November 2010. - Oregon Department of Environmental Quality (DEQ). 2011. *Water Quality Standards and Recommendations-Arsenic* . Debra Sturdevant author. Draft April 4, 2011. - Rosemond S., Q. Xie, K. Liber. 2008. *Arsenic concentration and speciation in five freshwater fish species from Back Bay near Yellowknife, NT. Canada* . Environmental Monitoring and Assessment. 147:199-210. - Schoof R.A., and J.W. Yager. 2007. *Variation of total and speciated arsenic in commonly consumed fish and seafood* . Human and Ecological Risk Assessment, 13:946-965. - Schoof R.A. 2014. *Elk Valley Water Quality Plan Annex L.1. Human Health Evaluation of Current Baseline Conditions* , Prepared for Teck Coal Limited, Sparwood, BC by ENVIRON International Corporation, July 2014. - United States Environmental Protection Agency (EPA). 1997a. *Arsenic and Fish Consumption*. EPA-823-R-
		Mercury in fish tissues was not related to the CCR released into the river system.	Mercury in fish tissue may be related to natural and anthropogenic sources. Potential sources will be evaluated on a site-specific basis, including but not limited to: 1) mercury concentrations in fish collected adjacent to the plant will be compared to concentrations in fish collected from sampling reaches downstream of the plant and upstream of the plant; 2) spatial distribution of mercury concentrations in sediments adjacent to the plant compared to upstream and downstream; 3) local/regional geology; 4) existing fish consumption advisories for mercury that encompass river miles starting upstream of the plant and continuing downstream of the plant; and 5) documented (industrial) sources of mercury upstream of the plant.

Table 1. Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments Under the TDEC Order (cont'd)
Summary of Key Studies Conducted for the Kingston Recovery Project

Lines of Evidence for the Ecological Risk Assessment

Study Title and Description	Major Findings	Key Lines of Evidence	Application to TDEC Order ERA
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Ecological Risk Assessment (BERA). Arcadis, August 3, 2012. EPA-AO-050 The BERA is a comprehensive evaluation of multiple receptors and pathways representing the aquatic/riparian foodweb in the Clinch, Emory, and Tennessee Rivers surrounding the Kingston Fossil Plant, incorporating the results of environmental samples (river water, sediment, sediment pore water, biological tissues), toxicity studies, fish and benthic macroinvertebrate community metrics, and dietary foodweb models. The extensive data collection provided multiple lines of evidence for most receptors evaluated in the BERA.	Weight of evidence risk characterization by receptor indicated: - negligible risks for fish, heron, osprey, and wood duck - low risks for aquatic vegetation, mammals (mink, raccoon, muskrat, gray bat), amphibians (toads and frogs), reptiles (turtles), killdeer, mallard, and tree swallow - moderate risks for benthic macroinvertebrates directly exposed to ash, arsenic and selenium in surface sediments for the most heavily impacted reaches of the Emory River, and low or negligiblefor all other areas of the Emory, Clinch, and Tennessee Rivers. The BERA identified benthic macroinvertebrate exposure to ash, arsenic, and selenium in sediment and potential dietary exposure to insectivorous birds that feed on benthic macroinvertebrates (killdeer and tree swallow) as the critical receptors and pathways requiring actions to manage risks. These findings supported the decision to implement a monitored natural recovery program, which was confirmed through long term monitoring.	The studies conducted during the KRP represent the conditions in the Clinch, Emory, and Tennessee Rivers in the vicinity of the Kingston Fossil Plant after as much ash as practical had been removed. The studies provide LOE for relationships between concentrations of ash and CCR constituents in sediment and surface water in the river system, concentrations in the tissues of ecological receptors, and potential adverse effects to individual organisms, populations, and communities.	None of the other TDEC Order plants have released similar volumes of residual CCR material (ash) to adjacent surface water bodies. The post-removal conditions in the river system and associated risks to ecological receptors documented in the BERA will be used as a "worst case" benchmark for comparing concentrations of ash and CCR Parameters in environmental media and biota collected for the TDEC Order plants.
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Ecological Risk Assessment (BERA) (cont'd)	*Fish* - Weight of evidence risk characterization concluded that ash and ash-related constituents posed a negligible risk to fish communities in the Clinch, Emory, and Tennessee Riversbased on fish community surveys, fish toxicity tests, and fish reproduction studies.	Two programs for fish community surveys were used to characterize fish abundance and diversity through direct measurement. The survey results indicated no substantive impairment to the fish community related to ash or CCR constituents.	The types of fish collected during the EIs for the TDEC Order plants are comparable to the types of fish analyzed for the KRP BERA. Concentrations of CCR Parameters in surface stream water, sediment, and fish tissues in streams adjacent to TDEC Order plants can be compared to concentrations evaluated in this KRP ERA to inform the characterization of risk to fish communities.
		The surface water toxicity testing program used fish as a test species, and fish toxicity tests were also conducted using ash-impacted sediment. These direct measures of potential toxicity found no significant health effects (i.e., no direct observations of reducted survivial, hatching succes, or developmental abnormalities).	
		Fish reproductive studies conducted to evaluate the bioaccumulation of metals of reproductive concern (such as selenium) in fish. No conclusive evidence of ecologically significant effects were observed from the fish reproductive studies.	Concentrations of CCR Parameters in fish tissues in streams adjacent to TDEC Order plants can be compared to concentrations evaluated in this KRP HHRA to infer the characterization of risk to fish communities.

Table 1. Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments Under the TDEC Order (cont'd)
Summary of Key Studies Conducted for the Kingston Recovery Project

Lines of Evidence for the Ecological Risk Assessment

Study Title and Description	Major Findings	Key Lines of Evidence	Application to TDEC Order ERA
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Ecological Risk Assessment (BERA) (cont'd)	*Benthic Invertebrates* - Weight of evidence characterization concluded moderate risks for benthic invertebrates directly exposed to ash, arsenic and selenium in surface sediments for the most heavily impacted reaches of the Emory River, and low or negligiblefor all other areas of the Emory, Clinch, and Tennessee Rivers. Benthic community metrics were given the greatest weight because they are a direct measurement of community health. Three other lines of evidence (sediment toxicity tests, benthic invertebrate tissue concentrations, and sediment porewater concentrations) were consistent but contrary to the benthic invertebrate community survey results, indicating the potential for low risk to benthic invertbrates.	Benthic invertebrate community surveys suggested that differences in benthic community metrics were largely explained by variability in sediment substrate. Statistical analysis indicated that ash and arsenic were the most closely associated with adverse effects.	Consistent with the weight of evidence hierarchy in the BERA, benthic community metrics will be the primary LOE for the TDEC Order ERAs.
		Statistical analysis indicated that ash and arsenic were the most closely associated with adverse effects. Selenium was shown to bioaccumulate in benthic invertebrates. However, tissue concentrations alone were not considered reliable predictors of toxicity to benthic communities in the river system (outside of laboratory conditions). Literature-derived effects values were considered the least relevant LOE.	Concentrations of CCR Parameters in sediment and mayfly tissue collected during the environmental investigations for the TDEC Order will be compared to comparable data from the KRP. Relative concentrations in sediment (especially % ash, arsenic, and selenium) from surface streams adjacent to a TDEC Order plant will be used to infer the characterization of risk to benthic invertebrate communities.
	Aquatic Vegetation - Risk to aquatic plants were characterized based on constituent concentrations in abiotic media (surface stream water, sediment, sediment pore water) and biotic media (periphyton and aquatic vegetation). Evidence based on comparison of abiotic media to literature values was given a low weight.	Concentrations of ash-related constituents in vegetation did not indicate that concentrations are higher in vegetation growing within downstream reaches (relative to reference areas).	Concentrations of CCR Parameters in sediment and surface stream water collected during the environmental investigations for the TDEC Order will be compared to comparable data from the KRP. Relative concentrations will be used to infer the characterization of risk to aquatic vegetation.
	Aquatic- and Riparian-Feeding Birds - Risk to piscivores (Heron and Osprey) is based on multiple LOEs - egg health metrics, egg concentrations, and dietary exposure models. The multiple lines of evidence consistently indicated a negligible risk to piscivore birds.	Eggs were collected from heron and osprey nests in impacted and reference locations. Eggs were measured for weight, volume, length, width, and clutch size to evaluate whether CCR constituents were impacting egg development, and egg tissue was analyzed for CCR constituents. Authors concluded the magnitudes of differences were small and not likely biologically meaningful to population viability.	The findings of dietary models used to evaluate risk to piscivorous birds to be evaluated in the ERAs for the TDEC Order plants will be compared to the findings of dietary models used in the KRP BERA to infer the characterization of risk to piscivore birds.
	Aerial-Feeding Brids and Mammals - Risk to aerial feeding birds is based on multiple LOEs for the Tree swallow - reproductive data, egg tissue concentrations, nestling tissue concentrations, and dietary exposure models. The weight of evidence supported a conclusion of low risk to aerial-feeding birds. Risk to aerial feeding mammals (bats) was based on dietary exposure models. The evidence suggests that ash-related COPECs pose, at most, low risks to aerial-feeding insectivorous mammals that forage over the river system. however, due to the use of probabilistic modeling, confidence in this conclusion was low.	The Tree swallow study included the construction of over 500 nest boxes. Tree swallow egg, eggshell, and nestling concentrations, egg and nestling health metrics, and reproductive measures were statistically compared between impacted and reference locations. The findings suggested a small, but uncertain reduction in female fledglings per swallow nest initially hypothesized to be associated with selenium bioaccumulation. There was no evidence for adverse effects of selenium on bats at the concentrations occurring in emergent insects, though laboratory studies do show reduced growth in young at such concentrations.	The findings of dietary models used to evaluate risk to aerial-feeding birds to be evaluated in the ERAs for the TDEC Order plants will be compared to the findings of dietary models used in the KRP BERA to infer the characterization of risk to aerial-feeding birds. The findings of dietary models used to evaluate risk to aerial-feeding mammals to be evaluated in the ERAs for the TDEC Order plants will be compared to the findings of dietary models used in the KRP BERA to infer the characterization of risk to aerial-feeding mammals.
	Amphibians - Weight of evidence characterization concluded a low risk to amphibian populations based on whole body frog and toad tissue data and evaluation of surface water and sediment chemistry data.	American toads, spring peepers, and upland chorus frogs were collected from two impacted locations, two unimpacted locations (north of the ash spill), and a reference location. Whole body tissue samples were analysed for CCR constituents. The authors concluded that selenium was the CCR constituent with the clearest trend between sites and year; however, when compared with literature-derived whole-body amphibian concentrations, the concentrations measured in impacted areas appeared to reflect natural variability of amphibians.	Concentrations of CCR Parameters in surface stream water adjacent to TDEC Order plants can be compared to concentrations evaluated in this KRP ERA to infer the characterization of risk to amphibians.

Table 1. Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments Under the TDEC Order (cont'd)
Summary of Key Studies Conducted for the Kingston Recovery Project

Lines of Evidence for the Ecological Risk Assessment

Study Title and Description	Major Findings	Key Lines of Evidence	Application to TDEC Order ERA
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Ecological Risk Assessment (BERA) (cont'd)	*Reptiles* - Weight of evidence characterization concluded a low risk to reptile populations based on turtle community surveys and chemical concentrations in turtle blood tissue, surface stream water, and sediment.	Turtle community surveys did not indicate alterations in community structure or obvious signs of illness in individual turtles. Concentrations of selenium and strontium in the blood of turtles from areas impacted by the ash release were higher than concentrations ins turtles from reference areas. These findings suggest increased exposure to turtles, but no adverse effects correlated with the blood concentrations of selenium and strontium could be found in the literature.	Concentrations of CCR Parameters in surface stream water and sediment adjacent to TDEC Order plants can be compared to concentrations evaluated in the KRP BERA to inform the characterization of risk to reptiles.
Updated Analysis and Temporal Trend Evaluations in Biota - Benthic Invertebrates (Arcadis 2015, 2020) Benthic invertebrate and fish community investigations were conducted in 2014 and 2017, as part of the Long-Term Monitoring Sampling and Analysis Plan (Jacobs 2013). The 2014 and 2017 studies assess benthic invertebrate tissue concentrations and potential impacts to benthic invertebrate community metrics across multiple impacted locations relative to reference locations in the Emory and Clinch Rivers and include toxicity testing in the laboratory. The 2014 and 2017 studies also included evaluation of fish reproductive health, bioaccumulation, physiological health, and community structure	Based on results of toxicity testing, sediment is not likely to impact benthic invertebrates in the Emory and Clinch Rivers.	Sediment samples from impacted sites at dilutions of 100%, 80%, 60%, 40%, and 20% impacted sediment showed no statistically significant reduction in survival or growth relative to sediment samples from reference locations.	Concentrations of CCR Parameters in sediment adjacent to TDEC Order plants can be compared to concentrations evaluated in this test to infer the characterization of risk to benthic invertebrates
	The 2014 benthic invertebrate community metrics were consistent with results from previous years. While some differences in community metrics were identified among impacted locations or between impacted locations compared to reference locations in 2017, these differences appear to be a reflection of substrate characteristics and natural variability in benthic communities, rather than negative impacts from residual ash.	Long-term monitoring supports conclusions of KRP BERA, which suggested that differences in benthic community metrics were largely explained by variability in sediment substrate.	This LOE increases the confidence of conclusions reached using benthic invertebrate community surveys, and provides additional support for monitored natural recovery as a potential remedial strategy.
	Fish community health, as indicated by fish community health data and sportfish surveys, indicate no apparent relation to the ash spill.	Long-term monitoring of fish community health are consistent with fish community surveys reviewed as part of the KRP BERA, which concluded no substantive impairment to the fish community related to ash or ash-related constituents.	This LOE increases the confidence of conclusions reached in the KRP BERA, and provides additional support for monitored natural recovery as a potential remedial strategy.
	Reproductive health for sentinel fish species (redear sunfish, bluegill sunfish, and largemouth bass) was evaluated between 2009 and 2017. The data indicate that there are no patterns to increases and decreases in the measures of reproductive health that were evaluated, and changes in condition measured at ash-impacted sites tend to be similar within each study year to those at reference sites.	Long-term monitoring of fish reproductive health is consistent with KRP BERA, which concluded no conclusive evidence of ecologically significant effects to fish reproductive health.	This LOE increases the confidence of conclusions reached in the KRP BERA, and provides additional support for monitored natural recovery as a potential remedial strategy.
	Fish tissue samples from sentinal species (redear sunfish, bluegill sunfish, and largemouth bass) were analyzed for arsenic, mercury and selenium. Selenium concentrations in fillets of these three species were higher in fish from impacted sites than from reference sites, consistent with previous years.	Selenium concentrations in fish fillets from impacted areas are higher than from reference sites	None of the other TDEC Order plants have released similar volumes of residual CCR material (ash) to adjacent surface water bodies. The potential effects from impacted areas will be used as a "worst case" benchmark for comparing results based on concentrations of ash and CCR Parameters in environmental media and biota collected for the TDEC Order plants.
	The health metrics for physiological and energetic responses were evaluated in sentinel fish (bluegill sunfish, redear sunfish, and largemouth bass).	Several health metrics that may be indicative of kidney or liver dysfunction were statistically different between impacted and reference sites.	

Notes:

CCR constituents are constituents serving to form, compose or make up the whole of CCR material

CCR Parameters are constituents listed In Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04

Appendix A
PUBLISHED INFORMATION ON PRIMARY CCR PARAMETERS IN FISH

MULTIPLE LINES OF EVIDENCE FOR THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS FOR TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION ORDER PLANTS

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PUBLISHED INFORMATION ON PRIMARY CCR PARAMETERS IN FISH

The Tennessee Department of Environment and Conservation (TDEC) Commissioner's Order No. OGC15-0177 (TDEC Order) established the process whereby TDEC will oversee the Tennessee Valley Authority's implementation of the 2015 United States Environmental Protection Agency (EPA) Final Coal Combustion Residuals (CCR) Rule to ensure coordination and compliance with Tennessee laws and regulations that govern the management and disposal of CCR (TDEC 2015). As per the TDEC Order, samples of environmental media are analyzed for the following CCR Parameters listed in Appendix III and Appendix IV of the Federal CCR Rule, Title 40 of the Code of Federal Regulations Part 257 (40 CFR 257):

- Antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium (total), cobalt, fluoride, lead, lithium, mercury (inorganic), molybdenum, pH, radium 226 & 228, selenium, sulfate, thallium, and total dissolved solids.

Samples of environmental media are also analyzed for five inorganic constituents listed in Appendix 1 of Tennessee Rule 0400-11-01-.04 that are not listed in 40 CFR 257:

- Copper, nickel, silver, vanadium, and zinc.

Consumption of locally-caught fish is an important pathway of exposure to contaminants for human and ecological receptors. Fish take up naturally-occurring metals/metalloids from their environment and incorporate some of them into tissue. The toxicity of metals depends on the chemical form and valence state, an important nuance that may not be represented by the toxicity factors used to estimate cancer risk and non-cancer hazard from total metals concentrations in environmental or biological media. Section 4.3.1 of the EPA *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1. Fish Sampling and Analysis* (EPA 2000) provides a discussion of metals in edible portions of fish. Of the CCR Parameters, the EPA listed inorganic arsenic, cadmium, methyl mercury, and selenium as priority target analytes for fish tissue sampling programs.

In the Kingston Recovery Project (KRP) baseline ecological risk assessment, inorganic arsenic and selenium associated with ash in river sediments were identified as primary CCR-associated ecological risk drivers. Arsenic was not a significant risk driver for human consumption of locally-caught fish because analytical speciation indicated organic arsenic was the predominant chemical form in fish fillet. Organic arsenic is relatively non-toxic. Fish tissue samples collected during the environmental investigations for the TDEC Order plants were analyzed for total metals. As pointed out by the KRP human health risk assessment, the chemical form of a metal in biota (fish) consumed by human receptors is an important line of evidence for understanding potential risk. Information relevant to interpreting the fish tissue analytical results from the TDEC Order Environmental Investigations is summarized below.

COAL COMBUSTION RESIDUALS

The majority of the information available in the literature focuses on the impacts of fly and bottom ashes; other coal combustion wastes have received limited study. CCR disposal in landfills and settling ponds can influence adjacent aquatic ecosystems directly, through CCR management unit effluent and surface runoff, and indirectly, through seepage and groundwater contamination. Major impacts are generally associated with changes in water chemistry, including changes in pH and concentrations of potentially toxic elements (Carlson and Adriano 1993).

Sediment samples containing a broad range of ash content collected during the KRP from the Emory and Clinch rivers post-CCR release were used in a tiered toxicity testing program that included a combination of 10-day acute sediment toxicity tests and longer-term partial life cycle “definitive” tests. Two species (*Hyalella azteca* and *Chironomus dilutus*) were used in these tests to evaluate potential effects of the CCR release on the benthic community. Arsenic (and to a much lesser extent, selenium) in the ash was identified as the likely toxicant(s) causing observed effects in the laboratory toxicity tests. Sites in the Emory and Clinch Rivers with the greatest statistical and biologically relevant effects had arsenic concentrations in sediments twice the probable effects concentration of 33 milligram per kilogram. These sites contained greater than 50% ash. Sites with less than approximately 50% ash in sediments exhibited fewer toxic responses relative to the reference sediment in the laboratory (Stojak et al. 2014).

Parallel laboratory studies were performed on river sediment porewater samples collected throughout the KRP by investigators using various collection and porewater extraction methods to better understand the relationships between ash content and dissolved metals/metalloids concentrations. These studies show a general pattern of porewater arsenic concentrations that support the above-described toxicity test results. That is, relatively low and stable arsenic concentrations occurred at less than approximately 40% to 50% ash content in sediments, followed by a roughly linear relationship between porewater arsenic and ash content above that point (Sherrard et al. 2015).

Saying this, as part of the HHERA the CCR parameters listed above (not just arsenic, mercury and selenium) and measured in soil, sediment and fish tissue will be compared to medium-specific and receptor-specific human health screening levels and media-based ecological screening criteria and Critical Body Residues (refer to **Section 3.1.1.1** and **3.1.1.2** above). Concentrations of CCR Parameters lower than their respective screening levels are an indication that risks to human and ecological receptors are acceptable; if concentrations are greater than the screening levels, other lines of evidence will be used in the risk characterization.

ARSENIC

Arsenic is a non-metallic element (metalloid) that occurs naturally and is widely distributed in the environment. The toxicity of arsenicals depends on the nature of the compounds, and particularly the valence state of the arsenic atom (EPA 2000). Typically, compounds containing trivalent (+3) arsenic are much more toxic than those containing pentavalent (+5) arsenic. The valence of the arsenic is a more important factor in determining toxicity than the organic or inorganic nature of the arsenic-containing

compound (EPA 2000), although organic forms of arsenic are generally less toxic than inorganic forms (see below). With respect to inorganic arsenic compounds, pentavalent forms of arsenic (arsenates) are less toxic than trivalent forms (arsenites) (EPA 2000).

Section 4.3.1 of the EPA *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1. Fish Sampling and Analysis* (EPA 2000) provides a discussion of metals in edible portions of fish including the chemical forms of arsenic most frequently found in fish and seafood. Seafood is a major source of trace amounts of arsenic in the human diet. However, arsenic in the edible parts of fish and shellfish is predominantly present as the arsenic-containing organic compound arsenobetaine, which has been shown to be metabolically stable and nontoxic in a number of studies (EPA 2000). The assumption that most of the arsenic present in fish fillet tissue is in the organic form is based on EPA guidance (EPA 2000); research conducted by EPA (EPA 1997); state regulatory agencies (Idaho DEQ 2010; Oregon DEQ 2011); peer-reviewed publications (Schoof and Yager 2007; Rosemond et al. 2008); and speciation of fish fillet samples collected to support the Baseline Human Health Risk Assessment for the KRP (Jacobs 2012). Arsenic was determined to be in the organic form for most, but not all fillet samples from bluegill, largemouth bass, and channel catfish analyzed for the baseline HHRA. The same types of fish were collected for the TDEC Order investigations from streams with conditions similar to the Clinch, Emory, and Tennessee Rivers associated with the Kingston Fossil Plant. It is therefore reasonable to assume that the types of arsenic in fish fillet tissue collected for the TDEC order would be comparable to the KRP results. Rather than completely excluding arsenic in fish fillet from the TDEC Order human health risk assessments, it will be assumed that inorganic forms of arsenic comprise 10% of the total reported arsenic for quantification of risks to consumers of sport-caught fish. The assumption that, on average, 10% or less of the total arsenic in fish fillet tissue is in the inorganic form is supported by Schoof and Yager (2007), Idaho DEQ (2010), Rosemond et al. (2008), Oregon DEQ (2011), and references provided in Schoof (2014). Inorganic arsenic may be present in fish tissue but is generally a minor component of the total arsenic content compared to arsenobetaine. If present, inorganic arsenic may be a concern for human consumers of fish and seafood. Consequently, it is critical to determine the chemical forms of arsenic present in fish tissue consumed by people.

The chemical species of arsenic detected in fish fillet samples from the Emory and Clinch Rivers is important information for interpreting the results for fish fillet samples collected from the Tennessee Valley Authority coal-fired power plants subject to the TDEC Order (TDEC Order plants). The predominant chemical form of arsenic present in fish fillet samples from the Emory and Clinch Rivers was organic arsenic. The same types of fish analyzed during the KRP (i.e., largemouth bass, crappie, sunfish, and catfish) are common sportfish throughout the Tennessee Valley. It is reasonable to assume that arsenic in the fillet of the same types of fish collected from other locations is also predominantly in the organic form.

MERCURY

Mercury is a metallic element that occurs naturally in the environment. Metallic or elemental mercury (Hg^0) is the main form of mercury released into the air by natural processes. Mercury bound to other chemicals may have valence states of either +1 (Hg^{1+}) or +2 (Hg^{2+}). Mercury with a valence state of +1 is



referred to as mercurous mercury, and mercury with a valence state of +2 (divalent) is referred to as mercuric mercury. Many inorganic and organic compounds of mercury can be formed from the mercuric cation (ATSDR 1999).

In the environment, inorganic mercury can be methylated by microorganisms to methylmercury. Methylmercury can accumulate in the tissues of organisms. The animals at the top of the food chain tend to accumulate the most methylmercury in their bodies. A source of mercury release to the environment may, therefore, lead to increased levels of methylmercury in tissues of large fish and mammals (ATSDR 1999).

The general population is most commonly exposed to mercury primarily from two sources: (1) eating fish and marine mammals that may contain some methylmercury in their tissues; or (2) from the release of elemental mercury from the dental amalgam used in fillings (ATSDR 1999). Dietary intake is the most important source of non-occupational exposure to mercury, with fish and other seafood products being the dominant source of mercury in the diet. Most of the mercury consumed in fish or other seafood is the highly absorbable methylmercury form.

It should be noted that the majority of the mercury measured in environmental samples collected from the Kingston Fossil Plant were the result of regional legacy contamination issues and not from the 2008 CCR release (Arcadis 2020). Arnwine et al. (2014) conducted a study to evaluate the potential bioaccumulation of metals in native game fish in streams draining four land-use categories (i.e., active coal mines, abandoned/reclaimed coal mines, non-coal mining activities, and reference areas) in Tennessee and found that mercury concentrations in fish fillets were highest in fish collected from reference areas followed by fish collected downstream of inactive coalfields. The results of this study suggest that mercury is a naturally-occurring regional contaminant in Tennessee and also is related to historical coal mining and other activities. Thus, mercury concentrations measured during some of the TDEC Order Environmental Investigations may have a regional ambient contribution that should be considered during the interpretation of human health and ecological risk assessment results for those facilities.

SELENIUM

Selenium is a non-metallic element (metalloid) that occurs naturally in the environment. It is distributed widely in nature and is found in most rocks and soils at concentrations between 0.1 and 2.0 milligram per kilogram (Fishbein 1983 as cited in ATSDR 2003). Selenium is ubiquitous in the environment, being released from both natural and anthropogenic sources. The principal releases of selenium into the environment as a consequence of human activities result from the combustion of coal (ATSDR 2003).

The primary factor determining the fate of selenium in the environment is its oxidation state. Selenium is stable in four valence states (-2, 0, +4, and +6) and forms chemical compounds similar to those of sulfur (ATSDR 2003). The heavy metal selenides (-2) are insoluble in water, as is elemental selenium; the inorganic alkali selenites (+4) and selenates (+6) are soluble in water (Weast 1988 as cited in ATSDR 2003) and are, therefore, more bioavailable.



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Selenium in an aquatic environment can be bioaccumulated by aquatic organisms (Chau and Riley 1965, Ohlendorf et al. 1986a, Rudd and Turner 1983a, and Saiki and Lowe 1987 as cited in ATSDR 2003). Soluble forms of selenium can be accumulated by plants. Although both selenite ($Se^{4+)}$ and selenate (Se^{6+}) are soluble forms of selenium, selenate was found to be the preferred form of selenium taken up by plants (Bañuelos and Meek 1990 as cited in ATSDR 2003). Terrestrial plants taking up soluble selenate and selenite can biosynthesize organic selenium compounds, predominantly selenomethionine and, to a lesser extent, selenocysteine; these compounds can be released to the soils once the plants die and decay (ATSDR 2003).

The primary sources of selenium in the human diet are meat products, and wheat bread and flour. Organ meats and seafood contain the highest concentrations of selenium (ATSDR 2003). However, it should be noted that selenium is an essential nutrient, and many individuals routinely ingest selenium as a dietary supplement.

Selenium in the tissues of fish and mayflies may be related to natural and anthropogenic sources. The potential for increased bioaccumulation of selenium in aquatic/riparian receptors from the management of CCR material will be evaluated using multiple lines of evidence, including but not limited to: 1) selenium concentrations in fish and mayfly tissues collected adjacent to the plant will be compared to concentrations in fish and mayfly tissues collected from sampling reaches downstream of the plant and upstream of the plant; 2) the spatial distribution of selenium concentrations in sediments adjacent to the plant compared to upstream and downstream; 3) local/regional geology; 4) concentrations of selenium in fish tissues (whole body, fillet, and ovaries) for protection of aquatic life (EPA 2016); 5) comparison of selenium concentrations in sediment, fish and mayfly tissues for the TDEC Order sites to concentrations in the same media collected for the KRP and Long Term Monitoring from reference and ash impacted reaches of the Clinch, Emory, and Tennessee Rivers; 6) KRP studies evaluating selenium concentrations in eggs and reproductive success of tree swallows (aerial feeding insectivores) from reference and ash impacted reaches of the Clinch, Emory and Tennessee Rivers; and 7) review of published reports of the relationships between selenium concentrations in environmental media (sediment and surface water) and uptake by aquatic organisms (benthic macroinvertebrates).

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APPENDIX B – SCREENING LEVELS USED IN THE HUMAN HEALTH RISK ASSESSMENT

APPENDIX B.1

PROPOSED RECEPTOR-SPECIFIC SCREENING LEVELS FOR HUMAN HEALTH

DRAFT

Stantec

Memo

To:	**TVA Core Team** **Tennessee Valley Authority**	**From:**	**Stantec**
File:	**Proposed Receptor-Specific Screening Levels for Human Health**	**Date:**	**June 25, 2021**

Reference: Proposed Receptor-Specific Screening Levels for Human Health (SSL_{HH})

INTRODUCTION AND REGULATORY CONTEXT

The purpose of this memorandum is to describe the derivation of receptor-specific screening levels (SSL_{HH}) for the human health risk assessment (HHRA) to be conducted within the regulatory context of the Tennessee Department of Environment and Conservation (TDEC) Commissioner's Order No. OGC15-0177, issued on August 6, 2015 and herein referred to as the TDEC Order. The Preamble to the TDEC Order states that one of the purposes of the Order is "*to establish a transparent, comprehensive process for the investigation, assessment, and remediation of unacceptable risks, resulting from the management and disposal of coal combustion residuals (CCR) at the Tennessee Valley Authority's (TVA) coal-fired power plants in Tennessee".*

As part of the TDEC Order, TVA is implementing Environmental Investigation Plans (EIPs) at the following seven TDEC Order plants in Tennessee:

- Allen Fossil (ALF) Plant
- Bull Run Fossil (BRF) Plant
- Cumberland Fossil (CUF) Plant
- Johnsonville Fossil (JOF) Plant
- John Sevier Fossil (JSF) Plant
- Kingston Fossil (KIF) Plant
- Watts Bar Fossil (WBF) Plant.

The EIP for each TDEC Order plant describes the investigation to be conducted. Multiple environmental media are being sampled at each TDEC Order plant for a common group of individual constituents, collectively called "CCR Parameters" (i.e., measurable representatives of components of CCR constituents), namely:

- antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium (total), cobalt, fluoride, lead, lithium, mercury (inorganic), molybdenum, pH (standard unit), radium 226 and 228 (radium 226+228), selenium, sulfate, thallium, and total dissolved solids (specified by TDEC and

found listed in Appendix III and Appendix IV of the Federal CCR Rule, Title 40 of the Code of Federal Regulations Part 257 (40 CFR 257)

- copper, nickel, silver, vanadium, and zinc (the five inorganic constituents listed in Appendix I of TN Rule 0400-11-01-.04 (i.e., TDEC regulations) that are not listed in 40 CFR 257).

Environmental samples were analyzed for up to 26 individual CCR Parameters (listed above), as applicable to the media.

As per the TDEC Order, the findings of the environmental investigations described in the EIPs will be provided in TDEC Order plant-specific Environmental Assessment Reports (EARs). Environmental sampling is complete, or nearing completion, and development of the EARs has begun. Corrective Action/Risk Assessment (CARA) Plans will follow the EARs, and as stipulated in the TDEC Order, the CARA Plans will specify the actions (i.e., corrective measures) TVA plans to take at the TDEC Order plants and the basis for those actions. Corrective measures may include remediation, risk assessment and institutional controls, or no further action.

APPLICATION OF HUMAN HEALTH SCREENING LEVELS IN THE EAR AND THE CARA

For the EARs, concentrations of CCR Parameters in surface stream water, surface stream sediments, groundwater, and biological tissues collected from fish and benthic macroinvertebrates (mayflies) are being compared to conservative generic screening levels (not specific to an individual human or ecological receptor) and protective of human health and the environment. Generic screening levels used in the EAR are criteria or standards published by the State of Tennessee and the U.S. Environmental Protection Agency (EPA), other regulatory entities, or results from applicable studies conducted during the Kingston Recovery Project. These generic screening levels are described in the Technical Memorandum, *Proposed Screening Levels for Data Analysis in Environmental Assessment Report (EAR)* (**Attachment A**).

Except for surface stream water used as domestic water supply, the generic screening levels used in the EAR are not applicable to human health exposure assessment. As such, the SSL_{HH} described in this Technical Memorandum will be used in the HHRA to evaluate CCR Parameters in exposure pathways (e.g., sediment, fish tissue) for which there are no generic human health screening levels. For the CARA, concentrations of CCR Parameters reported in a media data set are compared to SSL_{HH}, which allows the CARA to focus on the subset of CCR Parameters that may contribute to risk. CCR Parameters above the SSL_{HH} will be further evaluated in the HHRA as part of the CARA. The methods used to derive SSL_{HH} for potential human exposure to CCR Parameters in environmental media near the TDEC Order plants are described in detail in the following sections of this Technical Memorandum. If CCR Parameter concentrations are lower than the SSL_{HH}, these CCR parameters will not be further evaluated in the HHRA. CCR Parameters with concentrations higher than the SSL_{HH} will be further evaluated in the HHRA but should not be interpreted as evidence of unacceptable risk to human health.

POTENTIAL HUMAN RECEPTORS AND PATHWAYS

The TDEC Order plants covered by the TDEC Order are similar. They were constructed during an approximately 20-year period between the early 1950s and mid-1970s. The environmental settings are similar across the fleet. The TDEC Order plants are located on large rivers that are sources of public drinking water supplies and are widely used for boating and water sports, fishing, and shoreline activities. CCR Parameters potentially released from the CCR management units could be transported to nearby surface streams and rivers where human exposure might occur. Possible movement of CCR Parameters in groundwater beneath CCR management units to offsite potable wells and springs is another potential exposure pathway being considered in the HHRA.

Based on current knowledge of the TDEC Order plants and adjacent land use, human health risks for one onsite and four offsite human receptors are being assessed. These receptors and exposure pathways are described below.

POTENTIAL ONSITE RECEPTORS

TVA still actively manages CCR at the BRF Plant, CUF Plant, and KIF Plant but each of these also has previously closed CCR units. The BRF Plant is phasing out coal-fired power generation. Coal-fired power generation has ceased at the JOF Plant and the facility is in the process of being decommissioned. The JSF Plant and WBF Plant have been decommissioned. The ALF Plant is in the process of closing its CCR management units by removal to a lined landfill.

Trespasser

Casual unauthorized visitors (trespassers) might access closed CCR units in locations where there are no physical barriers (e.g., fencing or barricades), but the opportunity for direct contact with CCR Parameters in environmental media are extremely limited for this potential receptor. In addition, compared to the onsite trespasser the onsite worker described below is the more highly exposed receptor and the SSL_{HH} developed for that worker would be protective of the potential trespasser. Therefore, no SSL_{HH} were developed for the trespasser.

Onsite Worker

Under current and reasonable future land uses, onsite workers are expected to have only limited direct contact with CCR or environmental media impacted by CCR once a final cover has been installed. Direct contact to CCR material would be limited to an onsite worker engaged in minor repairs to the infrastructure (e.g., piping, surface water management, etc.), or replacing rip-rap on exterior retention dikes in locations where seeps may have occurred prior to closure. Such occasional maintenance projects may occur, but would be of short duration (i.e., exposure frequency of 20 days or less). Consequently, an onsite worker who is not engaged in large-scale construction projects or daily CCR management is the most applicable onsite receptor.

Groundwater beneath the TVA facilities is not a source of potable water and is unlikely to be a future source of potable water under reasonably anticipated future land use. The onsite worker would have, at most, minor incidental contact with surface stream water or stream sediments. The SSL_{HH} for the onsite worker assumes the following routes of exposure to CCR parameters in CCR material or soil (Soil SSL_{HH}):

- Incidental ingestion of soil or CCR material
- Dermal exposure to soil or CCR material
- Inhalation of particulates released from soil or CCR material
- External exposure to ionizing radiation (radium-226+228) from soil or CCR material.

POTENTIAL OFFSITE RECEPTORS

Four potential future offsite human receptor scenarios have been identified that are considered common to most TDEC Order plants under current and reasonable future land use.

- Residential use of surface stream water for domestic water supply
- Private residential use of groundwater and springs for potable supply
- Recreational use of rivers and streams
- Consumption of fish taken from rivers and streams near the TDEC Order plants.

These receptor scenarios are described in more detail below.

Residential Use of Surface Stream Water for Domestic Water Supply

Except for the ALF Plant (located on McKellar Lake Harbor in the Port of Memphis), there are public water utilities with intakes on the rivers where TDEC Order plants are located. State of Tennessee and EPA water quality criteria and standards are the human health screening levels for domestic water supply and surface stream water used in the EAR and are sufficient and appropriate for assessing human health risk for residential use of surface stream water as a source for domestic water supply. Consequently, no SSL_{HH} were developed for this receptor. These screening levels are described in the Technical Memorandum*, Proposed Screening Levels for Data Analysis in Environmental Assessment Report (EAR)* **(Attachment A)**.

Residential Use of Groundwater and Springs for Private Potable Supply

The potential migration of CCR Parameters in onsite groundwater to offsite locations where there may be private potable wells or springs will be addressed by water use surveys and groundwater modeling. EPA drinking water standards and Tennessee Groundwater Protection Standards consistent with the Federal CCR Rule are the human health screening levels for CCR Parameters in groundwater and are sufficient and appropriate for assessing human health risk for residential potable use of groundwater and springs. Consequently, no SSL_{HH} were developed for this receptor. These screening levels are described in the

Technical Memorandum, *Proposed Screening Levels for Data Analysis in the Environmental Assessment Report (EAR)* (**Attachment A**).

Recreational Receptors

An important part of TVA's mission is to support recreational use of the Tennessee Valley's environmental resources. The rivers and reservoirs around TDEC Order plants are used for recreational activities year-round. Fishing from the shore and from boats occurs almost all year, with springtime being particularly popular for sport fishing. Water sports such as swimming, water skiing, and jet skiing occur primarily during the warmer months of the year and coincide with high pool levels in the reservoir sections of the major rivers where TDEC Order plants are located. The cooler months coincide with lower pool levels, which results in areas of seasonally-exposed sediments near the shoreline.

The SSL_{HH} derived for potential human exposures to CCR Parameters during recreational activities assume the receptors are residents who live near TDEC Order plants and actively use the rivers and streams for recreation. Consistent with EPA default exposure factors, the total exposure duration for a resident engaged in recreational activities is assumed to be 26 years. Age-specific exposure factors (e.g., body weight, skin surface area, and sediment ingestion rates) were considered in deriving the SSL_{HH} for the beachcomber receptor exposure to CCR parameters in seasonally-exposed stream sediments. Exposure could begin at birth and continue into adulthood. Very young children (birth to < 6 years of age), and older children/adolescents (older than six years and up to 16 years of age) are considered more sensitive to non-cancer health effects and mutagenic carcinogens than adults. SSL_{HH} derived for non-cancer health effects for a young child exposed to chemical typically are lower (more conservative) than SSL_{HH} for an adult.

Recreational Beachcomber

During the cooler months, people engage in activities such as beachcombing, camping, and fishing along the riverbanks and accessible areas of seasonally-exposed sediments. For the HHRA, seasonally-exposed sediment is defined as sediment in near-shore areas of lakes and streams that are not completely covered by water during seasonally low water levels, thus are accessible to humans and wildlife during those periods. Sediments in the stream channels that are submerged under water all year are not a complete pathway of exposure for this receptor and will not be evaluated in the HHRA.

Recreational beachcomber receptors are likely adults (i.e., 16 years and older) and older children/adolescents (i.e., 6 to <16 years old) who do not require constant adult supervision. However, younger children (i.e., 0 to <6 years old) also may occasionally be present during these activities. Accordingly, a child recreational beachcomber receptor was included in the development of SSL_{HH}. Infants and toddlers (i.e., 0 to <2 years old) may accompany adults but would be expected to be in strollers or on blankets that would have limited opportunity for direct contact with seasonally-exposed sediments.

The following routes of exposure were considered in deriving receptor-specific screening levels for contact with CCR Parameters to seasonally-exposed sediment (Sediment SSL_{HH}):

- Incidental ingestion of sediment
- Dermal exposure
- External exposure to ionizing radiation (radium-226+228).

The recreational beachcomber receptor may occasionally ingest or have dermal contact with surface stream water while walking across wet areas, picking up objects under shallow water, or cleaning hands and fishing tackle. However, these routes of exposure are limited and not expected to contribute substantially to risk for this receptor. Furthermore, recreational exposure with CCR Parameters in surface stream water is covered by screening levels for use of surface stream water as a domestic water supply.

Recreational Swimmer

Swimming, wading, and other water-contact activities occur primarily during the warmer months of the year when water levels are at high pool and most sediments are under water. The same individual may be a recreational swimmer or water skier from April through September and a beachcomber from October through March. Recreational swimmers may come into contact with CCR Parameters in river or stream water via incidental ingestion of surface stream water and dermal contact with surface stream water. Rather than deriving separate screening levels for recreational contact with surface stream water, human health screening levels for domestic water supply, as described in the Technical Memorandum, *Proposed Screening Levels for Data Analysis in the Environmental Assessment Report (EAR)* **(Appendix A),** will be used to evaluate exposure for swimmers. Frequency and intensity of exposure to surface water used as domestic water supply by receptors of all age groups are greater than exposure to surface water through recreational contact, thus the screening levels for domestic water supply are protective of swimmers. CCR Parameters with concentrations higher than the screening levels will be further evaluated in the HHRA but should not be interpreted as evidence of unacceptable risk to human health. No SSL_{HH} were developed for recreational swimmers.

Consumer of Locally-Caught Sport Fish

Fishing, both from shore and from boats, is a popular activity year-round, and people of all ages [adults (ages 16 years and older), adolescents (6 to <16 years old) and children (0 to <6 years old)] eat locally-caught fish. In some cases, the recreational beachcomber also consumes fish that they have caught. Fish are also consumed by members of a fisherperson's family who do not themselves catch the fish. SSL_{HH} for CCR parameters in fish were derived using data presented in *EPA 2014b. Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations (*National Health and Nutrition Examination Survey *[NHANES] 2003-2010).* The *NHANES* (part of the National Center for Health Statistics) collected information on the types and amounts of fish consumed by demographics and geographic regions within the U.S. The purpose of the NHANES data was to support the development of ambient water quality standards for protection of human health based on the concentrations of contaminants in fish tissue. However, the data are also relevant for deriving SSL_{HH} for the HHRAs as discussed below.

NHANES collected information on consumption of fish in the following categories: Total Fish (all types); Marine Finfish and Shellfish; Total Finfish; Total Shellfish; Freshwater Finfish and Estuarine Shellfish; and Finfish and Shellfish by Trophic Level. Data were aggregated by demographics (including age ranges), and by U.S. geographic regions. The SSL_{HH} are based on consumption rates for Freshwater Finfish and Estuarine Shellfish for the Inland South geographic region (includes Tennessee). This dataset is most likely to represent the amounts of locally-caught sportfish (finfish) consumed by receptors in the Tennessee Valley. The 95th percentile consumption rates (Table 1) were used in the calculation of the SSL_{HH}.

The types of fish sampled for the environmental investigations represented different feeding guilds, as relevant for the ecological risk assessment. While all fish sampled will be evaluated in the ecological risk assessment, gizzard shad whole-body tissue results will be excluded from the HHRA because humans use this type of fish as bait for game fish. Turtles, frogs, mussels, and crayfish may be infrequently consumed, but their consumption is minor relative to that of fish, thus will not be evaluated separately in the HHRA. Receptor-specific screening levels for consumption of fish (Fish SSL_{HH}) is protective of exposures from ingestion of these other minor sources.

EXPOSURE PARAMETERS FOR DERIVING HUMAN HEALTH SCREENING LEVELS

The exposure parameters and rationale for the derivation of SSL_{HH} are presented in **Table 1**. The sources for the exposure parameters used in the derivation of SSL_{HH} include:

- Risk Assessment Guidance for Superfund (RAGS). Volume I: Human Health Evaluation Manual (Part A) (EPA 1989)
- Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (EPA 2002)
- Risk Assessment Guidance for Superfund (RAGS) Volume I: Human Health Evaluation Manual (Part E) (EPA 2004)
- Exposure Factors Handbook: 2011 Edition (EPA 2011)
- Compilation and Review of Data on Relative Bioavailability of Arsenic in Soil (EPA 2012)
- Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors (EPA 2014a)
- Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations (NHANES 2003-2010) (EPA 2014b)
- Region 4 Human Health Risk Assessment Supplemental Guidance (EPA 2018)
- Exposure Factors Handbook Chapter 3 (Update): Ingestion of Water and Other Select Liquids (EPA 2019)
- Preliminary Remediation Goals for Radionuclides (PRG) (EPA 2020b).

TOXICITY VALUES FOR DERIVING HUMAN HEALTH SCREENING LEVELS

Toxicity values for the SSL_{HH} calculations were obtained from the following sources, in general order of preference:

- Integrated Risk Information System (IRIS) Database as cited in EPA's Regional Screening Level (RSL) Tables (EPA 2020a)
- Provisional Peer Reviewed Toxicity Values (PPRTVs) as cited in EPA's RSL Tables (EPA 2020a)
- Agency for Toxic Substances and Disease Registry (ATSDR) Toxicology Profiles as cited in EPA's RSL Tables (EPA 2020a)
- California EPA toxicity values as cited in EPA's RSL Tables (EPA 2020a)
- PPRTV Appendix Screening Toxicity Values as cited in EPA's RSL Tables (EPA 2020a)
- Health Effects Assessment Summary Tables as cited in EPA's RSL Tables (EPA 2020a).

For Radium-226+228 specifically, default slope factors from the Preliminary Remediation Goals (PRG) calculator (EPA, 2020b) were used for the calculation of SSL_{HH}. Inorganic mercury is listed as a CCR parameter and the toxicity factor for the mercuric forms are used in deriving SSL_{HH} for non-biological media (sediment and CCR material). However, inorganic mercury is converted to methyl mercury by biological processes in the aquatic environment which then accumulates in biological tissues including fish muscle (fillet). It is assumed that human exposure from fish consumption is to methyl mercury rather than inorganic mercury. The chronic reference dose (RfD) of 0.0001 milligrams per kilogram per day (mg/kg-day) for methyl mercury was conservatively used to develop the Fish SSL_{HH} for consumption of locally caught fish. The toxicity values are presented in **Table 2**.

RfDs and reference concentrations (RfCs) were used for residential and recreational receptors; however, where available, subchronic RfDs and RfCs were used for onsite workers. Subchronic RfDs are specifically developed to be protective for short-term exposure to a compound, and the EPA recommends that subchronic oral RfDs should generally be used to evaluate the potential noncarcinogenic effects of exposure periods between two weeks and seven years. Therefore, since onsite workers are assumed to have an exposure duration of one year, subchronic RfDs and RfCs were generally considered more applicable than chronic values. However, the available subchronic RfDs for cadmium and copper are more conservative than the chronic toxicity values so additional review of the toxicity data was conducted to confirm the appropriate toxicity values for the onsite worker.

- An intermediate-duration oral minimal risk level (MRL) for cadmium (ATSDR 2012) was developed based on effects on bone density, whereas renal toxicity has been selected as the critical effect for EPA's IRIS chronic RfD (EPA 2020a) and a number of risk assessments (Health Canada 2020). EPA's IRIS chronic RfD of 0.001 mg/kg-day was last revised in 1989, but it is consistent with values developed by newer studies (e.g., 0.0008 mg/kg-day breakpoint indicative of the onset of pathological changes in renal effects [JECFA 2011]). As a result, the cadmium chronic RfD as presented in EPA's

RSL table (EPA 2020a) was used to evaluate both chronic and subchronic effects in the derivation of SSL_{HH} for cadmium for the onsite worker.

- Copper is an essential element, although both copper deficiency and overexposure can result in adverse effects. ATSDR (2004) noted that a number of acute-duration studies support the gastrointestinal tract as the sensitive target of toxicity in human, and therefore developed an intermediate-duration oral MRL for copper based on the only human study identified by ATSDR that evaluated gastrointestinal effects following intermediate exposure. Due to the limited availability of intermediate human studies to support the subchronic oral MRL, the more conservative and widely accepted copper chronic RfD as presented in EPA's RSL table (EPA 2020a) was used to evaluate both chronic and subchronic effects in the derivation of SSL_{HH} for copper.

HUMAN HEALTH SCREENING LEVELS CALCULATIONS

The equations used to develop SSL_{HH} for potentially complete exposure pathways to CCR Parameters by onsite workers, recreational beachcomber, and recreational user with consumption of locally-caught sport fish presented in this section are consistent with EPA guidance (EPA 1989; 1991; 2002; 2004; 2009a). For CCR Parameters that have been identified as producing carcinogenic effects, exposures are averaged for different stages of development by applying age-adjusted factors and equations adjusted in accordance with EPA guidance for carcinogenic effects (EPA 2020a). The exposure assumptions used in the SSL_{HH} calculations are presented in **Table 1**. The toxicity values used in the SSL_{HH} calculations are presented in **Table 2**. The SSL_{HH} for carcinogenic and non-carcinogenic CCR Parameters are based on a target cancer risk and hazard of $1x10^{-6}$ and 0.1, respectively. Detailed calculations of the carcinogenic and non-carcinogenic SSL_{HH} for each receptor are presented in **Tables B.1** through **B.9** in **Attachment B**.

The PRG equations presented in EPA's PRG User's Guide (EPA 2020b) and below were used in the quantification of potentially complete exposure pathways to Radium-226 and -228 within EPA's Peak PRG Calculator (EPA 2020b). Radium-226+228 SSL_{HH} were calculated using EPA's Peak PRG Calculator (EPA 2020b). Inputs and outputs from the Peak PRG calculator are presented in **Attachment C**.

The quantification of lead exposure differs from other analytes. Cause-and-effect relationships in humans have been correlated with blood concentrations of lead. Therefore, the preferred SSL_{HH} derivation approach for lead is the estimation of human blood lead concentrations associated with an exposure situation. The lead soil SSL_{HH} for an onsite worker, and lead sediment SSL_{HH} for an adult and adolescent recreational beachcomber were calculated using EPA's Adult Lead Model (ALM) (EPA 2017a). The ALM calculation output is presented in **Table B.10**. The sediment SSL_{HH} for a child recreational beachcomber was calculated using the Integrated Exposure Uptake Biokinetic Model (IEUBK) Version 1.1 (EPA 2009b). The IEUBK calculation output is presented in **Attachment D**. Default IEUBK input parameters were used except for a mother's blood lead concentration at childbirth of 0.6 microgram per deciliter (µg/dL) (EPA 2017b) and a sediment ingestion rate of 200 mg/day for age groups 12 to 84 months. A defensible SSL_{HH} for the consumption of locally caught sport fish could not be identified in applicable regulatory guidance or the scientific literature, nor could a SSL_{HH} be readily calculated. As such, a fish SSL_{HH} was not established for

lead. Lead will be evaluated as part of the HHRA, in the case that lead is detected in fish filet tissue collected as part of the environmental investigations.

EXPOSURE ROUTE AND PATHWAY-SPECIFIC SSL_{HH}

Soil

Onsite Worker Incidental Soil Ingestion

Cancer Incidental Ingestion SSL_{HH} (mg/kg) =

$$\frac{TR \times BW_w \times AT}{IR_{soil} \times EF_{soil} \times CSF_o \times ED_w \times RBA \times CF}$$

Where:

- TR = Target risk (unitless)
- BW_w = Body weight (kg)
- AT = Averaging time (period over which exposure is averaged – days)
- IR_{soil} = Ingestion rate of soil (milligrams per day [mg/day])
- EF_{soil} = Exposure frequency (days per year [days/year])
- CSF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$
- ED_w = Exposure duration (years)
- RBA = Relative bioavailability factor (unitless)
- CF = Conversion factor (10^{-6} kg/mg)

Radiological Cancer Incidental Ingestion SSL_{HH} (picocuries [pCi] per gram [g]) =

$$\frac{TR}{IR_{soil} \times EF_{soil} \times SF_o \times ED_w \times CF}$$

Where:

- TR = Target risk (unitless)
- IR_{soil} = Ingestion rate of soil (mg/day)
- EF_{soil} = Exposure frequency (days/year)
- SF_o = Ingestion slope factor (risk/pCi)

ED_w = Exposure duration (years)

CF = Conversion factor (10^{-3} g/mg)

Noncancer Incidental Ingestion SSL_{HH} (mg/kg) =

$$\frac{THQ \times BW_w \times AT}{IR_{soil} \times EF_{soil} \times \frac{1}{sRfD_o} \times ED_w \times RBA \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

BW_w = Body weight (kg)

AT = Averaging time (period over which exposure is averaged – days)

IR_{soil} = Ingestion rate of soil (mg/day)

EF_{soil} = Exposure frequency (days/year)

$sRfD_o$ = Subchronic oral reference dose (mg/kg-day)

ED_w = Exposure duration (years)

RBA = Relative bioavailability factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

Onsite Worker Dermal Soil Contact

Cancer Dermal Absorption SSL_{HH} (mg/kg) =

$$\frac{TR \times BW_w \times AT}{AF \times ABS \times SA_{soil} \times CSF_d \times EF_{soil} \times ED_w \times CF}$$

Where:

TR = Target risk (unitless)

BW_w = Body weight (kg)

AT = Averaging time (period over which exposure is averaged – days)

AF = Adherence factor of soil to skin (mg/square centimeter [cm^2])

ABS = Dermal absorption factor (unitless)

SA_{soil} = Skin surface area available for contact (cm^2)

CSF_d = Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$

EF_{soil} = Exposure frequency (days/year)

ED_w = Exposure duration (years)

CF = Conversion factor (10^{-6} kg/mg)

Noncancer Dermal Absorption SSL_{HH} (mg/kg) =

$$\frac{THQ \times BW_w \times AT}{AF \times ABS \times SA_{soil} \times \frac{1}{sRfD_d} \times EF_{soil} \times ED_w \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

BW_w = Body weight (kg)

AT = Averaging time (period over which exposure is averaged – days)

AF = Adherence factor of soil to skin (mg/cm^2)

ABS = Dermal absorption factor (unitless)

SA_{soil} = Skin surface area available for contact (cm^2)

$sRfD_d$ = Subchronic dermal reference dose (mg/kg-day)

EF_{soil} = Exposure frequency (days/year)

ED_w = Exposure duration (years)

CF = Conversion factor (10^{-6} kg/mg)

Onsite Worker Inhalation of Soil Particulates

Cancer Inhalation of Particulates SSL_{HH} (mg/kg) =

$$\frac{TR \times AT \times CF}{\left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times IUR \times EF_w \times ED_w}$$

Where:

TR = Target risk (unitless)

AT = Averaging time (days)

CF = Conversion factor (10^{-3} mg per µg)

PEF = Particulate emission factor for Other Construction Activities (cubic meters [m^3]/kg)

ET_w = Exposure time (hours/day)

IUR = Inhalation unit risk $(\mu g/m^3)^{-1}$

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

Radiological Cancer Inhalation of Particulates SSL_{HH} (pCi/g) =

$$\frac{TR}{\left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times SF_i \times EF_w \times IRA_w \times CF \times ED_w}$$

Where:

TR = Target risk (unitless)

PEF = Particulate emission factor for Other Construction Activities (m^3/kg)

ET_w = Exposure time (hours/day)

SF_i = Inhalation slope factor (risk/pCi)

EF_w = Exposure frequency (days/year)

IRA_w = Inhalation rate (m^3/day)

CF = Conversion factor (1000 g/kg)

ED_w = Exposure duration (years)

Noncancer Inhalation of Particulates SSL_{HH} (mg/kg) =

$$\frac{THQ \times AT}{\left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times \frac{1}{RfC} \times EF_w \times ED_w}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

PEF = Particulate emission factor (cubic meters [m^3]/kg)

ET_w = Exposure time (hours/day)

RfC = Reference concentration (mg/m^3)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

Radiological Cancer External Exposure SSL_{HH} (pCi/g) =

$$\frac{TR}{SF_{ext} \times EF_{soil} \times ACF_{ext} \times ED_w \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times GSF}$$

Where:

TR = Target risk (unitless)

SF_{ext} = External exposure slope factor (risk/yr per pCi/g)

EF_{soil} = Exposure frequency (days/year)

ACF_{ext} = Area correction factor (unitless)

ED_w = Exposure duration (years)

ET_w = Exposure time (hours/day)

GSF = Gamma shielding factor (unitless)

Sediment

Recreational Beachcomber Incidental Sediment Ingestion

Cancer Incidental Ingestion SSL_{HH} (mg/kg) =

$$\frac{TR \times AT}{CSF_o \times IF_{sed} \times RBA \times CF}$$

Where:

$$IF_{sed} = \frac{ED_{rec-c} \times EF_{rec-c} \times IR_{sed-c}}{BW_{rec-c}} + \frac{ED_{rec-y} \times EF_{rec-y} \times IR_{sed-y}}{BW_{rec-y}} + \frac{ED_{rec-a} \times EF_{rec-a} \times IR_{sed-a}}{BW_{rec-a}};$$

and

TR = Target risk (unitless)

AT = Averaging time (days)

CSF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$

IF_{sed} = Age-adjusted sediment ingestion factor (mg/kg)

RBA = Relative bioavailability factor

CF = Conversion factor (10^{-6} kg/mg)

ED_{rec-c} = Child (0 to <6) exposure duration (years)

EF_{rec-c} = Child (0 to <6) exposure frequency (days/year)

IR_{sed-c} = Child (0 to <6) sediment ingestion rate (mg/day)

BW_{rec-c} = Child (0 to <6) body weight (kg)

ED_{rec-y} = Adolescent (6 to <16) exposure duration (years)

EF_{rec-y} = Adolescent (6 to <16) exposure frequency (days/year)

IR_{sed-y} = Adolescent (6 to <16) sediment ingestion rate (mg/day)

BW_{rec-y} = Adolescent (6 to <16) body weight (kg)

ED_{rec-a} = Adult (16 to <26) exposure duration (years)

EF_{rec-a} = Adult (16 to <26) exposure frequency (days/year)

IR_{sed-a} = Adult (16 to <26) sediment ingestion rate (mg/day)

BW_{rec-a} = Adult (16 to <26) body weight (kg)

Radiological Cancer Incidental Ingestion SSL_{HH} (pCi/g) =

$$\frac{TR}{SF_o \times IF_{sed} \times CF}$$

Where:

$$IF_{sed}=(ED_{rec\text{-}cy} \times EF_{rec\text{-}cy} \times IR_{sed\text{-}cy})+(ED_{rec\text{-}a} \times EF_{rec\text{-}a} \times IR_{sed\text{-}a})\ ;$$

and

TR = Target risk (unitless)

SF_o = Ingestion slope factor (risk/pCi)

IF_{sed} = Age-adjusted sediment ingestion factor (mg)

CF = Conversion factor (10^{-3} g/mg)

$ED_{rec\text{-}cy}$ = Child (0 to <6) and adolescent (6 to <16) exposure duration (years)

$EF_{rec\text{-}cy}$ = Child (0 to <6) and adolescent (6 to <16) exposure frequency (days/year)

$IR_{sed\text{-}cy}$ = Child (0 to <6) and adolescent (6 to <16) sediment ingestion rate (mg/day)

$ED_{rec\text{-}a}$ = Adult (16 to <26) exposure duration (years)

$EF_{rec\text{-}a}$ = Adult (16 to <26) exposure frequency (days/year)

$IR_{sed\text{-}a}$ = Adult (16 to <26) sediment ingestion rate (mg/day)

Noncancer Incidental Ingestion SSL_{HH} for a child (0 to <6) (mg/kg) =

$$\frac{THQ \times AT \times BW_{rec\text{-}c}}{\frac{1}{RfD_o} \times ED_{rec\text{-}c} \times EF_{rec\text{-}c} \times IR_{sed\text{-}c} \times RBA \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

$BW_{rec\text{-}c}$ = Child (0 to <6) body weight (kg)

RfD_o = Oral reference dose (mg/kg-day)

$ED_{rec\text{-}c}$ = Child (0 to <6) exposure duration (years)

$EF_{rec\text{-}c}$ = Child (0 to <6) exposure frequency (days/year)

$IR_{sed\text{-}c}$ = Child (0 to <6) soil ingestion rate (mg/day)

RBA = Relative bioavailability factor

CF = Conversion factor (10^{-6} kg/mg)

Noncancer Incidental Ingestion SSL_{HH} for an adolescent (6 to <16) (mg/kg) =

$$\frac{THQ \times AT \times BW_{rec\text{-}y}}{\frac{1}{RfD_o} \times ED_{rec\text{-}y} \times EF_{rec\text{-}y} \times IR_{sed\text{-}y} \times RBA \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

$BW_{rec\text{-}y}$ = Adolescent (6 to <16) body weight (kg)

RfD_o = Oral reference dose (mg/kg-day)

$ED_{rec\text{-}y}$ = Adolescent (6 to <16) exposure duration (years)

$EF_{rec\text{-}y}$ = Adolescent (6 to <16) exposure frequency (days/year)

$IR_{sed\text{-}y}$ = Adolescent (6 to <16) soil ingestion rate (mg/day)

RBA = Relative bioavailability factor

CF = Conversion factor (10^{-6} kg/mg)

Recreational Beachcomber Dermal Contact with Sediment

Cancer Dermal Absorption SSL_{HH} (mg/kg) =

$$\frac{TR \times AT}{CSF_d \times DF_{sed} \times ABS \times CF}$$

Where:

$$DF_{sed} = \frac{ED_{rec\text{-}c} \times EF_{rec\text{-}c} \times SA_{rec\text{-}c} \times AF_{rec\text{-}c}}{BW_{rec\text{-}c}} + \frac{ED_{rec\text{-}y} \times EF_{rec\text{-}y} \times SA_{rec\text{-}y} \times AF_{rec\text{-}y}}{BW_{rec\text{-}y}} + \frac{ED_{rec\text{-}a} \times EF_{rec\text{-}a} \times SA_{rec\text{-}a} \times AF_{rec\text{-}a}}{BW_{rec\text{-}a}};$$

and

TR = Target risk (unitless)

AT = Averaging time (days)

CSF_d = Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$

DF_{sed} = Age-adjusted sediment dermal factor (mg/kg)

ABS = Skin absorption factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

$ED_{rec\text{-}c}$ = Child (0 to <6) exposure duration (years)

$EF_{rec\text{-}c}$ = Child (0 to <6) exposure frequency (days/year)

$SA_{rec\text{-}c}$ = Child (0 to <6) skin surface area (cm^2)

$AF_{rec\text{-}c}$ = Child (0 to <6) skin adherence factor (mg/cm^2)

$BW_{rec\text{-}c}$ = Child (0 to <6) body weight (kg)

$ED_{rec\text{-}y}$ = Adolescent (6 to <16) exposure duration (years)

$EF_{rec\text{-}y}$ = Adolescent (6 to <16) exposure frequency (days/year)

$SA_{rec\text{-}y}$ = Adolescent (6 to <16) skin surface area (cm^2)

$AF_{rec\text{-}y}$ = Adolescent (6 to <16) skin adherence factor (mg/cm^2)

$BW_{rec\text{-}y}$ = Adolescent (6 to <16) body weight (kg)

$ED_{rec\text{-}a}$ = Adult (16 to <26) exposure duration (years)

$EF_{rec\text{-}a}$ = Adult (16 to <26) exposure frequency (days/year)

$SA_{rec\text{-}a}$ = Adult (16 to <26) skin surface area (cm^2)

$AF_{rec\text{-}a}$ = Adult (16 to <26) skin adherence factor (mg/cm^2)

$BW_{rec\text{-}a}$ = Adult (16 to <26) body weight (kg)

Noncancer Dermal Absorption SSL_{HH} for a child (0 to <6) (mg/kg) =

$$\frac{THQ \times AT \times BW_{rec\text{-}c}}{\frac{1}{RfD_d} \times ED_{rec\text{-}c} \times EF_{rec\text{-}c} \times SA_{rec\text{-}c} \times AF_{rec\text{-}c} \times ABS \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

$BW_{rec\text{-}c}$ = Child body weight (kg)

RfD_d = Dermal reference dose (mg/kg-day)

ED_{rec-c} = Child (0 to <6) exposure duration (years)

EF_{rec-c} = Child (0 to <6) exposure frequency (days/year)

SA_{rec-c} = Child (0 to <6) skin surface area (cm^2)

AF_{rec-c} = Child (0 to <6) skin adherence factor (mg/cm^2)

ABS = Skin absorption factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

Noncancer Dermal Absorption SSL_{HH} for an adolescent (6 to <16) (mg/kg) =

$$\frac{THQ \times AT \times BW_{rec-y}}{\frac{1}{RfD_d} \times ED_{rec-y} \times EF_{rec-y} \times SA_{rec-y} \times AF_{rec-y} \times ABS \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

BW_{rec-y} = Adolescent body weight (kg)

RfD_d = Dermal reference dose (mg/kg-day)

ED_{rec-y} = Adolescent (6 to <16) exposure duration (years)

EF_{rec-y} = Adolescent (6 to <16) exposure frequency (days/year)

SA_{rec-y} = Adolescent (6 to <16) skin surface area (cm^2)

AF_{rec-y} = Adolescent (6 to <16) skin adherence factor (mg/cm^2)

ABS = Skin absorption factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

Radiological Cancer External Exposure SSL_{HH} (pCi/g) =

$$\frac{TR}{SF_{ext} \times EF_{rec} \times \left(\frac{1\ year}{365\ day}\right) \times ED_{rec} \times ACF_{ext} \times ET_{rec} \times \left(\frac{1\ day}{24\ Hours}\right) \times GSF}$$

Where:

TR = Target risk (unitless)

SF_{ext} = External exposure slope factor (risk/yr per pCi/g)

EF_{rec} = Exposure frequency (days/year)

ED_{rec} = Exposure duration (years)

ACF_{ext} = Area correction factor (unitless)

ET_{rec} = Exposure time (hours/year)

GSF = Gamma shielding factor (unitless)

Fish

Consumer of Locally-Caught Sport Fish

Cancer Ingestion SSL_{HH} (mg/kg) =

$$\frac{TR \times AT}{CSF_o \times IF_{fish} \times CF}$$

Where:

$$IF_{fish} = \frac{ED_{fish\text{-}c} \times EF_{fish\text{-}c} \times IR_{fish\text{-}c}}{BW_{fish\text{-}c}} + \frac{ED_{fish\text{-}y} \times EF_{fish\text{-}y} \times IR_{fish\text{-}y}}{BW_{fish\text{-}y}} + \frac{ED_{fish\text{-}a} \times EF_{fish\text{-}a} \times IR_{fish\text{-}a}}{BW_{fish\text{-}a}};$$

and

TR = Target risk (unitless)

AT = Averaging time (days)

CSF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$

IF_{fish} = Age-adjusted fish ingestion factor (mg/kg)

CF = Conversion factor (10^{-6} kg/mg)

$ED_{fish\text{-}c}$ = Child (0 to <6) exposure duration (years)

$EF_{fish\text{-}c}$ = Child (0 to <6) exposure frequency (days/year)

$IR_{fish\text{-}c}$ = Child (0 to <6) fish consumption rate (mg/day)

BW_{fish-c} = Child (0 to <6) body weight (kg)

ED_{fish-c} = Adolescent (6 to <16) exposure duration (years)

EF_{fish-y} = Adolescent (6 to <16) exposure frequency (days/year)

IR_{fish-y} = Adolescent (6 to <16) fish consumption rate (mg/day)

BW_{fish-y} = Adolescent (6 to <16) body weight (kg)

ED_{fish-a} = Adult (16 to <26) exposure duration (years)

EF_{fish-a} = Adult (16 to <26) exposure frequency (days/year)

IR_{fish-a} = Adult (16 to <26) fish consumption rate (mg/day)

BW_{fish-a} = Adult (16 to <26) body weight (kg)

Radionuclide Cancer Ingestion SSL_{HH} (pCi/g) =

$$\frac{TR}{SF_f \times ED_{fish} \times EF_{fish} \times IR_{fish} \times \left(\frac{10^{-3}\ g}{1\ mg}\right) \times CF_{fish}}$$

Where:

TR = Target risk (unitless)

SF_f = Fish slope factor (risk/pCi)

ED_{fish} = Exposure duration (years)

EF_{fish} = Exposure frequency (days/year)

IR_{fish} = Fish consumption rate (mg/day)

CF_{fish} = Contaminated fish fraction (unitless)

Noncancer Ingestion SSL_{HH} for a child (0 to <6) (mg/kg) =

$$\frac{THQ \times AT \times BW_{fish-c}}{\frac{1}{RfD_o} \times ED_{fish-c} \times EF_{fish-c} \times IR_{fish-c} \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

$BW_{fish\text{-}c}$ = Child (0 to <6) body weight (kg)

RfD_o = Oral reference dose (mg/kg-day)

$ED_{fish\text{-}c}$ = Child (0 to <6) exposure duration (years)

$EF_{fish\text{-}c}$ = Child (0 to <6) exposure frequency (days/year)

$IR_{fish\text{-}c}$ = Child (0 to <6) fish consumption rate (mg/day)

CF = Conversion factor (10^{-6} kg/mg)

Noncancer Ingestion SSL_{HH} for an adolescent (6 to <16) (mg/kg) =

$$\frac{THQ \times AT \times BW_{fish\text{-}y}}{\frac{1}{RfD_o} \times ED_{fish\text{-}y} \times EF_{fish\text{-}y} \times IR_{fish\text{-}y} \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

$BW_{fish\text{-}y}$ = Adolescent (6 to <16) body weight (kg)

RfD_o = Oral reference dose (mg/kg-day)

$ED_{fish\text{-}y}$ = Adolescent (6 to <16) exposure duration (years)

$EF_{fish\text{-}y}$ = Adolescent (6 to <16) exposure frequency (days/year)

$IR_{fish\text{-}y}$ = Adolescent (6 to <16) fish consumption rate (mg/day)

CF = Conversion factor (10^{-6} kg/mg)

TOTAL SSL_{HH} CALCULATIONS

Total (i.e., including the relevant exposure pathways) onsite worker and recreational beachcomber SSL_{HH} were calculated based on a combination of exposure pathway-specific SSL_{HH}. In order to calculate a total SSL_{HH} that represents a CCR Parameter concentration in each medium that is protective of the identified exposure routes at a cumulative target cancer risk of 1×10^{-6} or a hazard quotient of 0.1, the target risk or hazard quotient for each exposure pathway-specific SSL_{HH} was apportioned across all routes of exposure within the pathway. A summary of cancer, non-carcinogenic, and lowest SSL_{HH} for each receptor is presented in **Table 3**.

Total SSL_{HH} for onsite workers were estimated using the following equations:

$$\text{Soil } SSL_{HH} = \frac{1}{SUM}$$

where:

$$SUM = \left(\frac{1}{\text{Ingestion } SSL_{HH}}\right) + \left(\frac{1}{\text{Dermal } SSL_{HH}}\right) + \left(\frac{1}{\text{Inhalation } SSL_{HH}}\right)$$

and where:

SSL_{HH} = cumulative SSL_{HH} for onsite workers (mg/kg)

SUM = sum of 1/exposure route-specific SSL_{HH}

Ingestion SSL_{HH} = SSL_{HH} for incidental ingestion of soil (mg/kg)

Dermal SSL_{HH} = SSL_{HH} for dermal contact with soil (mg/kg)

Inhalation SSL_{HH} = SSL_{HH} for inhalation of particulates (mg/kg)

Total SSL_{HH} for recreational beachcombers were estimated using the following equations:

$$\text{Sediment } SSL_{HH} = \frac{1}{SUM}$$

where:

$$SUM = \left(\frac{1}{\text{Ingestion } SSL_{HH}}\right) + \left(\frac{1}{\text{Dermal } SSL_{HH}}\right)$$

and where:

SSL_{HH} = cumulative SSL_{HH} for recreational beachcombers (mg/kg)

SUM = sum of 1/exposure route-specific SSL_{HH}

Ingestion SSL_{HH} = SSL_{HH} for incidental ingestion of sediment (mg/kg)

Dermal SSL_{HH} = SSL_{HH} for dermal contact with sediment (mg/kg)

CONCLUSION

This memorandum describes the methodology and assumptions used to derive SSL_{HH} for 1) onsite workers potentially exposed to CCR Parameters in CCR material or soil, 2) offsite recreational beachcombers potentially exposed to CCR parameters in seasonally exposed sediments, and 3) offsite consumers of locally-

caught sport fish potentially exposed to CCR parameters via the consumption of locally-caught sport fish. Human health screening levels for domestic water supply, as described in the Technical Memorandum, *Proposed Screening Levels for Data Analysis in the Environmental Assessment Report* (EAR) **(Appendix A)**, will be used to evaluate exposure for offsite swimmers. A summary of SSL_{HH} is presented in **Table 3**. These SSL_{HH} and screening levels for domestic water supply will be used to identify CCR parameters and exposure pathways to be further evaluated in the HHRA.

CLOSURE

This Technical Memorandum entitled *Proposed Receptor-Specific Screening Levels for Human Health* was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of TVA (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

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Reference: Proposed Receptor-Specific Screening Levels for Human Health

TABLES

Table 1 Exposure Assumptions Used in the Development of Human Health Receptor-Specific Screening Levels
Table 2 Toxicity Values Used in the Development of Human Health Receptor-Specific Screening Levels
Table 3 Summary of Human Health Receptor-Specific Screening Levels

ATTACHMENTS

Attachment A – Proposed Screening Levels for Data Analysis in Environmental Assessment Report (EAR)

Attachment B – Development of Receptor-Specific Screening Levels for Human Health
Table B.1 Cancer Receptor-Specific Screening Level Calculations for an Onsite Worker Exposed to Soil
Table B.2 Non-Cancer Receptor-Specific Screening Level Calculations for an Onsite Worker Exposed to Soil
Table B.3 Particulate Emissions Factor Calculation for an Onsite Worker
Table B.4 Cancer Receptor-Specific Screening Level Calculations for a Recreational User - Beachcomber Exposed to Sediment
Table B.5 Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Child) - Beachcomber Exposed to Sediment
Table B.6 Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Adolescent) - Beachcomber Exposed to Sediment
Table B.7 Cancer Receptor-Specific Screening Level Calculations for a Recreational User - Consumer of Locally Caught Sport Fish
Table B.8 Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Child) - Consumer of Locally-Caught Sport Fish
Table B.9 Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Adolescent) - Consumer of Locally-Caught Sport Fish
Table B.10 Adult Lead Model Calculation Spreadsheet

Attachment C –EPA PRG Calculator Inputs and Outputs
Table C.1 Peak PRG Calculator Input for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)
Table C.2 Peak PRG Calculator Ra-226 Output for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)
Table C.3 Peak PRG Calculator Ra-228 Output for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)
Table C.4 Peak PRG Calculator Input for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)
Table C.5 Peak PRG Calculator Ra-226 Output for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)
Table C.6 Peak PRG Calculator Ra-228 Output for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Attachment D – IEUBK Calculation Output

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Reference: Proposed Receptor-Specific Screening Levels for Human Health

TABLES

Table 1 – Exposure Assumptions Used in the Development of Receptor-Specific Screening Levels for Human Health

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
Soil and CCR Materials	On-Site Worker	Adult	Ingestion	IR_{soil}	Ingestion Rate of Soil	mg/day	330	-	-	Soil ingestion rate for a construction worker (EPA 2002)
				EF_w	Exposure Frequency	days/yr	20	-	-	5 days a week for 4 weeks (Site-specific assumption)
				CF	Conversion Factor	kg/mg	1E-06	-	-	-
				ED_w	Exposure Duration	yrs	1	-	-	Exposure duration for a construction worker (EPA 2002)
				RBA	Relative Bioavailability Factor	unitless	0.6 (Arsenic) 1 (Other chemicals)	-	-	Default (EPA 2012)
				BW_w	Body Weight	kg	80	-	-	Adult worker body weight (EPA 2014a)
				$AT\text{-}NC_w$	Averaging Time (noncancer)	days	28	-	-	7 days/week for 4 weeks
				AT- C	Averaging Time (cancer)	days	25,550	-	-	Lifetime (70 years) x 365 days/year (EPA 1989)
			Dermal	CF	Conversion Factor	kg/mg	1E-06	-	-	-
				AF	Adherence factor of soil to skin	mg/cm^2-event	0.3	-	-	Default adherence factors for a construction worker (EPA 2002)
				ABS	Dermal absorption fraction	unitless	Chemical Specific	-	-	EPA 2004
				SA_{soil}	Skin surface area available for contact	cm^2	3527	-	-	Worker skin surface area (EPA 2014a).
				EF_w	Exposure Frequency	days/yr	20	-	-	5 days a week for 4 weeks (Site-specific assumption)
				Edw	Exposure Duration	yrs	1	-	-	Exposure duration for a construction worker (EPA 2002)
				BW_w	Body Weight	kg	80	-	-	Adult worker body weight (EPA 2014a)
				$AT\text{-}NC_w$	Averaging Time (noncancer)	days	28	-	-	7 days/week for 4 weeks
				AT- C	Averaging Time (cancer)	days	25,550	-	-	Lifetime (70 years) x 365 days/year (EPA 1989)
			Inhalation	CF	Conversion Factor	mg/µg	1E-03	-	-	-
				IRA	Inhalation Rate for Radionuclide	m^3/day	60	-	-	EPA 2020b
				ET_w	Exposure Time	hours/day	8	-	-	Worker air exposure time (EPA 2014a)
				PEF	Particulate Emission Factor	m^3/kg	1.56E+06	-	-	Regional Screening Level (RSL) Calculator Construction Worker - Other Construction Activities scenario (Site-specific assumption)
				EF_w	Exposure Frequency	days/yr	20	-	-	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	yrs	1	-	-	Exposure duration for a construction worker (EPA 2002)
				$AT\text{-}NC_w$	Averaging Time (noncancer)	days	28	-	-	7 days/week for 4 weeks
				AT- C	Averaging Time (cancer)	days	25,550	-	-	Lifetime (70 years) x 365 days/year (EPA 1989)
			External Exposure	EF_{soil}	Exposure Frequency	days/yr	20	-	-	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	yrs	1	-	-	Exposure duration for a construction worker (EPA 2002)
				ACF	Site Area for Area Correction Factor	acres	0.5	-	-	EPA 2020b
				GSF	Clean Soil Thickness for Gamma Shielding Factor	cm	0.0	-	-	EPA 2020b
				ET_o	Exposure Time - Outdoor	unitless	8	-	-	Worker soil exposure time (EPA 2014a)

Table 1 – Exposure Assumptions Used in the Development of Receptor-Specific Screening Levels for Human Health

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
Seasonally Exposed Sediment along Shoreline	Recreational User - Beachcomber	Adult/ Adolescent/ Child	Ingestion	IR_{sed}	Ingestion Rate of Sediment	mg/day	100	200	200	Default Ingestion Rate for adult and child resident (EPA 2014a)
				EF_{rec}	Exposure Frequency	days/yr	52	52	52	Recreational user may be exposed to sediment during the winter when water levels are lower, exposing the sediment. Exposure to near shore sediments is assumed to be two days per week from October through March. No exposure to sediment is assumed from April to through September (Site-specific assumption).
				CF	Conversion Factor	kg/mg	1E-06	1E-06	1E-06	-
				ED_{rec}	Exposure Duration	yrs	10	10	6	Total exposure duration is equal to a resident (26 years) because recreators are assumed to living adjacent to the river (EPA 2014a). Child and adolescent are receptors living adjacent to the river from 0 to <6 years old and 6 to <16 years old, respectively (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26) minus the adolescent duration (10) and the child duration (6).
				RBA	Relative Bioavailability Factor	unitless	0.6 (Arsenic) 1 (Other chemicals)	0.6 (Arsenic) 1 (Other chemicals)	0.6 (Arsenic) 1 (Other chemicals)	Default (EPA 2012)
				BW_{rec}	Body Weight	kg	80	44.3	15	Adult and child body weights are equal to default body weights for child and adult residents (EPA 2014a). Adolescent body weight is equal to the weighted average of mean body weights for 6 to <16 years (Table 8-1, EPA 2011).
				$AT\text{-}NC_{rec}$	Averaging Time (noncancer)	days	3,650	3650	2190	$ED_{adult/adol/child}$ x 365 days/year (EPA 1989)
				AT- C	Averaging Time (cancer)	days	25,550	25,550	25,550	Lifetime (70 years) x 365 days/year (EPA 1989)
			Dermal	CF	Conversion Factor	kg/mg	1E-06	1E-06	1E-06	-
				AF_{rec}	Adherence factor of soil to skin	mg/cm^2	0.07	0.2	0.2	Default adherence factors for adult and child resident (EPA 2014a)
				ABS	Dermal absorption fraction	unitless	Chemical Specific	Chemical Specific	Chemical Specific	EPA 2004
				SA_{rec}	Skin surface area available for contact	cm^2	6,032	3,754	2,373	The adult and child surface areas are equal to default surface areas for adult and child residents (EPA 2014a). The adolescent surface areas are equal to weighted average of mean values (Tables 7-2, EPA 2011) for head, hands, arms and legs for 6 to <16 years adjusted for forearm and lower leg using forearm and lower leg-specific data (Table 7-12, EPA 2011) for males and lower leg-specific data (Table 7-13, EPA 2011) for females.
				EF_{sed}	Exposure Frequency	days/yr	52	52	52	Recreational user may be exposed to sediment during the winter when water levels are lower, exposing the sediment. Exposure to near shore sediments is assumed to be two days per week from October through March. No exposure to sediment is assumed from April to through September (Site-specific assumption).
				ED_{rec}	Exposure Duration	yrs	10	10	6	Total exposure duration is equal to a resident (26 years) because recreators are assumed to living adjacent to the river (EPA 2014a). Child and adolescent are receptors living adjacent to the river from 0 to <6 years old and 6 to <16 years old, respectively (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26) minus the adolescent duration (10) and the child duration (6).
				BW_{rec}	Body Weight	kg	80	44.3	15	Adult and child body weight equal to the adult and child resident (EPA 2014a). Adolescent body weight is equal to the weighted average of mean body weights for 6 to <16 years (Table 8-1, EPA 2011).
				$AT\text{-}NC_{rec}$	Averaging Time (noncancer)	days	3,650	3,650	2,190	ED_{adult} x 365 days/year (EPA 1989)
				AT- C	Averaging Time (cancer)	days	25,550	25,550	25,550	Lifetime (70 years) x 365 days/year (EPA 1989)

Table 1 – Exposure Assumptions Used in the Development of Receptor-Specific Screening Levels for Human Health

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
Fish	Recreational User - Consumer of Locally-Caught Sport Fish	Adult/ Adolescent/ Child	Ingestion	CF	Conversion Factor	kg/mg	1E-06	1E-06	1E-06	-
				EF_{fish}	Exposure Frequency	days/yr	350	350	350	Default exposure frequency for residents (EPA 2014a)
				IR_{fish}	Fish intake rate	g ww/day	32.7	12.8	8.7	Adult fish intake rates equal to 95th percentile fish consumption rates for inland south region (Table 9a, EPA 2014b). Adolescent and child fish intake rates are age-adjusted 95th percentile fish consumption rates for 1 to <6 years old and 6 to <16 years old, respectively (Table 20a, EPA 2014b).
				ED_{fish}	Exposure Duration	yrs	10	10	6	Total exposure duration is equal to an adult resident (26 years) because recreators are assumed to be an adult living adjacent to the river (EPA 2014a). Child exposure duration equal to a child resident (EPA 2014a). An adolescent is a receptor living adjacent to the river from 6 to <16 years old (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26) minus the adolescent duration (10) and the child duration (6).
				BW_{fish}	Body Weight	kg	80	44.3	15	Adult and child body weight equal to the adult and child resident (EPA 2014a). Adolescent body weight is equal to the weighted average of mean body weights for 6 to <16 years (Table 8-1, EPA 2011).
				$AT\text{-}NC_{fish}$	Averaging Time (noncancer)	days	3,650	3650	2190	$ED_{adult/adol/child}$ x 365 days/year (EPA 1989)
				AT- C	Averaging Time (cancer)	days	25,550	25,550	25,550	Lifetime (70 years) x 365 days/year (EPA 1989)
Seasonally Exposed Sediment along Shoreline	Recreational User-Beachcomber	Adult/ Adolescent/ Child	External Exposure	EF_{sed}	Exposure Frequency	days/yr	52	52	52	Recreational user may be exposed to sediment during the winter when water levels are lower, exposing the sediment. Exposure to near shore sediments is assumed to be two days per week from October through March (Site-specific assumption)
				ED_{rec}	Exposure Duration	yrs	10	10	6	Total exposure duration is equal to a resident (26 years) because recreators are assumed to living adjacent to the river (EPA 2014a). Child and adolescent are receptors living adjacent to the river from 0 to <6 years old and 6 to <16 years old, respectively (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26) minus the adolescent duration (10) and the child duration (6).
				ACF Area	Site Area for Area Correction Factor	acres	0.5	0.5	0.5	EPA 2020b
				GSF Soil Thickness	Clean Soil Thickness for Gamma Shielding Factor	cm	0	0	0	EPA 2020b
				ET_o	Exposure Time - Outdoor	unitless	0.0833	0.0833	0.0833	Beachcomber assumed to be exposed to sediment 2 hours per event (Site-specific)

Notes:

- not applicable
cm - centimeters
cm^2 - square centimeters
days/yr - days per year
g ww/day - grams wet weight per day
kg - kilogram
kg/mg - kilograms per milligram
m^3/day - cubic meters per day
m^3/kg - cubic meters per kilogram
mg/cm^2 - milligrams per square centimeters
mg/cm^2-event - milligrams per square centimeters per event
mg/day - milligrams per day
mg/µg - milligrams per microgram
yrs - year

Table 2 - Toxicity Values Used in the Development of Human Health Receptor-Specific Screening Levels

Analyte	CAS	Cancer Slope Factor (mg/kg-day)$^{-1}$ Oral		Cancer Slope Factor (mg/kg-day)$^{-1}$ Dermal[c]		IUR ($\mu g/m^3$)$^{-1}$ Inhalation		Chronic RfD (mg/kg-day) Oral		Chronic RfD (mg/kg-day) Dermal[c]		Subchronic RfD[a] (mg/kg-day) Oral		Subchronic RfD[a] (mg/kg-day) Dermal[c]		Subchronic RfC[a] (mg/m^3) Inhalation		ABS_{GI}[b] (%)
Inorganics																		
Antimony	7440-36-0	na	na	na	na	na	na	4.0E-04	I	6.0E-05	R	4.0E-04	P	6.0E-05	R	1.0E-03	A	15%
Arsenic	7440-38-2	1.5E+00	I	1.5E+00	R	4.3E-03	I	3.0E-04	I	3.0E-04	R	3.0E-04	cr	3.0E-04	R	1.5E-05	C	100%
Barium	7440-39-3	na	na	na	na	na	na	2.0E-01	I	1.4E-02	R	2.0E-01	A	1.4E-02	R	5.0E-03	H	7%
Beryllium	7440-41-7	na	na	na	na	2.4E-03	I	2.0E-03	I	1.4E-05	R	5.0E-03	H	3.5E-05	R	2.0E-05	I	0.7%
Boron	7440-42-8	na	na	na	na	na	na	2.0E-01	I	2.0E-01	R	2.0E-01	A	2.0E-01	R	2.0E-02	H	100%
Cadmium (soil)	7440-43-9	na	na	na	na	1.8E-03	I	1.0E-03	I	2.5E-05	R	1.0E-03	cr	2.5E-05	R	1.0E-05	A	2.5%
Cadmium (water)	7440-43-9, wate	na	na	na	na	1.8E-03	I	5.0E-04	I	2.5E-05	R	5.0E-04	A	2.5E-05	R	1.0E-05	A	5%
Calcium	7440-70-2	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Chromium[d]	7440-47-3	na	na	na	na	na	na	1.5E+00	I	2.0E-02	R	1.5E+00	H	2.0E-02	R	5.0E-03	A	1.3%
Cobalt	7440-48-4	na	na	na	na	9.0E-03	P	3.0E-04	P	3.0E-04	R	3.0E-03	P	3.0E-03	R	2.0E-05	P	100%
Copper	7440-50-8	na	na	na	na	na	na	4.0E-02	H	4.0E-02	R	4.0E-02	cr	4.0E-02	R	na	na	100%
Fluoride	16984-48-8	na	na	na	na	na	na	4.0E-02	C	4.0E-02	R	4.0E-02	cr	4.0E-02	R	1.3E-02	C	100%
Lead	7439-92-1	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	100%
Lithium	7439-93-2	na	na	na	na	na	na	2.0E-03	P	2.0E-03	R	2.0E-03	P	2.0E-03	R	na	na	100%
Mercury[e]	7439-97-6	na	na	na	na	na	na	3.0E-04	I	2.1E-05	R	2.0E-03	A	1.4E-04	R	3.0E-04	I	7%
Methyl Mercury	22967-92-6	na	na	na	na	na	na	1.0E-04	I	na	na	na	na	na	na	na	na	100%
Molybdenum	7439-98-7	na	na	na	na	na	na	5.0E-03	I	5.0E-03	R	6.0E-02	A	6.0E-02	R	2.0E-03	A	100%
Nickel	7440-02-0	na	na	na	na	2.6E-04	C	2.0E-02	I	8.0E-04	R	2.0E-02	H	8.0E-04	R	2.0E-04	A	4%
Selenium	7782-49-2	na	na	na	na	na	na	5.0E-03	I	5.0E-03	R	5.0E-03	H	5.0E-03	R	2.0E-02	C	100%
Silver	7440-22-4	na	na	na	na	na	na	5.0E-03	I	2.0E-04	R	5.0E-03	H	2.0E-04	R	na	na	4%
Sulfate	14808-79-8	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Thallium	7440-28-0	na	na	na	na	na	na	1.0E-05	G	1.0E-05	R	4.0E-05	X	4.0E-05	R	na	na	100%
Vanadium	7440-62-2	na	na	na	na	na	na	5.0E-03	U	1.3E-04	R	1.0E-02	A	2.6E-04	R	1.0E-04	A	2.6%
Zinc	7440-66-6	na	na	na	na	na	na	3.0E-01	I	3.0E-01	R	3.0E-01	A	3.0E-01	R	na	na	100%

Sources:

A Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels as cited in the USEPA RSL Calculator (EPA, 2020a)

C California Environmental Protection Agency (CalEPA) Toxicity Values as cited in the USEPA RSL Calculator (EPA, 2020a)

cr chronic value

G Regional Screening Levels (RSLs) User's Guide (EPA, 2020a)

H Health Effects Assessment Summary Tables (HEAST) as cited in the USEPA RSL Calculator (EPA, 2020a)

I Integrated Risk Information System (IRIS) Database as cited in the USEPA RSL Calculator (EPA, 2020a)

P Provisional Peer Reviewed Toxicity Values (PPRTVs) as cited in the USEPA RSL Calculator (EPA, 2020a)

R route extrapolation

X Screening values in chemical-specific PPRTV Appendices as cited in the USEPA RSL Calculator (EPA, 2020a)

Table 2 - Toxicity Values Used in the Development of Human Health Receptor-Specific Screening Levels

Analyte	CAS	Cancer Slope Factor (mg/kg-day)$^{-1}$		IUR ($\mu g/m^3$)$^{-1}$	Chronic RfD (mg/kg-day)		Subchronic RfD[a] (mg/kg-day)		Subchronic RfC[a] (mg/m^3)	ABS_{GI}[b]
		Oral	Dermal[c]	Inhalation	Oral	Dermal[c]	Oral	Dermal[c]	Inhalation	(%)

Notes:

[a] Subchronic RfDs and RfCs obtained from EPA's RSL Tables (EPA, 2020a) were used unless otherwise noted in text.

[b] Values are from USEPA Risk Assessment Guidance for Superfund (RAGS) Part E. Where no specific ABS_{GI} is available, the ABS_{GI} is assumed to be 100 percent (EPA, 2004).

[c] The following equations are used as recommended by the EPA (2004) to estimate dermal CSFs and RfDs from the ingestion toxicity values when ABS_{GI} is less than 50 percent:

Dermal RfD = Oral RfD x ABS_{GI} and Dermal CSF = Oral SF/ABS_{GI}.

When ABS_{GI} is greater than 50 percent, the dermal CSF and/or RfD is assumed to be equal to the oral CSF and/or RfD (EPA, 2004).

[d] Trivalent chromium used as a surrogate

[e] Mercuric chloride used as a surrogate

% - percent

ABS_{GI} - oral absorption efficiency

CAS - Chemical Abstracts Service registry number

CSF - cancer slope factor

IUR - inhalation unit risk

EPA - United States Environmental Protection Agency

mg/kg-day - milligram(s) per kilogram per day

mg/m^3 - milligram(s) per cubic meter

$\mu g/m^3$ - microgram(s) per cubic meter

na - not available/applicable

RfD - reference dose

RfC - reference concentration

URF - unit risk factor

Table 3 - Summary of Human Health Receptor-Specific Screening Levels

Analyte	CAS	Onsite Worker Soil SSL_{HH}			Recreational User - Beachcomber Sediment SSL_{HH}				Recreational User - Consumer of Locally-Caught Sport Fish Fish SSL_{HH}			
		Cancer	Non-Cancer	Lowest	Cancer	Non-Cancer Child (0 to <6)	Non-Cancer Adolescent (6 to <16)	Lowest	Cancer	Non-Cancer Child (0 to <6)	Non-Cancer Adolescent (6 to <16)	Lowest
		(mg/kg or pCi/g)			(mg/kg or pCi/g)				(mg/kg or pCi/g wet weight)			
Antimony	7440-36-0	na	1.3E+01	1.3E+01	na	2.1E+01	6.2E+01	2.1E+01	na	7.2E-02	1.4E-01	7.2E-02
Arsenic	7440-38-2	2.4E+02	5.9E+00	5.9E+00	3.4E+00	2.4E+01	6.5E+01	3.4E+00	4.7E-03	5.4E-02	1.1E-01	4.7E-03
Barium	7440-39-3	na	2.2E+03	2.2E+03	na	1.1E+04	3.1E+04	1.1E+04	na	3.6E+01	7.2E+01	3.6E+01
Beryllium	7440-41-7	2.5E+03	1.2E+01	1.2E+01	na	1.1E+02	3.1E+02	1.1E+02	na	3.6E-01	7.2E-01	3.6E-01
Boron	7440-42-8	na	4.5E+03	4.5E+03	na	1.1E+04	3.1E+04	1.1E+04	na	3.6E+01	7.2E+01	3.6E+01
Cadmium	7440-43-9	3.3E+03	5.4E+00	5.4E+00	na	4.8E+01	1.4E+02	4.8E+01	na	1.8E-01	3.6E-01	1.8E-01
Calcium	7440-70-2	na	na	na	na	na	na	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na	na	na	na	na	na	na
Chromium	7440-47-3	na	3.1E+03	3.1E+03	na	7.9E+04	2.3E+05	7.9E+04	na	2.7E+02	5.4E+02	2.7E+02
Cobalt	7440-48-4	6.6E+02	1.2E+01	1.2E+01	na	1.6E+01	4.7E+01	1.6E+01	na	5.4E-02	1.1E-01	5.4E-02
Copper	7440-50-8	na	1.4E+03	1.4E+03	na	2.1E+03	6.2E+03	2.1E+03	na	7.2E+00	1.4E+01	7.2E+00
Fluoride	16984-48-8	na	1.2E+03	1.2E+03	na	2.1E+03	6.2E+03	2.1E+03	na	na	na	na
Lead	7439-92-1	na	na	1.3E+02	na	7.8E+01	1.1E+03	7.8E+01	na	na	na	na
Lithium	7439-93-2	na	6.8E+01	6.8E+01	na	1.1E+02	3.1E+02	1.1E+02	na	3.6E-01	7.2E-01	3.6E-01
Mercury	7439-97-6	na	5.0E+01	5.0E+01	na	1.6E+01	4.7E+01	1.6E+01	na	1.8E-02	3.6E-02	1.8E-02
Molybdenum	7439-98-7	na	8.0E+02	8.0E+02	na	2.6E+02	7.8E+02	2.6E+02	na	9.0E-01	1.8E+00	9.0E-01
Nickel	7440-02-0	2.3E+04	1.1E+02	1.1E+02	na	1.1E+03	3.1E+03	1.1E+03	na	3.6E+00	7.2E+00	3.6E+00
Radium-226+228	13982-63-3/15262-20-1	6.5E+00	na	6.5E+00	3.1E-01	na	na	3.1E-01	na	na	na	na
Selenium	7782-49-2	na	1.7E+02	1.7E+02	na	2.6E+02	7.8E+02	2.6E+02	na	9.0E-01	1.8E+00	9.0E-01
Silver	7440-22-4	na	1.7E+02	1.7E+02	na	2.6E+02	7.8E+02	2.6E+02	na	9.0E-01	1.8E+00	9.0E-01
Sulfate	14808-79-8	na	na	na	na	na	na	na	na	na	na	na
Thallium	7440-28-0	na	1.4E+00	1.4E+00	na	5.3E-01	1.6E+00	5.3E-01	na	1.8E-03	3.6E-03	1.8E-03
Vanadium	7440-62-2	na	5.5E+01	5.5E+01	na	2.6E+02	7.8E+02	2.6E+02	na	9.0E-01	1.8E+00	9.0E-01
Zinc	7440-66-6	na	1.0E+04	1.0E+04	na	1.6E+04	4.7E+04	1.6E+04	na	5.4E+01	1.1E+02	5.4E+01

Notes:

CAS - Chemical Abstracts Service registry number

mg/kg - milligrams per kilogram

na - not available/applicable

pCi/g - picocuries per gram

SSL_{HH} - receptor-specific screening level for human health

1. SSL_{HH} for all receptors calculated using a target risk and hazard of 1×10^{-6} and 0.1, respectively

2. Mercury SSL_{HH} for consumer of sport caught fish were calculated using the chronic reference dose for methyl mercury.

3. Fish SSL_{HH} were not developed for fluoride, sulfate and Radium 226+228 because these parameters were not analyzed in fish tissues as indicated in the Environmental Investigation Plans.

Stantec

TVA Core Team Tennessee Valley Authority

Reference: Proposed Receptor-Specific Screening Levels for Human Health

ATTACHMENT A – PROPOSED SCREENING LEVELS FOR DATA ANALYSIS IN ENVIRONMENTAL ASSESSMENT REPORT (EAR)

(SUBMITTED TO TDEC MARCH 31, 2021)

Stantec

Memo

To:	Missy Hedgecoth, Roy Quinn, Brandon Boyd, Paul Thomas	From:	Stantec
File:	Proposed Screening Levels for Sample Results in Environmental Assessment Report (EAR)	Date:	March 26, 2021

Reference: Proposed Screening Levels for Sample Results in the EAR

PURPOSE OF THE TECHNICAL MEMORANDUM

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to the Tennessee Valley Authority (TVA) for coal combustion residuals (CCR) compliance pursuant to the provisions of Tennessee's solid waste management and remediation laws. As part of the TDEC Order, Stantec is implementing Environmental Investigation Plans (EIPs) at seven TVA Fossil Plants in Tennessee. The EIP for each fossil plant provides Sampling and Analysis Plans (SAPs) for the types of investigations to be conducted at each fossil plant. As specified in the TDEC Order, within 60 days of the completion of the environmental investigations TVA is required to submit an Environmental Assessment Report (EAR), which shall provide *"…an analysis of the extent of soil, surface water, and ground water contamination by CCR at the site. The Department shall evaluate the EAR to determine if the extent of CCR contamination has been fully defined".* Collection of environmental samples is complete or nearing completion at all TVA Fossil Plants subject to the TDEC Order, and development of the EARs has commenced.

As required by the TDEC Order, samples of environmental media were analyzed for the following parameters listed in Appendix III and Appendix IV of the Federal CCR Rule, Title 40 of the Code of Federal Regulations Part 257 (40 CFR 257):

- antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium (total), cobalt, fluoride, lead, lithium, mercury (inorganic), molybdenum, pH (SU), radium 226 & 228, selenium, sulfate, thallium, and total dissolved solids.

Samples were also analyzed for five inorganic constituents listed in Appendix 1 of TN Rule 0400-11-01-.04 that are not listed in 40 CFR 257:

- copper, nickel, silver, vanadium, and zinc.

This Technical Memorandum describes proposed screening levels for the CCR Parameters analyzed in environmental investigation samples. The purpose of the screening levels in the EAR is to identify CCR Parameters in the environmental media that require further assessment in the Corrective Action Risk

Assessment Plan (CARA) to be submitted within 60 days of TDEC approval of the EAR. The screening levels used to evaluate environmental sample results are generic (not specific to an individual person or ecological receptor) and protective – frequently referred to as conservative. Environmental samples were analyzed for up to 26 individual CCR Parameters (listed above), as applicable to the media. CCR Parameters above screening levels will be further evaluated in the human health and ecological risk assessment in the CARA. Screening levels for protection of human health are proposed for groundwater and surface water. Screening levels for protection of ecological receptors are proposed for surface water, mayfly and fish tissue, and sediment. If there is more than one applicable screening level for an environmental medium (e.g. surface water), the lowest value will be selected to evaluate those analytical results in the EAR.

PROPOSED SCREENING LEVELS BY MEDIA

Groundwater

The proposed screening levels for groundwater are protective of the drinking water pathway for residential receptors. Analytical results for parameters detected in groundwater will be compared to screening levels obtained from the following hierarchy of sources:

- US EPA Maximum Contaminant Levels (MCLs)
- Tennessee MCLs in State of Tennessee Solid Waste Processing and Disposal (TN Rule 0400-11-01)
- US EPA groundwater protection standards listed in Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments (40 CFR Part 257.95(h))
- US EPA Secondary Maximum Contaminant Levels (SMCLs)
- US EPA residential tap water Regional Screening Levels (RSL).

The Proposed Human Health Screening Levels for Groundwater for the EAR are presented in Table 1.

Surface Water

Applicable screening levels for surface water are presented for human exposure through use of surface water for drinking water supply and for protection of fish and freshwater aquatic life. When more than one screening level is identified for the same parameter, the lowest of the available values is proposed as the screening level to evaluate surface water analytical results in the EAR.

Analytical results for parameters detected in surface water will be compared to screening levels for domestic water supply obtained from the following hierarchy of sources:

- State of Tennessee Drinking Water Standards (TN DWS) promulgated in the following Rules:
    - General Water Quality Criteria, Surface Water used for Domestic Water Supply (TN Rule 0400-40-03-.03)
    - Solid Waste Processing and Disposal (TN Rule 0400-11-01)

    - Public Water Systems (TN Rule 0400-45-01-.06 MCLS and 0400-45-01-.12 Secondary drinking water regulations)
- US EPA MCLs
- US EPA SMCLs
- US EPA residential tap water RSL
- US EPA Drinking Water Lifetime Health Advisory Level or HAL; (March 2018).

The proposed human health screening levels for surface water are identical to the screening levels for groundwater described previously, except for lead and zinc. The Tennessee criteria for lead for surface water used for Domestic Water Supply (TN Rule 0400-40-03-.03) is 5 micrograms per liter (µg/L) compared to the Tennessee Solid Waste Rule (TN Rule 0400-11-01) criteria of 15 µg/L which is also the alternative GWPS under the CCR Rule. The human health screening level for zinc in surface water is the US EPA Lifetime Health Advisory Level (HAL) of 2,000 µg/L derived from the oral RfD of 0.3 mg/kg bw-day to protect against immune and hematological effects. For groundwater, the screening level for zinc is the SMCL of 5,000 µg/L based on objectionable metallic taste. Selection of the SMCL for groundwater is consistent with the proposed hierarchy of sources.

The Proposed Human Health Screening Levels for Surface Water in the EAR are presented in Table 2.

Surface water screening levels for protection of freshwater aquatic life were identified from the sources described below. Published values for both acute and chronic effects are not available for all parameters analyzed in surface water. Where both acute and chronic values were available, the chronic values were selected since they are lower and more protective than acute values. For some parameters chronic screening levels are published for both total and dissolved concentrations. Hardness-dependent parameters (cadmium, chromium, lead, copper, nickel, silver, and zinc) are expressed as dissolved concentrations and adjusted where appropriate based on stream-specific water chemistry. All other parameters are expressed as total recoverable concentrations (TN Rule 0400-40-03-.03).

The majority of the surface water screening values to be used in the EARs and Ecological Risk Assessments (ERAs) for the TVA fossil plants under the TDEC Order are the Surface Water Screening Values for Hazardous Waste Sites referenced from *USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update)* or the TDEC General Water Quality Criteria (Chapter 0400-40-03, General Water Quality Criteria). Surface water screening levels that are hardness-dependent have been calculated using the formulae presented in the TDEC General Water Quality Criteria guidelines using site-specific hardness values for the major water bodies at each of the fossil plants. The mean hardness values for each of the major water bodies were determined using the data collected during the Environmental Investigations (EI) at each fossil plant and conservatively rounded down for use in the calculations.

The only surface water screening values that were not referenced from the TDEC or USEPA Region 4 sources cited above were for Radium-226 & -228. The surface water screening values for Radium-226 & -228 were the Biota Concentration Guides (BCG) for water referenced from the U. S. Department of Energy (DOE) report titled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, DOE Standard (DOE-STD-1153-2019). The BCG is the limiting concentration of a radionuclide in soil, sediment,

or water that would not cause dose rate criteria for protection of populations of aquatic and terrestrial biota to be exceeded.

Human Health and Ecological Screening Levels for Surface Water are presented in Table 2. The proposed screening level for evaluation of surface water in the EAR is the lowest (most conservative) of the available values for each parameter. National Oceanic and Atmospheric Administration's (NOAA) Screening Quick Reference Tables (SQuiRTs) (Buchman 2008) were also reviewed to determine whether additional surface water screening values could be derived for constituents without screening levels in Table 2. Although the SQuiRTs provide screening levels for the dissolved fraction for several constituents where USEPA Region 4 and TDEC screening levels are unavailable, these screening values were not selected because some primary sources presented in SQuiRTs have been superseded and the SQuiRTs were developed in 2008 and are no longer being maintained by NOAA.

Mayfly Critical Body Residues

The mayfly tissue critical body residue values proposed as screening levels were referenced from the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment* (BERA) (Arcadis 2012), which used values from the USEPA/USACE Environmental Residue-Effects Database (ERED). A number of other potential sources of critical body residue data were searched in order to identify additional data and to fill data gaps but no additional data were located. Per Arcadis (2012) "CBR data were selected from literature-derived values from the ERED. The selection process included only whole-body data for the closest relevant species (i.e., mayfly) and life stages (e.g., adult selected over egg) for growth, mortality, or reproductive endpoints. Combined or absorbed doses were preferred over water only exposures. If the data were unpaired (i.e., only a NOAEL or LOAEL was available), either the highest NOAEL or the lowest LOAEL was selected. The corresponding value was extrapolated from the available value by a factor of 10. If only effects concentrations were available (e.g., LC_{50}, ED_{25}, etc.), the lowest effects concentration was selected as the LOAEL, and the estimated NOAEL was set at 1/10th the LOAEL value." The screening levels based on CBR values presented in Arcadis (2012) have been reviewed and accepted by TDEC and USEPA as part of their review and acceptance of the River System BERA (Arcadis 2012). As such, these values have been vetted and deemed acceptable for use as screening levels in the EAR for the fossil plants under the Commissioner's Order. Data presented in the ERED will be further evaluated and CBR values revised, if necessary, as part of the ecological risk assessments presented in the Corrective Action/Risk Assessment (CARA) reports for each of the fossil plants under the Commissioner's Order.

The Proposed Screening Levels for Mayfly Tissue Critical Body Residues for the EAR are presented in Table 3.

Fish Tissue Critical Body Residues

Human consumption of CCR parameters detected in fish fillet samples will be evaluated in the Human Health Risk Assessment in the CARA Plan.

The fish tissue critical body residue values proposed as screening levels for most of the constituents were referenced from the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment* (BERA) (Arcadis 2012), which used values from the USEPA/USACE ERED. As discussed above, the methodology for selecting the fish tissue critical body residue values and the screening levels based on CBR values presented in Arcadis (2012) have been

reviewed and accepted by TDEC and USEPA as part of their review and acceptance of the River System BERA (Arcadis 2012). As such, these values have been vetted and deemed acceptable for use as screening levels in the EAR for the fossil plants under the Commissioner's Order. Data presented in the ERED will be further evaluated and CBR values revised, if necessary, as part of the ecological risk assessments presented in the CARA reports for each of the fossil plants under the Commissioner's Order.

The fish tissue screening levels for selenium were referenced from the Chronic Ambient Water Quality Criterion for Selenium (USEPA 2016). A number of other potential sources of critical body residue data were searched in order to identify additional data and to fill data gaps but no additional data were located.

The Proposed Screening Levels for Fish Tissue Critical Body Residues for the EAR are presented in Table 4.

Sediment

Most of the proposed sediment screening values to be used to evaluate investigation analytical results in the EAR were derived by MacDonald, et al. (2003) in their paper *Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters* and adopted by USEPA Region 4 as their recommended Freshwater Sediment Screening Values presented in *Region 4 Ecological Risk Assessment Supplemental Guidance, March 2018 Update, Screening Values*. The Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) values derived by MacDonald, et al. (2003) are consensus-based values derived from multiple toxicity test results for a number of benthic species and are the basis for the majority of the USEPA Region 4 freshwater sediment screening values and correspond to USEPA Region 4 Ecological Screening Value (chronic) and Refinement Screening Value (acute) sediment screening values, respectively.

The USEPA Region 4 Freshwater Sediment Screening Values are recommended to be used for sediment screening values for the following constituents in sediment: antimony, arsenic, cadmium, chromium, cobalt, lead, mercury, selenium (acute), copper, nickel, silver, and zinc.

Several other sources, including NOAA's Screening Quick Reference Tables (SQuiRTs) (Buchman 2008), were referenced to identify sediment screening values in instances where USEPA Region 4 did not have recommended screening values or where other screening values were deemed more toxicologically defensible.

USEPA Region 4 does not have sediment screening values for percent ash; therefore, site-specific values were referenced from the approved EIP and the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System BERA* (Arcadis 2012). Sediment samples from the Emory and Clinch Rivers submitted for laboratory toxicity testing using standard aquatic organisms contained approximately 20 to 90 percent ash. Exposure to sediment with 40 percent ash was associated with 25 percent decreased survival and growth reduction in the test organisms compared to reference sediments. This was considered a biologically significant effect. 20 percent ash was proposed as the threshold triggering quantitative analysis of a sediment sample in the EIPs approved by TDEC. The EIPs for each fossil plant used a value of 20 percent ash in sediment samples as a Phase 1 screening level to determine if additional chemical analyses would be required. If a sediment sample from the zero to six-inch depth increment had less than 20 percent ash composition, then the sample was deemed to have insufficient ash content to pose deleterious effects from ash itself and sediment samples from deeper depth

increments would not be analyzed further. Based on this rationale, the 20 percent ash content is proposed as the chronic sediment screening value for percent ash.

The acute sediment screening value for percent ash is referenced from the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System BERA* (Arcadis 2012). The Kingston BERA (Arcadis 2012) presented multiple toxicity test results that indicated sediment samples with 40 percent ash or greater were associated with statistically and biologically significant adverse effects. Based on these toxicity test results; 40 percent ash content is proposed as the acute sediment screening value for percent ash.

USEPA Region 4 provides sediment screening values for barium based on a study conducted by USEPA Region 5 in 1977 titled *Guidelines for the Pollution Classification of Great Lakes Harbor Sediments*. The sediment ESVs for barium derived by USEPA Region 5 (1977) and cited by USEPA Region 4 (2018) are not effects-based and are not based on measured toxicity to benthic or other organisms, which brings into question their defensibility for use in determining potential ecological risk to sediment-dwelling organisms. An alternative to the USEPA Region 4 sediment screening values for barium (and several other inorganics) is provided by The Netherlands National Institute for Public Health and the Environment (RIVM) in their report titled *Environmental Risk Limits for Nine Trace Elements* (van Vlaardingen, et al., 2005). The RIVM methodology utilizes toxicity data from the scientific literature to derive Environmental Risk Limits (ERL) including: 1) Maximum Permissible Concentration (MPC); and 2) Serious Risk Addition (SRA_{eco}).

The MPC as defined in the Netherlands report (RIVM 2005) is the concentration of a substance in air, water, soil, or sediment that should protect all species in ecosystems from adverse effects of that substance. Depending on the amount of toxicological data available, the lowest toxicity result is divided by a fixed value (assessment factor). When enough data are available, a cut-off value is used. This is the fifth percentile if a species sensitivity distribution of No-Observed-Effect-Concentration (NOEC) is used. This is the hazardous concentration for five percent of the species. This definition correlates well with the definition of the TEC as defined by MacDonald, et al. (2003) and adopted by USEPA Region 4 for chronic sediment screening levels.

The Serious Risk Addition (SRA_{eco}) concentration is the concentration of a substance in soil, sediment, or groundwater at which functions in these compartments will be seriously affected or are threatened to be negatively affected. This is assumed to occur when 50 percent of the species and/or 50 percent of the microbial and enzymatic processes are possibly affected. This definition correlates well with the definition of Probable Effect Concentration (PEC) as defined by MacDonald, et al. (2003) and adopted by USEPA Region 4 for acute sediment screening levels.

Literature-based toxicity data for effects on growth, reproduction or survival are used in the derivation of MPC and SRA_{eco} values. All categories are further subdivided into chronic and acute toxicity values. Chronic values (NOEC or EC_{10}) and acute values (EC_{50} or LC_{50}) are referenced or derived from the relevant studies. The lowest value (the most sensitive toxicity endpoint) of the available data per species is selected. The SRA_{eco} for the water compartment is derived by applying an assessment factor of 10 to the geometric mean of the selected acute toxicity data, which results in an SRA_{eco}, acute. This SRA_{eco}, acute is then compared to the geometric mean of all selected chronic data (SRA_{eco}, chronic). The lower of the SRA_{eco}, acute and the SRA*eco*, chronic value is defined as the SRA_{eco} for the water compartment. No toxicity data were identified for sediment; therefore, all of the MPC and the SRA_{eco} values for sediment

were calculated using surface water toxicity data and equilibrium partitioning by applying sediment-to-water partition coefficients.

The MPC of 240 mg/kg is proposed as the chronic sediment screening value for barium and the SRA_{eco} value of 22,925 mg/kg is proposed as the acute sediment screening value for barium.

USEPA Region 4, or any of the other sources researched for potential sediment screening values, does not provide sediment screening values for beryllium, molybdenum, thallium, or vanadium. As such, the MPC and the SRA_{eco} values for these constituents as derived using the RIVM (van Vlaardingen, et al., 2005) methodology are proposed as sediment screening values.

USEPA Region 4 references the Los Alamos National Laboratory (LANL) ECORISK database (2017) as the source for the sediment screening values for selenium. The chronic sediment screening value is identified as the "No Effect Ecological Screening Value" and the acute sediment screening value is identified as the "Low Effect Ecological Screening Value" in the ECORISK database; however, the source and toxicological basis (if any) of these values is not presented in the ECORISK database. Alternatively, Lemly (2002) has proposed a sediment screening value of 2.0 mg/kg in his book *Selenium Assessment in Aquatic Ecosystems* (2002). The screening level proposed by Lemly (2002) is based on selenium concentrations in sediment that result in body residues in benthic invertebrates that result in deleterious effects to fish and aquatic birds that consume benthic invertebrates. According to Lemly (2002), benthic invertebrates can tolerate significantly higher concentrations of selenium in sediment. Thus, the most important aspect of selenium concentrations in sediment is not direct toxicity to benthic invertebrates themselves, but the dietary source of selenium that benthic invertebrates provide to fish and wildlife species that feed on benthic invertebrates. Based on the information presented by Lemly (2002), 2.0 mg/kg is proposed as the chronic screening value for selenium in sediment and the acute sediment screening value is proposed as 2.9 mg/kg, which is the Refinement Screening Value as presented in USEPA Region 4 (2018). These sediment screening values are conservative compared to the remediation goals for selenium in sediment (3.0 – 3.2 mg/kg) presented in *the Kingston Ash Recovery Project Non-Time Critical Removal Action for the River System Long-Term Monitoring Sampling and Analysis Plan* (TVA, 2013).

USEPA Region 4 does not provide sediment screening values for Radium-226 or Radium-228. However, the DOE provides Biota Concentration Guides (BCG) for sediment in their guidance *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019). The BCG is defined as the limiting concentration of a radionuclide in soil, sediment, or water that would not cause dose rate criteria for protection of populations of aquatic and terrestrial biota to be exceeded. DOE (2019) presents BCG of 100 pCi/g for Radium-226 and 90 pCi/g for Radium-228. These values are recommended for sediment screening values for Radium-226 and Radium-228 individually and the lower of these two values (90 pCi/g) is recommended as the sediment screening value for combined Radium-226 & -228.

The Proposed Ecological Screening Levels for Freshwater Sediment for the EAR are presented in Table 5.

REFERENCES

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ATTACHMENTS

Table 1. Proposed Human Health Screening Levels for Groundwater. Environmental Assessment Report

Table 2. Proposed Human Health and Ecological Screening Levels for Surface Water. Environmental Assessment Report

Table 3. Proposed Screening Levels for May Fly Tissue Critical Body Residues. Environmental Assessment Report

Table 4. Proposed Screening Levels for Fish Tissue Critical Body Residues. Environmental Assessment Report

Table 5. Proposed Ecological Screening Levels for Freshwater Sediment. Environmental Assessment Report

Table 1. Proposed Human Health Screening Levels for Groundwater
Environmental Assessment Report

CCR Parameters	Groundwater Screening Levels (µg/L)	Source
CCR Rule Appendix III Constituents :		
Boron	4,000	RSL
Calcium	--	--
Chloride	250,000	SMCL
Fluoride	4,000	MCL
pH	6.5-8.5 S.U.	SMCL
Sulfate	250,000	SMCL
Total Dissolved Solids	500,000	SMCL
CCR Rule Appendix IV Constituents :		
Antimony	6	MCL
Arsenic	10	MCL
Barium	2,000	MCL
Beryllium	4	MCL
Cadmium	5	MCL
Chromium (total)	100	MCL
Cobalt	6	CCR Rule GWPS
Fluoride	4,000	MCL
Lead	15	CCR Rule GWPS
Lithium	40	CCR Rule GWPS
Mercury	2	MCL
Molybdenum	100	CCR Rule GWPS
Radium-226 & 228	5 pCi/L	MCL
Selenium	50	MCL
Thallium	2	MCL
TDEC Appendix I Constituents :		
Copper	1,300	MCLG
Nickel	100	TN MCL
Silver	100	TN MCL
Vanadium	86	RSL
Zinc	5,000	SMCL

Notes:

CCR: coal combustion residuals
GWPS: groundwater protection standards
MCL: USEPA maximum contaminant level
MCLG: Maximum contaminant level goal
pCi/L: picocuries per liter
RSL: USEPA regional screening level
SMCL: USEPA secondary maximum contaminant level
TN MCL: maximum contaminant level promulgated by State of Tennessee
µg/L: micrograms per liter

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

CCR Parameters	Bull Run Fossil Plant																
	Human Health Surface Water Screening Levels		Ecological Surface Water Screening Levels														
			Bull Run Creek (Hardness = 140 mg/L)					Clinch River (Hardness = 120 mg/L)					Worthington Branch (Hardness = 175 mg/L)				
	(µg/L)	Source	Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)	
CCR Rule Appendix III Constituents :																	
Boron	4,000	RSL	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a
Calcium	--	--	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a
Chloride	250,000	SMCL	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
pH	6 - 9 S.U.	TN DWS	6.5 - 9	NA	NA	NA	b	6.5 - 9	NA	NA	NA	b	6 - 9	NA	NA	NA	b
Sulfate	250,000	SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
Total Dissolved Solids	500,000	TN DWS/SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
CCR Rule Appendix IV Constituents :																	
Antimony	6	TN DWS/MCL	190	900	NA	NA	a	190	900	NA	NA	a	190	900	NA	NA	a
Arsenic	10	TN DWS/MCL	150	340	150	340	a	150	340	150	340	a	150	340	150	340	a
Barium	2,000	TN DWS/MCL	220	2,000	NA	NA	a	220	2,000	NA	NA	a	220	2,000	NA	NA	a
Beryllium	4	TN DWS/MCL	11	93	NA	NA	a	11	93	NA	NA	a	11	93	NA	NA	a
Cadmium*	5	TN DWS/MCL	1.03	2.65	0.925	2.47	b	0.914	2.28	0.824	2.14	b	1.23	3.30	1.09	3.04	b
Chromium*	100	TN DWS/MCL	114	2375	97.6	751	b	100	2093	86.1	662	b	136	2851	117	901	b
Cobalt	6	RSL	19	120	NA	NA	a	19	120	NA	NA	a	19	120	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
Lead*	5	TN DWS	4.88	125	3.62	93.0	b	4.01	103	3.07	78.7	b	6.49	166	4.60	118	b
Lithium	40	RSL	440	910	NA	NA	a	440	910	NA	NA	a	440	910	NA	NA	a
Mercury	2	TN DWS/MCL	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a
Molybdenum	100	RSL	800	7,200	NA	NA	a	800	7,200	NA	NA	a	800	7,200	NA	NA	a
Radium-226 & 228	5 pCi/L	MCL	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c
Selenium	50	TN DWS/MCL	3.1	20	NA	NA	b	3.1	20	NA	NA	b	3.1	20	NA	NA	b
Thallium	2	TN DWS/MCL	6	54	NA	NA	a	6	54	NA	NA	a	6	54	NA	NA	a
TDEC Appendix I Constituents :																	
Copper*	1,300	MCL	12.4	19.2	11.9	18.5	b	10.9	16.6	10.5	16.0	b	15.0	23.7	14.4	22.8	b
Nickel*	100	TN DWS	69.3	624	69.1	622	b	60.9	547	60.7	546	b	83.7	753	83.5	752	b
Silver*	100	TN DWS/SMCL	NA	6.75	NA	5.74	b	NA	5.18	NA	4.40	b	NA	9.91	NA	8.42	b
Vanadium	86	RSL	27	79	NA	NA	a	27	79	NA	NA	a	27	79	NA	NA	a
Zinc*	2,000	HAL	159	159	157	156	b	140	140	138	137	b	193	193	190	188	b

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

CCR Parameters	Cumberland Fossil Plant																
	Human Health Surface Water Screening Levels		Ecological Surface Water Screening Levels														
			Cumberland River (Hardness = 100 mg/L)					Wells Creek (Hardness = 140 mg/L)					Unnamed Tributary (Hardness = 750 mg/L)[d]				
	(µg/L)	Source	Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)	
CCR Rule Appendix III Constituents :																	
Boron	4,000	RSL	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a
Calcium	--	--	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a
Chloride	250,000	SMCL	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
pH	6 - 9 S.U.	TN DWS	6.5 - 9	NA	NA	NA	b	6.5 - 9	NA	NA	NA	b	6.5 - 9	NA	NA	NA	b
Sulfate	250,000	SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
Total Dissolved Solids	500,000	TN DWS/SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
CCR Rule Appendix IV Constituents :																	
Antimony	6	TN DWS/MCL	190	900			a	190	900			a	190	900			a
Arsenic	10	TN DWS/MCL	150	340	150	340	a	150	340	150	340	a	150	340	150	340	a
Barium	2,000	TN DWS/MCL	220	2,000	NA	NA	a	220	2,000	NA	NA	a	220	2,000	NA	NA	a
Beryllium	4	TN DWS/MCL	11	93	NA	NA	a	11	93	NA	NA	a	11	93	NA	NA	a
Cadmium*	5	TN DWS/MCL	0.790	1.91	0.718	1.80	b	1.03	2.65	0.925	2.47	b	2.39	7.42	2.03	6.58	b
Chromium*	100	TN DWS/MCL	86.2	1803	74.1	570	b	114	2375	97.6	751	b	268	5612	231	1773	b
Cobalt	6	RSL	19	120	NA	NA	a	19	120	NA	NA	a	19	120	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
Lead*	5	TN DWS	3.18	81.6	2.52	64.6	b	4.88	125	3.62	93.0	b	18.6	477	10.9	281	b
Lithium	40	RSL	440	910	NA	NA	a	440	910	NA	NA	a	440	910	NA	NA	a
Mercury	2	TN DWS/MCL	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a
Molybdenum	100	RSL	800	7,200	NA	NA	a	800	7,200	NA	NA	a	800	7,200	NA	NA	a
Radium-226 & 228	5 pCi/L	MCL	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c
Selenium	50	TN DWS/MCL	3.1	20	NA	NA	b	3.1	20	NA	NA	b	3.1	20	NA	NA	b
Thallium	2	TN DWS/MCL	6	54	NA	NA	a	6	54	NA	NA	a	6	54	NA	NA	a
TDEC Appendix I Constituents :																	
Copper*	1,300	MCL	9.33	14.0	8.96	13.4	b	12.4	19.2	11.9	18.5	b	30.5	51.7	29.3	49.6	b
Nickel*	100	TN DWS	52.2	469	52.0	468	b	69.3	624	69.1	622	b	169	1516	168	1513	b
Silver*	100	TN DWS/SMCL	NA	3.78	NA	3.22	b	NA	6.75	NA	5.74	b	NA	41.1	NA	34.9	b
Vanadium	86	RSL	27	79	NA	NA	a	27	79	NA	NA	a	27	79	NA	NA	a
Zinc*	2,000	HAL	120	120	118	117	b	159	159	157	156	b	388	388	382	379	b

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Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

CCR Parameters	Johnsonville Fossil Plant							John Sevier Fossil Plant								
	Human Health Surface Water Screening Levels		Ecological Surface Water Screening Levels					Ecological Surface Water Screening Levels								
			Tennessee River (Hardness = 60 mg/L)					Holston River (Hardness = 100 mg/L)					Polly Branch (Hardness = 100 mg/L)				
	(µg/L)	Source	Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)	
CCR Rule Appendix III Constituents :																	
Boron	4,000	RSL	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a
Calcium	--	--	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a
Chloride	250,000	SMCL	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
pH	6 - 9 S.U.	TN DWS	6.5 - 9	NA	NA	NA	b	6.5 - 9	NA	NA	NA	b	6 - 9	NA	NA	NA	b
Sulfate	250,000	SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
Total Dissolved Solids	500,000	TN DWS/SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
CCR Rule Appendix IV Constituents :																	
Antimony	6	TN DWS/MCL	190	900	NA	NA	a	190	900	NA	NA	a	190	900	NA	NA	a
Arsenic	10	TN DWS/MCL	150	340	150	340	a	150	340	150	340	a	150	340	150	340	a
Barium	2,000	TN DWS/MCL	220	2,000	NA	NA	a	220	2,000	NA	NA	a	220	2,000	NA	NA	a
Beryllium	4	TN DWS/MCL	11	93	NA	NA	a	11	93	NA	NA	a	11	93	NA	NA	a
Cadmium*	5	TN DWS/MCL	0.526	1.16	0.489	1.12	b	0.790	1.91	0.718	1.80	b	0.790	1.91	0.718	1.80	b
Chromium*	100	TN DWS/MCL	56.7	1187	48.8	375	b	86.2	1803	74.1	570	b	86.2	1803	74.1	570	b
Cobalt	6	RSL	19	120	NA	NA	a	19	120	NA	NA	a	19	120	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
Lead*	5	TN DWS	1.66	42.6	1.44	36.9	b	3.18	81.6	2.52	64.6	b	3.18	81.6	2.52	64.6	b
Lithium	40	RSL	440	910	NA	NA	a	440	910	NA	NA	a	440	910	NA	NA	a
Mercury	2	TN DWS/MCL	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a
Molybdenum	100	RSL	800	7,200	NA	NA	a	800	7,200	NA	NA	a	800	7,200	NA	NA	a
Radium-226 & 228	5 pCi/L	MCL	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c
Selenium	50	TN DWS/MCL	3.1	20	NA	NA	b	3.1	20	NA	NA	b	3.1	20	NA	NA	b
Thallium	2	TN DWS/MCL	6	54	NA	NA	a	6	54	NA	NA	a	6	54	NA	NA	a
TDEC Appendix I Constituents :																	
Copper*	1,300	MCL	6.03	8.65	5.79	8.31	b	9.33	14.0	8.96	13.4	b	9.33	14.0	8.96	13.4	b
Nickel*	100	TN DWS	33.9	305	33.8	304	b	52.2	469	52.0	468.24	b	52.2	469	52.0	468	b
Silver*	100	TN DWS/SMCL	NA	1.57	NA	1.34	b	NA	3.78	NA	3.22	b	NA	3.78	NA	3.22	b
Vanadium	86	RSL	27	79	NA	NA	a	27	79	NA	NA	a	27	79	NA	NA	a
Zinc*	2,000	HAL	77.7	77.7	76.6	76.0	b	120	120	118	117	b	120	120	118	117	b

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

CCR Parameters	Watts Bar Fossil Plant						
	Human Health Surface Water Screening Levels		Ecological Surface Water Screening Levels				
			Tennessee River (Hardness = 75 mg/L)				
	(µg/L)	Source	Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)	
CCR Rule Appendix III Constituents :							
Boron	4,000	RSL	7,200	34,000	NA	NA	a
Calcium	--	--	116,000	NA	NA	NA	a
Chloride	250,000	SMCL	230,000	860,000	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a
pH	6 - 9 S.U.	TN DWS	6.5 - 9	NA	NA	NA	b
Sulfate	250,000	SMCL	NA	NA	NA	NA	
Total Dissolved Solids	500,000	TN DWS/SMCL	NA	NA	NA	NA	
CCR Rule Appendix IV Constituents :							
Antimony	6	TN DWS/MCL	190	900	NA	NA	a
Arsenic	10	TN DWS/MCL	150	340	150	340	a
Barium	2,000	TN DWS/MCL	220	2,000	NA	NA	a
Beryllium	4	TN DWS/MCL	11	93	NA	NA	a
Cadmium*	5	TN DWS/MCL	0.628	1.44	0.579	1.38	b
Chromium*	100	TN DWS/MCL	68.1	1425	58.6	450	b
Cobalt	6	RSL	19	120	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a
Lead*	5	TN DWS	2.21	56.6	1.84	47.2	b
Lithium	40	RSL	440	910	NA	NA	a
Mercury	2	TN DWS/MCL	0.77	1.4	0.77	1.4	a
Molybdenum	100	RSL	800	7,200	NA	NA	a
Radium-226 & 228	5 pCi/L	MCL	3 pCi/L	3 pCi/L	NA	NA	c
Selenium	50	TN DWS/MCL	3.1	20	NA	NA	b
Thallium	2	TN DWS/MCL	6	54	NA	NA	a
TDEC Appendix I Constituents :							
Copper*	1,300	MCL	7.30	10.7	7.00	10.2	b
Nickel*	100	TN DWS	40.9	368	40.8	367	b
Silver*	100	TN DWS/SMCL	NA	2.31	NA	1.96	b
Vanadium	86	RSL	27	79	NA	NA	a
Zinc*	2,000	HAL	93.9	93.9	92.6	91.8	b

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

Notes:
* The freshwater screening values are hardness dependent. These screening values were adjusted using the following equations and parameters provided in TDEC 2019:
Acute Screening Levels (dissolved) = exp{mA[ln(hardness)]+bA } (CF)
Chronic Screening Levels (dissolved) = exp{mC [ln(hardness)]+bC} (CF)

Parameters	mA	bA	mC	bC	Conversation Factor (CF)	
					CMC	CCC
Cadmium	0.9798	-3.866	0.7977	-3.909	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]
Chromium III	0.819	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	2.555	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

ug/L: micrograms per liter
NA = not applicable
SMCL: USEPA secondary maximum contaminant level
HAL: Health advisory level
MCL: USEPA maximum contaminant level
MCLG: Maximum contaminant level goal
TN DWS: drinking water standard promulgated by State of Tennessee
RSL: USEPA regional screening level for residential tapwater (November 2020)

a USEPA Region 4 Surface Water Screening Values for Hazardous Waste Sites (March 2018 Revision).
b Tennessee Department of Environment and Consevation (TDEC), 2019. Chapter 0400-40-03, General Water Quality Criteria.
c U.S. Department of Energy (DOE), 2019. DOE Standard (DOE-STD-1153-2019), A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. Biota Concentration Guides for water of 4 pCi/L for Radium-226 and 3 pCi/L for Radium-228.
d The mean hardness of surface water in the Unnamed Tributary is approximately 750 mg/L; however, per TDEC water quality guidelines TDEC, 2019), a hardness value of 400 mg/L was used to calculate hardness-dependent water quality criteria.

Red highlight denotes bioaccumulative constituent (USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update).

Table 3. Proposed Screening Levels for Mayfly Tissue Critical Body Residues
Environmental Assessment Report

CCR Parameters	Mayfly Tissue Critical Body Residue NOAEL (mg/kg-ww)	Mayfly Tissue Critical Body Residue LOAEL (mg/kg-ww)	
CCR Rule Appendix III Constituents :			
Boron	NA	NA	
Calcium	NA	NA	
Chloride	NA	NA	
Fluoride	NA	NA	
pH	NA	NA	
Sulfate	NA	NA	
Total Dissolved Solids	NA	NA	
CCR Rule Appendix IV Constituents :			
Antimony	NA	NA	
Arsenic	0.0249	0.249	a
Barium	NA	NA	
Beryllium	NA	NA	
Cadmium	15.6	156	a
Chromium (total)	0.144	1.44	a
Cobalt	0.1061	1.061	
Fluoride	NA	NA	
Lead	269	2690	a
Lithium	NA	NA	
Mercury	2.7	27	a
Molybdenum	NA	NA	
Radium-226 & 228	NA	NA	
Selenium	0.051	0.51	a
Thallium	1.206	12.06	a
TDEC Appendix I Constituents :			
Copper	26	260	a
Nickel	0.115	1.15	a
Silver	0.23	2.3	a
Vanadium	0.604	6.04	a
Zinc	382	3820	a

Notes:

a Arcadis, 2012. Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment (BERA).

Toxicity values were selected from the U.S. Army Corps of Engineers/ USEPA Environmental Residue-Effects Database (ERED).

mg/kg-ww - milligrams per kilogram, wet weight

Red highlight denotes bioaccumulative constituent (USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update).

Table 4. Proposed Screening Levels for Fish Tissue Critical Body Residues
Environmental Assessment Report

CCR Parameters	Whole Body Fish Tissue Critical Body Residue			Liver Tissue Critical Body Residue			Muscle Tissue Critical Body Residue			Ovary Tissue Critical Body Residue		
	NOAEL (mg/kg-ww)	LOAEL (mg/kg-ww)		NOAEL (mg/kg-ww)	LOAEL (mg/kg-ww)		NOAEL (mg/kg-ww)	LOAEL (mg/kg-ww)		NOAEL (mg/kg-ww)	LOAEL (mg/kg-ww)	
CCR Rule Appendix III Constituents :												
Boron	NA	NA		NA	NA		NA	NA		NA	NA	
Calcium	NA	NA		NA	NA		NA	NA		NA	NA	
Chloride	NA	NA		NA	NA		NA	NA		NA	NA	
Fluoride	NA	NA		NA	NA		NA	NA		NA	NA	
pH	NA	NA		NA	NA		NA	NA		NA	NA	
Sulfate	NA	NA		NA	NA		NA	NA		NA	NA	
Total Dissolved Solids	NA	NA		NA	NA		NA	NA		NA	NA	
CCR Rule Appendix IV Constituents :												
Antimony	NA	NA		NA	NA		NA	NA		NA	NA	
Arsenic	0.04	0.4	a	0.569	5.69	a	0.076	0.76	a	8.4	84	a
Barium	NA	NA		NA	NA		NA	NA		NA	NA	
Beryllium	5.13	51.3	a	NA	NA		NA	NA		NA	NA	
Cadmium	0.0019	0.019	a	0.0000137	0.000137	a	0.03	0.12	a	NA	NA	
Chromium (total)	0.128	1.28	a	0.042	0.42	a	NA	NA		NA	NA	
Cobalt	NA	NA		NA	NA		NA	NA		NA	NA	
Fluoride	NA	NA		NA	NA		NA	NA		NA	NA	
Lead	0.0278	0.278	a	0.0393	0.393	a	2.3	23	a	NA	NA	
Lithium	NA	NA		NA	NA		NA	NA		NA	NA	
Mercury	0.006	0.06	a	0.0009	0.009	a	0.08	0.8	a	NA	NA	
Molybdenum	NA	NA		NA	NA		NA	NA		NA	NA	
Radium-226 & 228	NA	NA		NA	NA		NA	NA		NA	NA	
Selenium	8.5	8.5	b	0.524	5.24	a	11.3	11.3	b	15.1	15.1	b
Thallium	0.027	0.27	a	NA	NA		NA	NA		NA	NA	
TDEC Appendix I Constituents :												
Copper	0.196	1.96	a	6.52	65.2	a	3.4	34	a	NA	NA	
Nickel	11.81	118.1	a	8.22	82.2	a	11.81	118.1	a	NA	NA	
Silver	0.0114	0.114	a	19	190	a	NA	NA		NA	NA	
Vanadium	0.68	2.7	a	0.03	0.3	a	NA	NA		NA	NA	
Zinc	0.45	4.5	a	3.4	34	a	NA	NA		NA	NA	

Notes:

a Arcadis, 2012. Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment (BERA).
Toxicity values were selected from the U.S. Army Corps of Engineers/USEPA Environmental Residue-Effects Database (ERED).

b USEPA, 2016. Chronic Ambient Water Quality Criterion for Selenium. Fish tissue concentrations expressed as mg/kg-dry weight.

mg/kg-ww - milligrams per kilogram, wet weight

Red highlight denotes bioaccumulative constituent (USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update).

Table 5. Proposed Ecological Screening Levels for Freshwater Sediment
Environmental Assessment Report

CCR Parameters	Freshwater Sediment Screening Values		Sediment Quality Assessment Guidelines[a]	
	Chronic (mg/kg-dw)	Acute (mg/kg-dw)	TEC (mg/kg-dw)	PEC (mg/kg-dw)
CCR Rule Appendix III Constituents :				
Percent Ash	20% b	40% c	NA	NA
Boron	NA	NA	NA	NA
Calcium	NA	NA	NA	NA
Chloride	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA
pH	NA	NA	NA	NA
Sulfate	NA	NA	NA	NA
Total Dissolved Solids	NA	NA	NA	NA
CCR Rule Appendix IV Constituents :				
Antimony	2	25 e	NA	NA
Arsenic	9.8	33 e	9.8	33
Barium	240	22925 f	NA	NA
Beryllium	1.2	42 f	NA	NA
Cadmium	1	5 e	1	5
Chromium	43.4	111 e	43	110
Cobalt	50	NA e	50	NA
Fluoride	NA	NA	NA	NA
Lead	35.8	128 e	36	130
Lithium	NA	NA	NA	NA
Mercury	0.18	1.1 e	0.18	1.1
Molybdenum	38	69760 f	NA	NA
Radium-226 & 228	90 pCi/g	90 pCi/g d	NA	NA
Selenium	2 g	2.9 e	NA	NA
Thallium	1.2	10 f	NA	NA
TDEC Appendix I Constituents :				
Copper	31.6	149 e	32	150
Nickel	22.7	48.6 e	23	49
Silver	1	2.2 e	NA	NA
Vanadium	66	564 f	NA	NA
Zinc	121	459 e	120	460

Notes:
mg/kg-dw - Milligrams per kilogram dry weight
NA - Not Available

a MacDonald, et al., 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters. TEC - Threshold Effect Concentration, PEC - Probable Effect Concentration.
b Environmental Investigation Plans (EIP) for TVA fossil plants under the TDEC Consent Order.
c Arcadis, 2012. Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment (BERA).
d U.S. Department of Energy (DOE), 2019. DOE Standard (DOE-STD-1153-2019), A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. Biota Concentration Guides for sediment of 100 pCi/g for Radium-226 and 90 pCi/g for Radium-228.
e USEPA Region 4 Sediment Screening Values for Hazardous Waste Sites (March 2018 Revision).
f National Institute for Public Health and the Environment (RIVM), 2005. Environmental Risk Limits for Nine Trace Elements. The Maximum Permissible Concentration (MPC) is used for the chronic value and the Serious Risk Addition (SRAeco) is used for the acute value.
g Lemly, A.D., 2002. Selenium Assessment in Aquatic Ecosystems
Red highlight denotes bioaccumulative constituent (USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update).

Stantec

TVA Core Team Tennessee Valley Authority

Reference: Proposed Receptor-Specific Screening Levels for Human Health

ATTACHMENT B - DEVELOPMENT OF RECEPTOR-SPECIFIC SCREENING LEVELS FOR HUMAN HEALTH

Table B.1 - Cancer Receptor-Specific Screening Level Calculations for an Onsite Worker Exposed to Soil

Analyte	CAS	Soil SSL_{HH} (mg/kg)	Pathway-Specific SSL_{HH}			Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$		Unit Risk Factor $(\mu g/m^3)^{-1}$
			Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Inhalation SSL_{HH} (mg/kg)	Oral	Dermal	Inhalation
Antimony	7440-36-0	na	na	na	na	na	na	na
Arsenic	7440-38-2	2.4E+02	3.4E+02	2.1E+03	1.4E+03	1.5E+00	1.5E+00	4.3E-03
Barium	7440-39-3	na	na	na	na	na	na	na
Beryllium	7440-41-7	2.5E+03	na	na	2.5E+03	na	na	2.4E-03
Boron	7440-42-8	na	na	na	na	na	na	na
Cadmium	7440-43-9	3.3E+03	na	na	3.3E+03	na	na	1.8E-03
Calcium	7440-70-2	na	na	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na	na	na
Chromium	7440-47-3	na	na	na	na	na	na	na
Cobalt	7440-48-4	6.6E+02	na	na	6.6E+02	na	na	9.0E-03
Copper	7440-50-8	na	na	na	na	na	na	na
Fluoride	16984-48-8	na	na	na	na	na	na	na
Lead	7439-92-1	na	na	na	na	na	na	na
Lithium	7439-93-2	na	na	na	na	na	na	na
Mercury	7439-97-6	na	na	na	na	na	na	na
Molybdenum	7439-98-7	na	na	na	na	na	na	na
Nickel	7440-02-0	2.3E+04	na	na	2.3E+04	na	na	2.6E-04
Selenium	7782-49-2	na	na	na	na	na	na	na
Silver	7440-22-4	na	na	na	na	na	na	na
Sulfate	14808-79-8	na	na	na	na	na	na	na
Thallium	7440-28-0	na	na	na	na	na	na	na
Vanadium	7440-62-2	na	na	na	na	na	na	na
Zinc	7440-66-6	na	na	na	na	na	na	na

Notes:

CAS - Chemical Abstracts Service registry number

mg/kg - milligrams per kilogram

mg/kg-d - milligrams per kilogram per day

$\mu g/m^3$ - micrograms per cubic meter

na - not available/applicable

SSL_{HH} - receptor-specific screening levels for human health

Table B.2 - Non-Cancer Receptor-Specific Screening Level Calculations for an Onsite Worker Exposed to Soil

Analyte	CAS	Soil SSL_{HH} (mg/kg)	Pathway-Specific SSL_{HH}			Subchronic Reference Dose (mg/kg-d)		Subchronic Reference Concentration (mg/m^3)
			Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Inhalation SSL_{HH} (mg/kg)	Oral	Dermal	Inhalation
Antimony	7440-36-0	1.3E+01	1.4E+01	na	6.5E+02	4.0E-04	6.0E-05	1.0E-03
Arsenic	7440-38-2	5.9E+00	1.7E+01	1.1E+02	9.8E+00	3.0E-04	3.0E-04	1.5E-05
Barium	7440-39-3	2.2E+03	6.8E+03	na	3.3E+03	2.0E-01	1.4E-02	5.0E-03
Beryllium	7440-41-7	1.2E+01	1.7E+02	na	1.3E+01	5.0E-03	3.5E-05	2.0E-05
Boron	7440-42-8	4.5E+03	6.8E+03	na	1.3E+04	2.0E-01	2.0E-01	2.0E-02
Cadmium	7440-43-9	5.4E+00	3.4E+01	2.6E+02	6.5E+00	1.0E-03	2.5E-05	1.0E-05
Calcium	7440-70-2	na	na	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na	na	na
Chromium	7440-47-3	3.1E+03	5.1E+04	na	3.3E+03	1.5E+00	2.0E-02	5.0E-03
Cobalt	7440-48-4	1.2E+01	1.0E+02	na	1.3E+01	3.0E-03	3.0E-03	2.0E-05
Copper	7440-50-8	1.4E+03	1.4E+03	na	na	4.0E-02	4.0E-02	na
Fluoride	16984-48-8	1.2E+03	1.4E+03	na	8.5E+03	4.0E-02	4.0E-02	1.3E-02
Lead	7439-92-1	na	na	na	na	na	na	na
Lithium	7439-93-2	6.8E+01	6.8E+01	na	na	2.0E-03	2.0E-03	na
Mercury	7439-97-6	5.0E+01	6.8E+01	na	2.0E+02	2.0E-03	1.4E-04	3.0E-04
Molybdenum	7439-98-7	8.0E+02	2.0E+03	na	1.3E+03	6.0E-02	6.0E-02	2.0E-03
Nickel	7440-02-0	1.1E+02	6.8E+02	na	1.3E+02	2.0E-02	8.0E-04	2.0E-04
Selenium	7782-49-2	1.7E+02	1.7E+02	na	1.3E+04	5.0E-03	5.0E-03	2.0E-02
Silver	7440-22-4	1.7E+02	1.7E+02	na	na	5.0E-03	2.0E-04	na
Sulfate	14808-79-8	na	na	na	na	na	na	na
Thallium	7440-28-0	1.4E+00	1.4E+00	na	na	4.0E-05	4.0E-05	na
Vanadium	7440-62-2	5.5E+01	3.4E+02	na	6.5E+01	1.0E-02	2.6E-04	1.0E-04
Zinc	7440-66-6	1.0E+04	1.0E+04	na	na	3.0E-01	3.0E-01	na

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
mg/m^3 - milligrams per cubic meter
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.3 - Particulate Emissions Factor Calculation for an Onsite Worker

Site-specific

Construction Worker Equation Inputs for Soil - Other Construction Activities

Variable	Construction Worker Soil - Other Default Value	Form-input Value
$A_{c\text{-}doz}$ (areal extent of dozing) acres	0	0.5
A_{excav} (area of excavation site) m^2	0	2023.42821
$A_{c\text{-}grade}$ (areal extent of grading) acres	0	0.5
A (PEF Dispersion Constant)	2.4538	2.4538
A_{surf} (areal extent of site) m^2	2023.43	2023.43
A_{till} (areal extent of tilling) acres	0	0.5
$B_{l\text{-}doz}$ (dozing blade length) m	0	2.44
$B_{l\text{-}grade}$ (grading blade length) m	0	2.44
B (PEF Dispersion Constant)	17.566	17.566
C (PEF Dispersion Constant)	189.0426	189.0426
d_{excav} (average depth of excavation site) m	0	1
F_D Unitless Dispersion Correction Factor	0.185837208	0.193145487
F(x) (function dependant on U_m/U_t derived using Cowherd et al. (1985))	0.194	0.194
$M_{m\text{-}doz}$ (Gravimetric soil moisture content) %	7.9	7.9
$M_{m\text{-}excav}$ (Gravimetric soil moisture content) %	12	12
M_{wind} (dust emitted by wind erosion) g	51288.84717	51288.84717
$N_{A\text{-}doz}$ (number of times site was dozed)	0	2
$N_{A\text{-}dump}$ (number of times soil is dumped)	2	2
$N_{A\text{-}grade}$ (number of times site was graded)	0	2
$N_{A\text{-}till}$ (number of times soil is tilled)	2	2
Q/C_{sa} (inverse of the ratio of the geometric mean air concentration to the emission flux at the center of a square source) g/m^2-s per kg/m^3	14.31407	14.31407
p_{soil} (density) g/cm^3 - chemical-specific	1.68	1.68
s_{doz} (soil silt content) %	6.9	6.9
AF_{cw} (skin adherence factor - construction worker) mg/cm^2	0.3	0.3
AT_{cw} (averaging time - construction worker) days	365	28
BW_{cw} (body weight - construction worker) kg	80	80
ED_{cw} (exposure duration - construction worker) yr	1	1
EF_{cw} (exposure frequency - construction worker) day/yr	250	20
ET_{cw} (exposure time - construction worker) hr/day	8	8
THQ (target hazard quotient) unitless	0.1	1
IRS_{cw} (soil ingestion rate - construction worker) mg/day	330	330
LT (lifetime) yr	70	70
SA_{cw} (surface area - construction worker) cm^2/day	3527	3527
TR (target cancer risk) unitless	0.000001	0.000001
S_{doz} (dozing speed) kph	11.4	11.4
S_{grade} (grading speed) kph	11.4	11.4
s_{till} (soil silt content) %	18	18
t_c (overall duration of construction) hours	8400	672
T_c (overall duration of construction) s	30240000	2419200
T (time over which traffic occurs) s	7200000	576000
T_t (overall duration of traffic) s	7200000	576000

Table B.3 - Particulate Emissions Factor Calculation for an Onsite Worker

Site-specific

Construction Worker Equation Inputs for Soil - Other Construction Activities

Variable	Construction Worker Soil - Other Default Value	Form-input Value
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value) m/s	11.32	11.32
V (fraction of vegetative cover)	0	0
Particulate Emission Factor (m3/kg)		**1558751**

Output generated 01DEC2020:14:08:30

Notes:

The particulate emission factor (PEF) was calculated using the inputs shown and the Regional Screening Level (RSL) Calculator Construction Worker - Other Construction Activities scenario. https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search

site-specific value

% - percent
cm^2 - square centimeters
hr - hours
g - grams
g/cm^2 - grams per square centimeter
g/cm^3 - grams per cubic centimeter
g/m^2-s per kg/m^3 - grams per square meter - second per kilogram per cubic meter
kg - kilograms
km - kilometers
kph - kilometers per hour
m - meters
m^2 - square meters
m^3/kg - cubic meter(s) per kilogram
mg - milligrams
mg/cm^2 - milligrams per square centimeters
m/s - meter(s) per second
s - second(s)
yr - year(s)

Table B.4 - Cancer Receptor-Specific Screening Level Calculations for a Recreational User - Beachcomber Exposed to Sediment

Analyte	CAS	Pathway-Specific SSL_{HH}			Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$ [b]	
		Sediment SSL_{HH} (mg/kg)	Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Oral	Dermal
Antimony	7440-36-0	na	na	na	na	na
Arsenic	7440-38-2	3.4E+00	3.9E+00	2.6E+01	1.5E+00	1.5E+00
Barium	7440-39-3	na	na	na	na	na
Beryllium	7440-41-7	na	na	na	na	na
Boron	7440-42-8	na	na	na	na	na
Cadmium	7440-43-9	na	na	na	na	na
Calcium	7440-70-2	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na
Chromium	7440-47-3	na	na	na	na	na
Cobalt	7440-48-4	na	na	na	na	na
Copper	7440-50-8	na	na	na	na	na
Fluoride	16984-48-8	na	na	na	na	na
Lead	7439-92-1	na	na	na	na	na
Lithium	7439-93-2	na	na	na	na	na
Mercury	7439-97-6	na	na	na	na	na
Molybdenum	7439-98-7	na	na	na	na	na
Nickel	7440-02-0	na	na	na	na	na
Selenium	7782-49-2	na	na	na	na	na
Silver	7440-22-4	na	na	na	na	na
Sulfate	14808-79-8	na	na	na	na	na
Thallium	7440-28-0	na	na	na	na	na
Vanadium	7440-62-2	na	na	na	na	na
Zinc	7440-66-6	na	na	na	na	na

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.5 - Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Child) - Beachcomber Exposed to Sediment

Analyte	CAS	Pathway-Specific SSL_{HH}			Reference Dose (mg/kg-d) [b]	
		Sediment SSL_{HH} (mg/kg)	Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Oral	Dermal
Antimony	7440-36-0	2.1E+01	2.1E+01	na	4.0E-04	6.0E-05
Arsenic	7440-38-2	2.4E+01	2.6E+01	2.2E+02	3.0E-04	3.0E-04
Barium	7440-39-3	1.1E+04	1.1E+04	na	2.0E-01	1.4E-02
Beryllium	7440-41-7	1.1E+02	1.1E+02	na	2.0E-03	1.4E-05
Boron	7440-42-8	1.1E+04	1.1E+04	na	2.0E-01	2.0E-01
Cadmium	7440-43-9	4.8E+01	5.3E+01	5.5E+02	1.0E-03	2.5E-05
Calcium	7440-70-2	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na
Chromium	7440-47-3	7.9E+04	7.9E+04	na	1.5E+00	2.0E-02
Cobalt	7440-48-4	1.6E+01	1.6E+01	na	3.0E-04	3.0E-04
Copper	7440-50-8	2.1E+03	2.1E+03	na	4.0E-02	4.0E-02
Fluoride	16984-48-8	2.1E+03	2.1E+03	na	4.0E-02	4.0E-02
Lead	7439-92-1	na	na	na	na	na
Lithium	7439-93-2	1.1E+02	1.1E+02	na	2.0E-03	2.0E-03
Mercury	7439-97-6	1.6E+01	1.6E+01	na	3.0E-04	2.1E-05
Molybdenum	7439-98-7	2.6E+02	2.6E+02	na	5.0E-03	5.0E-03
Nickel	7440-02-0	1.1E+03	1.1E+03	na	2.0E-02	8.0E-04
Selenium	7782-49-2	2.6E+02	2.6E+02	na	5.0E-03	5.0E-03
Silver	7440-22-4	2.6E+02	2.6E+02	na	5.0E-03	2.0E-04
Sulfate	14808-79-8	na	na	na	na	na
Thallium	7440-28-0	5.3E-01	5.3E-01	na	1.0E-05	1.0E-05
Vanadium	7440-62-2	2.6E+02	2.6E+02	na	5.0E-03	1.3E-04
Zinc	7440-66-6	1.6E+04	1.6E+04	na	3.0E-01	3.0E-01

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.6 - Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Adolescent) - Beachcomber Exposed to Sediment

Analyte	CAS	Sediment SSL_{HH} (mg/kg)	Pathway-Specific SSL_{HH}		Reference Dose (mg/kg-d) [b]	
			Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Oral	Dermal
Antimony	7440-36-0	6.2E+01	6.2E+01	na	4.0E-04	6.0E-05
Arsenic	7440-38-2	6.5E+01	7.8E+01	4.1E+02	3.0E-04	3.0E-04
Barium	7440-39-3	3.1E+04	3.1E+04	na	2.0E-01	1.4E-02
Beryllium	7440-41-7	3.1E+02	3.1E+02	na	2.0E-03	1.4E-05
Boron	7440-42-8	3.1E+04	3.1E+04	na	2.0E-01	2.0E-01
Cadmium	7440-43-9	1.4E+02	1.6E+02	1.0E+03	1.0E-03	2.5E-05
Calcium	7440-70-2	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na
Chromium	7440-47-3	2.3E+05	2.3E+05	na	1.5E+00	2.0E-02
Cobalt	7440-48-4	4.7E+01	4.7E+01	na	3.0E-04	3.0E-04
Copper	7440-50-8	6.2E+03	6.2E+03	na	4.0E-02	4.0E-02
Fluoride	16984-48-8	6.2E+03	6.2E+03	na	4.0E-02	4.0E-02
Lead	7439-92-1	na	na	na	na	na
Lithium	7439-93-2	3.1E+02	3.1E+02	na	2.0E-03	2.0E-03
Mercury	7439-97-6	4.7E+01	4.7E+01	na	3.0E-04	2.1E-05
Molybdenum	7439-98-7	7.8E+02	7.8E+02	na	5.0E-03	5.0E-03
Nickel	7440-02-0	3.1E+03	3.1E+03	na	2.0E-02	8.0E-04
Selenium	7782-49-2	7.8E+02	7.8E+02	na	5.0E-03	5.0E-03
Silver	7440-22-4	7.8E+02	7.8E+02	na	5.0E-03	2.0E-04
Sulfate	14808-79-8	na	na	na	na	na
Thallium	7440-28-0	1.6E+00	1.6E+00	na	1.0E-05	1.0E-05
Vanadium	7440-62-2	7.8E+02	7.8E+02	na	5.0E-03	1.3E-04
Zinc	7440-66-6	4.7E+04	4.7E+04	na	3.0E-01	3.0E-01

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.7 - Cancer Receptor-Specific Screening Level Calculations for a Recreational User - Consumer of Locally-Caught Sport Fish

Analytes	CAS	Fish SSL_{HH} (mg/kg wet weight)	Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$ Oral
Antimony	7440-36-0	na	na
Arsenic	7440-38-2	4.7E-03	1.5E+00
Barium	7440-39-3	na	na
Beryllium	7440-41-7	na	na
Boron	7440-42-8	na	na
Cadmium	7440-43-9	na	na
Calcium	7440-70-2	na	na
Chloride	16887-00-6	na	na
Chromium	7440-47-3	na	na
Cobalt	7440-48-4	na	na
Copper	7440-50-8	na	na
Fluoride	16984-48-8	na	na
Lead	7439-92-1	na	na
Lithium	7439-93-2	na	na
Mercury	7439-97-6	na	na
Molybdenum	7439-98-7	na	na
Nickel	7440-02-0	na	na
Selenium	7782-49-2	na	na
Silver	7440-22-4	na	na
Sulfate	14808-79-8	na	na
Thallium	7440-28-0	na	na
Vanadium	7440-62-2	na	na
Zinc	7440-66-6	na	na

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.8 - Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Child) - Consumer of Locally-Caught Sport Fish

Analytes	CAS	Fish SSL_{HH} (mg/kg wet weight)	Reference Dose (mg/kg-d) Oral
Antimony	7440-36-0	7.2E-02	4.0E-04
Arsenic	7440-38-2	5.4E-02	3.0E-04
Barium	7440-39-3	3.6E+01	2.0E-01
Beryllium	7440-41-7	3.6E-01	2.0E-03
Boron	7440-42-8	3.6E+01	2.0E-01
Cadmium	7440-43-9	1.8E-01	1.0E-03
Calcium	7440-70-2	na	na
Chloride	16887-00-6	na	na
Chromium	7440-47-3	2.7E+02	1.5E+00
Cobalt	7440-48-4	5.4E-02	3.0E-04
Copper	7440-50-8	7.2E+00	4.0E-02
Fluoride	16984-48-8	na	4.0E-02
Lead	7439-92-1	na	na
Lithium	7439-93-2	3.6E-01	2.0E-03
Mercury	7439-97-6	1.8E-02	1.0E-04
Molybdenum	7439-98-7	9.0E-01	5.0E-03
Nickel	7440-02-0	3.6E+00	2.0E-02
Selenium	7782-49-2	9.0E-01	5.0E-03
Silver	7440-22-4	9.0E-01	5.0E-03
Sulfate	14808-79-8	na	na
Thallium	7440-28-0	1.8E-03	1.0E-05
Vanadium	7440-62-2	9.0E-01	5.0E-03
Zinc	7440-66-6	5.4E+01	3.0E-01

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.9 - Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Adolescent) - Consumer of Locally-Caught Sport Fish

Analytes	CAS	Fish SSL_{HH} (mg/kg wet weight)	Reference Dose (mg/kg-d) Oral
Antimony	7440-36-0	1.4E-01	4.0E-04
Arsenic	7440-38-2	1.1E-01	3.0E-04
Barium	7440-39-3	7.2E+01	2.0E-01
Beryllium	7440-41-7	7.2E-01	2.0E-03
Boron	7440-42-8	7.2E+01	2.0E-01
Cadmium	7440-43-9	3.6E-01	1.0E-03
Calcium	7440-70-2	na	na
Chloride	16887-00-6	na	na
Chromium	7440-47-3	5.4E+02	1.5E+00
Cobalt	7440-48-4	1.1E-01	3.0E-04
Copper	7440-50-8	1.4E+01	4.0E-02
Fluoride	16984-48-8	na	4.0E-02
Lead	7439-92-1	na	na
Lithium	7439-93-2	7.2E-01	2.0E-03
Mercury	7439-97-6	3.6E-02	1.0E-04
Molybdenum	7439-98-7	1.8E+00	5.0E-03
Nickel	7440-02-0	7.2E+00	2.0E-02
Selenium	7782-49-2	1.8E+00	5.0E-03
Silver	7440-22-4	1.8E+00	5.0E-03
Sulfate	14808-79-8	na	na
Thallium	7440-28-0	3.6E-03	1.0E-05
Vanadium	7440-62-2	1.8E+00	5.0E-03
Zinc	7440-66-6	1.1E+02	3.0E-01

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.10 – Adult Lead Model Calculation Spreadsheet

Calculations of Preliminary Remediation Goals (PRGs) for Soil in Nonresidential Areas

U.S. EPA Technical Review Workgroup for Lead, Adult Lead Committee

Version date 06/14/2017

EDIT RED CELLS

Variable	Description of Variable	Units	On-Site Worker GSDi and PbBo from Analysis of NHANES 2009-2014	Recreational User (Adolescent) - Beachcomber GSDi and PbBo from Analysis of NHANES 2009-2014
$PbB_{fetal,\ 0.95}$	Target PbB in fetus (e.g., 2-8 µg/dL)	µg/dL	5	5
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4	0.4
GSD_i	Geometric standard deviation PbB	--	1.8	1.8
PbB_0	Baseline PbB	µg/dL	0.6	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.330	0.200
$AF_{S,\ D}$	Absorption fraction (same for soil and dust)	--	0.12	0.12
$EF_{S,\ D}$	Exposure frequency (same for soil and dust)	days/yr	20	52
$AT_{S,\ D}$	Averaging time (same for soil and dust)	days/yr	28	365
PRG in Soil for no more than 5% probability that fetal PbB exceeds target PbB		**ppm**	**134**	**1,106**

Notes:

days/yr - days per year

g/day - grams per day

NHANES - National Health and Nutrition Examination Survey

PbB - blood lead concentration

PRG - Preliminary Remediation Goals

ppm - parts per million

µg/day - micrograms per day

µg/dL - micrograms per deciliter

USEPA - United States Environmental Protection Agency

Stantec

TVA Core Team Tennessee Valley Authority

Reference: Proposed Receptor-Specific Screening Levels for Human Health

ATTACHMENT C – EPA PRG CALCULATOR INPUTS AND OUTPUTS

Table C.1 - Peak PRG Calculator Input for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)

Variable	Construction Worker Soil - Other Default Value	Form-input Value
A (PEF Dispersion Constant)	2.45	2.45
B (PEF Dispersion Constant)	17.6	17.6
C (PEF Dispersion Constant)	189	189
Cover layer thickness for GSF (gamma shielding factor) cm	0 cm	0 cm
F_D Unitless Dispersion Correction Factor	0.186	0.193
F(x) (function dependant on U_m/U_t derived using Cowherd	0.194	0.194
PEF`$_{sc}$ (subchronic particulate emission factor) m^3/kg		1,558,751
concentration to the emission flux at the center of a square source) g/m^2-s per kg/m^3	14.3	14.3
Site area for ACF (area correction factor) m^2	1,000,000 m^2	2,000 m^2
ED_{cw} (exposure duration - construction worker) yr	1.00	1.00
EF_{cw} (exposure frequency - construction worker) day/yr	250	20.0
ET_{cw} (exposure time - construction worker) hr/day	8.00	8.00
IRA_{cw} (soil inhalation rate - construction worker) m^3/day	60.0	60.0
IRS_{cw} (soil ingestion rate - construction worker) mg/day	330	330
t_{cw} (time - construction worker) yr	1.00	1.00
TR (target cancer risk) unitless	1.00E-06	1.00E-06
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value) m/s	11.3	11.3
V (fraction of vegetative cover)	0	0

Notes:

site-specific value

cm - centimeters
g/m^2-s per kg/m^3 - grams per square meter - second per kilogram per cubic meter
hr - hours
m^2 - square meters
m^3 - cubic meters
m^3/kg - cubic meter(s) per kilogram
mg - milligrams
m/s - meter(s) per second
yr - year(s)

Table C.2 - Peak PRG Calculator Ra-226 Output for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)

Construction Worker Peak Risk PRGs for Soil - Other Construction Activities

Peak PRG Results	Ingestion PRG TR=1.0E-06 (pCi/g)	Inhalation PRG TR=1.0E-06 (pCi/g)	External Exposure PRG TR=1.0E-06 (pCi/g)	Total PRG TR=1.0E-06 (pCi/g)
Peak PRG for Ra-226 @ PRG units	*6.89E+01*	*6.98E+01*	*7.73E+00*	*6.53E+00*
Peak start time for maximum risk (yrs)	*1.35E+02*	*1.17E+02*	*1.18E-01*	*7.38E+01*
Maximum risk during peak interval (unitless)	*1.45E-08*	*1.43E-08*	*1.29E-07*	*1.53E-07*
Maximum risk-rate during peak interval (risk/yr)	*8.91E-09*	*7.23E-09*	*1.14E-07*	*1.14E-07*

Table C.3 - Peak PRG Calculator Ra-228 Output for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)

Construction Worker Peak Risk PRGs for Soil - Other Construction Activities

Peak PRG Results	Ingestion PRG TR=1.0E-06 (pCi/g)	Inhalation PRG TR=1.0E-06 (pCi/g)	External Exposure PRG TR=1.0E-06 (pCi/g)	Total PRG TR=1.0E-06 (pCi/g)
Peak PRG for Ra-228 @ PRG units	*2.31E+02*	*3.55E+01*	*9.32E+00*	*7.20E+00*
Peak start time for maximum risk (yrs)	*1.00E-08*	*3.31E+00*	*2.81E+00*	*2.87E+00*
Maximum risk during peak interval (unitless)	*4.33E-09*	*2.82E-08*	*1.07E-07*	*1.39E-07*
Maximum risk-rate during peak interval (risk/yr)	*4.42E-09*	*1.96E-08*	*6.36E-08*	*6.36E-08*

Table C.4 - Peak PRG Calculator Input for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Variable	Recreator Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	16.2302
B (PEF Dispersion Constant)	18.7762	18.7762
City (Climate Zone)	Default	Default
C (PEF Dispersion Constant)	216.108	216.108
Cover layer thickness for GSF (gamma shielding factor) cm	0 cm	0 cm
$CF_{rec\text{-}fowl}$ (fowl contaminated fraction) unitless	1	0
$CF_{rec\text{-}game}$ (game contaminated fraction) unitless	1	0
ED_{rec} (exposure duration - recreator) yr		26
EF_{rec} (exposure frequency - recreator) day/yr		52
$f_{p\text{-}fowl}$ (fowl on-site fraction) unitless	1	1
$f_{p\text{-}game}$ (land game on-site fraction) unitless	1	1
$f_{s\text{-}fowl}$ (fraction of year fowl is on site) unitless	1	1
$f_{s\text{-}game}$ (fraction of year land game is on site) unitless	1	1
$IRGF_{rec}$ (fowl consumption rate) g/day		0
$IRGL_{rec}$ (land game consumption rate) g/day		0
$MLF_{pasture}$ (pasture plant mass loading factor) unitless	0.25	0.25
$Q_{p\text{-}fowl}$ (fowl fodder intake rate) kg/day		0
$Q_{p\text{-}game}$ (land game fodder intake rate) kg/day		0
$Q_{s\text{-}fowl}$ (fowl soil intake rate) kg/day		0
$Q_{s\text{-}game}$ (land game soil intake rate) kg/day		0
t_{rec} (time - recreator) yr		26
TR (target cancer risk) unitless	0.000001	0.000001
F(x) (function dependent on U_m/U_t) unitless	0.194	0.194
PEF (particulate emission factor) m^3/kg	1359344438	1359344438
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	93.77
A_s (acres)	0.5	0.5
Site area for ACF (area correction factor) m^2	1000029 m^2	2000 m^2
ED_{rec} (exposure duration - recreator) yr		26
$ED_{rec\text{-}a}$ (exposure duration - recreator adult) yr		10
$ED_{resc\text{-}c}$ (exposure duration - recreator child) yr		16
EF_{rec} (exposure frequency - recreator) day/yr		52
$EF_{rec\text{-}a}$ (exposure frequency - recreator adult) day/yr		52
$EF_{rec\text{-}c}$ (exposure frequency - recreator child) day/yr		52
ET_{rec} (exposure time - recreator) hr/day		2
$ET_{rec\text{-}a}$ (exposure time - recreator) hr/day		2
$ET_{rec\text{-}c}$ (exposure time - recreator) hr/day		2
$IFA_{rec\text{-}adj}$ (age-adjusted inhalation rate - recreator) m^3		0
$IFS_{rec\text{-}adj}$ (age-adjusted soil intake rate - recreator) mg		218400
$IRA_{rec\text{-}a}$ (inhalation rate - recreator adult) m^3/day	20	0
$IRA_{rec\text{-}c}$ (inhalation rate - recreator child) m^3/day	10	0

Table C.4 - Peak PRG Calculator Input for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Variable	Recreator Soil Default Value	Form-input Value
IRS_{rec-a} (soil intake rate - recreator adult) mg/day	100	100
IRS_{rec-c} (soil intake rate - recreator child) mg/day	200	200
t_{rec} (time - recreator) yr		26
TR (target cancer risk) unitless	0.000001	0.000001
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Notes:

site-specific value

cm - centimeters
g - grams
g/m^2-s per kg/m^3 - grams per square meter - second per kilogram per cubic meter
hr - hours
kg - kilograms
m^2 - square meters
m^3 - cubic meters
m^3/kg - cubic meter(s) per kilogram
mg - milligrams
m/s - meter(s) per second
yr - year(s)

Table C.5 - Peak PRG Calculator Ra-226 Output for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Recreator Peak Risk PRGs for Soil

Peak PRG Results	Ingestion PRG TR=1.0E-06 (pCi/g)	Inhalation PRG TR=1.0E-06 (pCi/g)	External Exposure PRG TR=1.0E-06 (pCi/g)	Soil to Game Consumption PRG TR=1.0E-06 (pCi/g)	Soil to Fowl Consumption PRG TR=1.0E-06 (pCi/g)	Total PRG TR=1.0E-06 (pCi/g)
Peak PRG for Ra-226 @ PRG units	*8.54E-01*	-	*4.60E-01*	-	-	*3.08E-01*
Peak start time for maximum risk (yrs)	*1.23E+02*	-	*6.82E-02*	-	-	*9.04E+01*
Maximum risk during peak interval (unitless)	*1.17E-06*	-	*2.17E-06*	-	-	*3.25E-06*
Maximum risk-rate during peak interval (risk/yr)	*2.59E-08*	-	*7.40E-08*	-	-	*7.40E-08*

Table C.6 - Peak PRG Calculator Ra-228 Output for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Recreator Peak Risk PRGs for Soil

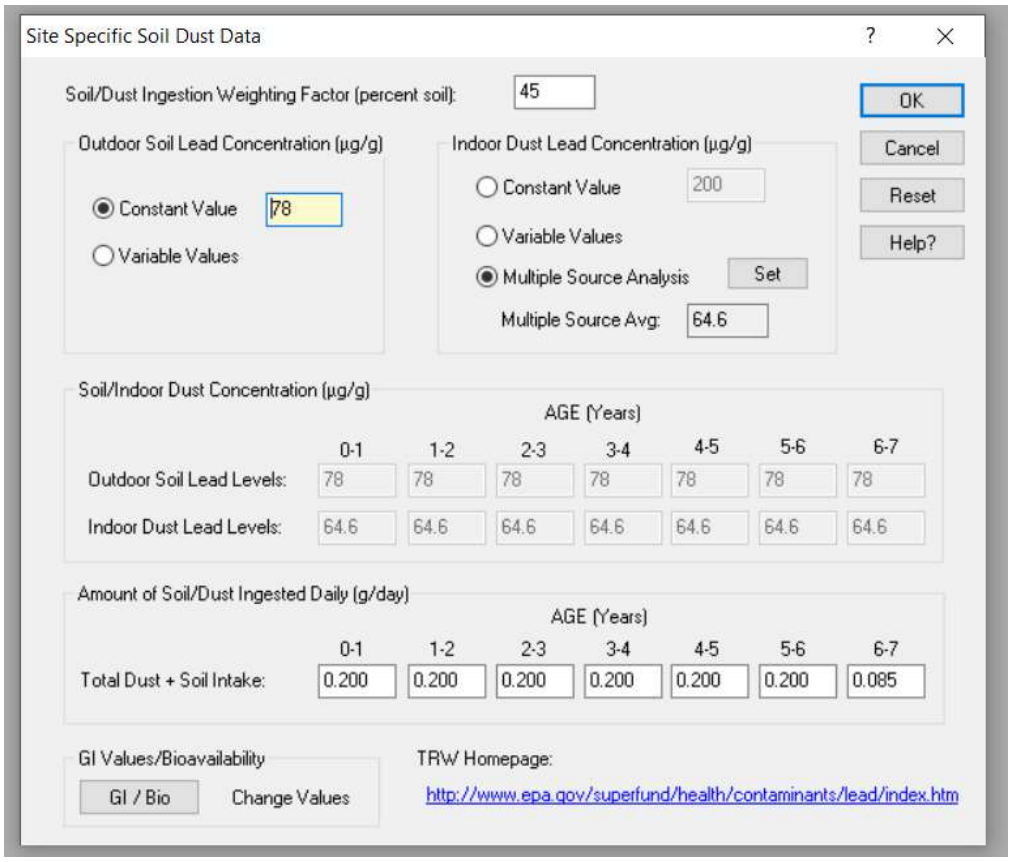
Peak PRG Results	Ingestion PRG TR=1.0E-06 (pCi/g)	Inhalation PRG TR=1.0E-06 (pCi/g)	External Exposure PRG TR=1.0E-06 (pCi/g)	Soil to Game Consumption PRG TR=1.0E-06 (pCi/g)	Soil to Fowl Consumption PRG TR=1.0E-06 (pCi/g)	Total PRG TR=1.0E-06 (pCi/g)
Peak PRG for Ra-228 @ PRG units	*5.55E+00*	-	*1.09E+00*	-	-	*9.11E-01*
Peak start time for maximum risk (yrs)	*1.00E-08*	-	*1.00E-08*	-	-	*1.00E-08*
Maximum risk during peak interval (unitless)	*1.80E-07*	-	*9.18E-07*	-	-	*1.10E-06*
Maximum risk-rate during peak interval (risk/yr)	*1.66E-08*	-	*4.14E-08*	-	-	*4.14E-08*

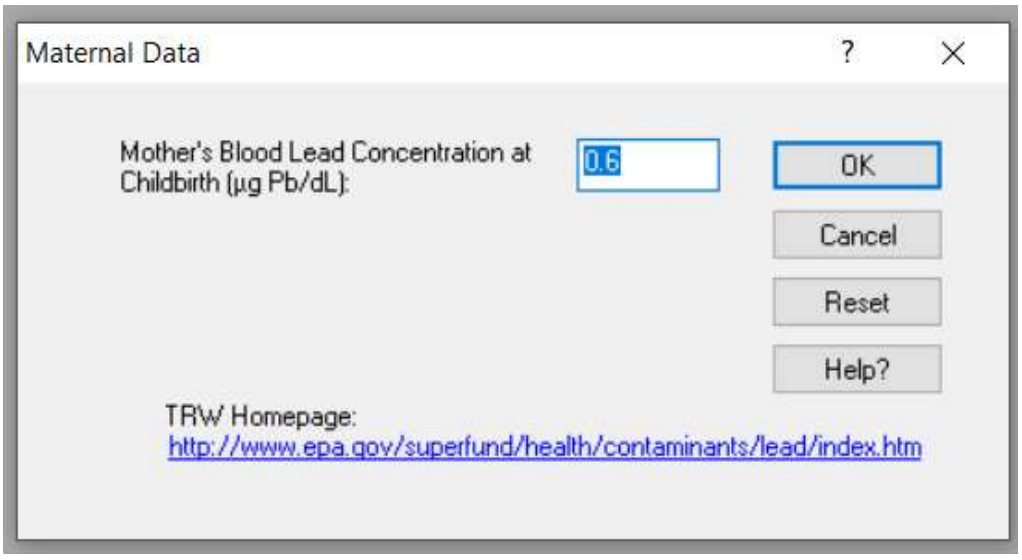
Stantec

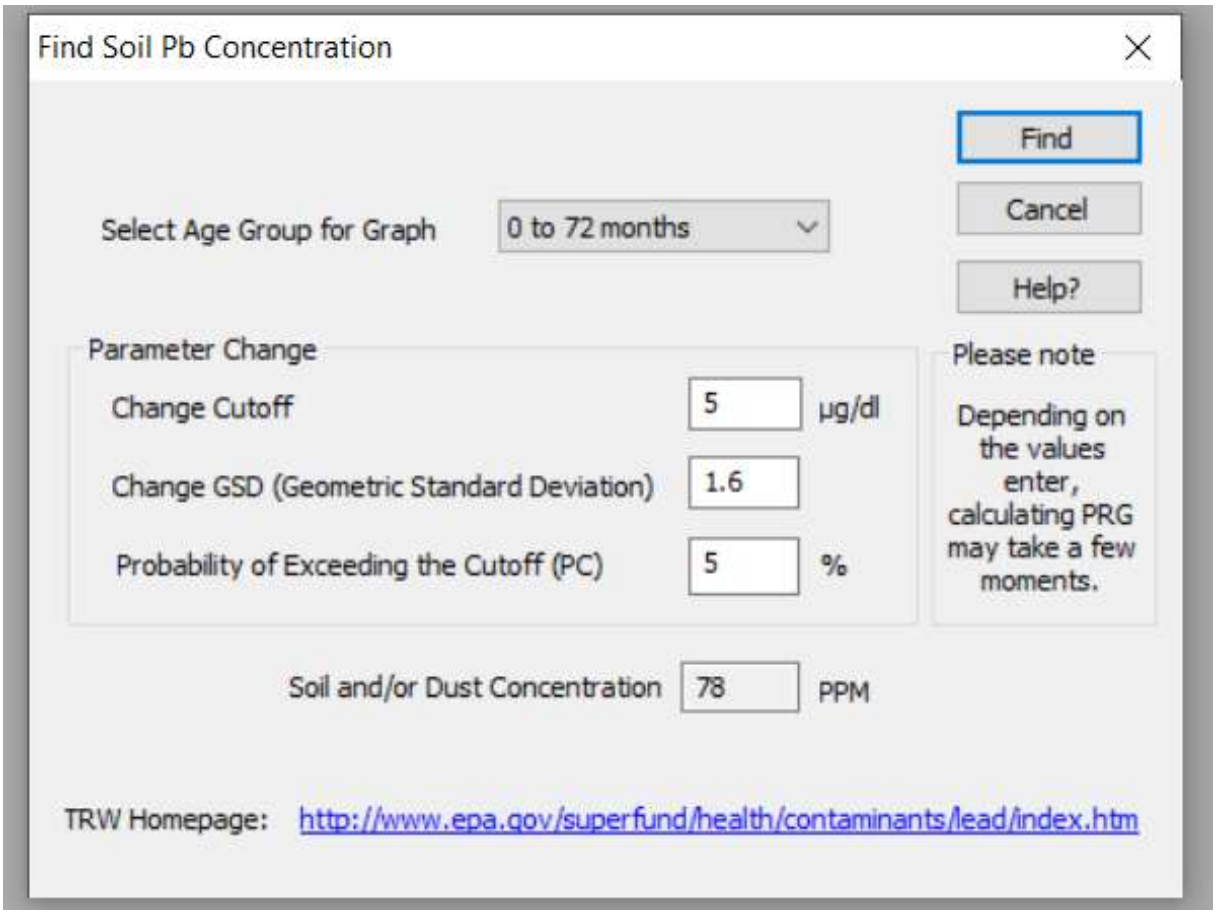
TVA Core Team Tennessee Valley Authority

Reference: Proposed Receptor-Specific Screening Levels for Human Health

ATTACHMENT D – IEUBK CALCULATION OUTPUT


Site Specific Soil Dust Data
Soil/Dust Ingestion Weighting Factor (percent soil): 45
OK
Cancel
Reset
Help?
Outdoor Soil Lead Concentration (µg/g)
Constant Value 78
Variable Values
Indoor Dust Lead Concentration (µg/g)
Constant Value 200
Variable Values
Multiple Source Analysis Set
Multiple Source Avg: 64.6
Soil/Indoor Dust Concentration (µg/g)
AGE (Years)
0-1 1-2 2-3 3-4 4-5 5-6 6-7
Outdoor Soil Lead Levels: 78 78 78 78 78 78 78
Indoor Dust Lead Levels: 64.6 64.6 64.6 64.6 64.6 64.6 64.6
Amount of Soil/Dust Ingested Daily (g/day)
AGE (Years)
0-1 1-2 2-3 3-4 4-5 5-6 6-7
Total Dust + Soil Intake: 0.200 0.200 0.200 0.200 0.200 0.200 0.085
GI Values/Bioavailability
GI / Bio
Change Values
TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm


Maternal Data
Mother's Blood Lead Concentration at Childbirth (µg Pb/dL): 0.6
OK
Cancel
Reset
Help?
TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm


Find Soil Pb Concentration
Find
Cancel
Help?
Select Age Group for Graph
0 to 72 months
Parameter Change
Change Cutoff
5
µg/dl
Change GSD (Geometric Standard Deviation)
1.6
Probability of Exceeding the Cutoff (PC)
5
%
Please note
Depending on the values enter, calculating PRG may take a few moments.
Soil and/or Dust Concentration
78
PPM
TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm

LEAD MODEL FOR WINDOWS Version 1.1

==========

Model Version: 1.1 Build11
User Name:
Date:
Site Name:
Operable Unit:
Run Mode: Research

==========

****** Air ******

Indoor Air Pb Concentration: 30.000 percent of outdoor.
Other Air Parameters:

Age	Time Outdoors (hours)	Ventilation Rate (m^3/day)	Lung Absorption (%)	Outdoor Air Pb Conc (µg Pb/m^3)
.5-1	1.000	2.000	32.000	0.100
1-2	2.000	3.000	32.000	0.100
2-3	3.000	5.000	32.000	0.100
3-4	4.000	5.000	32.000	0.100
4-5	4.000	5.000	32.000	0.100
5-6	4.000	7.000	32.000	0.100
6-7	4.000	7.000	32.000	0.100

****** Diet ******

Age	Diet Intake(µg/day)
.5-1	2.260
1-2	1.960
2-3	2.130
3-4	2.040
4-5	1.950
5-6	2.050
6-7	2.220

****** Drinking Water ******

Water Consumption:

Age	Water (L/day)
.5-1	0.200
1-2	0.500
2-3	0.520
3-4	0.530
4-5	0.550
5-6	0.580
6-7	0.590

Drinking Water Concentration: 4.000 µg Pb/L

****** Soil & Dust ******

Multiple Source Analysis Used
Average multiple source concentration: 64.600 µg/g

Mass fraction of outdoor soil to indoor dust conversion factor: 0.700
Outdoor airborne lead to indoor household dust lead concentration: 100.000
Use alternate indoor dust Pb sources? No

Age	Soil (µg Pb/g)	House Dust (µg Pb/g)
.5-1	78.000	64.600
1-2	78.000	64.600
2-3	78.000	64.600
3-4	78.000	64.600
4-5	78.000	64.600
5-6	78.000	64.600
6-7	78.000	64.600

****** Alternate Intake ******

Age	Alternate (µg Pb/day)
.5-1	0.000
1-2	0.000
2-3	0.000
3-4	0.000
4-5	0.000
5-6	0.000
6-7	0.000

****** Maternal Contribution: Infant Model ******

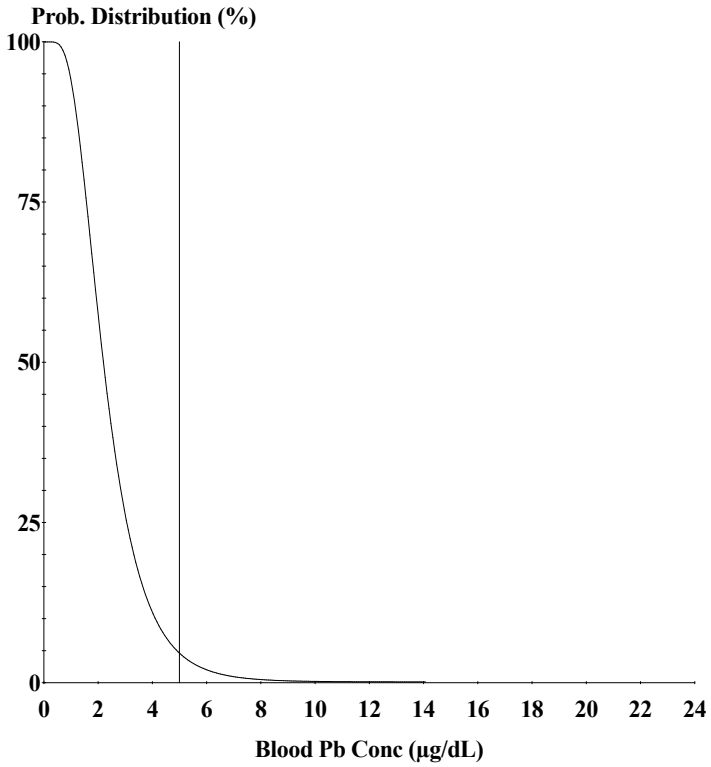
Maternal Blood Concentration: 0.600 µg Pb/dL

****
CALCULATED BLOOD LEAD AND LEAD UPTAKES:
****

Year	Air (µg/day)	Diet (µg/day)	Alternate (µg/day)	Water (µg/day)
.5-1	0.021	1.062	0.000	0.376
1-2	0.034	0.931	0.000	0.950
2-3	0.062	1.018	0.000	0.994
3-4	0.067	0.981	0.000	1.020
4-5	0.067	0.943	0.000	1.064
5-6	0.093	0.995	0.000	1.126
6-7	0.093	1.090	0.000	1.159

Year	Soil+Dust (µg/day)	Total (µg/day)	Blood (µg/dL)
.5-1	3.984	5.443	3.0
1-2	4.025	5.939	2.6
2-3	4.051	6.126	2.3
3-4	4.078	6.146	2.2
4-5	4.099	6.172	2.1
5-6	4.112	6.325	1.9
6-7	1.769	4.112	1.4

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Cutoff = 5.000 µg/dl
Geo Mean = 2.302
GSD = 1.600
% Above = 4.947

Age Range = 12 to 84 months

Run Mode = Research

APPENDIX C – SUPPORTING INFORMATION FOR DATA EVALUATION AND CALCULATION OF EXPOSURE POINT CONCENTRATIONS

APPENDIX C.1

EAR STATISTICAL ANALYSES

(APPENDIX E OF THE WBF PLANT ENVIRONMENTAL ASSESSMENT REPORT)

APPENDIX E –
STATISTICAL ANALYSES

APPENDIX E.1

STATISTICAL ANALYSIS OF BACKGROUND SOIL DATA

DRAFT

Appendix E.1 – Statistical Analysis of Background Soil Data

TDEC Commissioner's Order:
Environmental Assessment Report
Watts Bar Fossil Plant
Spring City, Tennessee

March 31, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

REVISION LOG

Revision	Description	Date
0	Submittal to TDEC	November 7, 2023
1	Addresses January 31, 2024 TDEC Review Comments and Issued for TDEC	March 31, 2024

Sign-off Sheet

This document entitled Appendix E.1 – Statistical Analysis of Background Soil Data was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____

Chris La Londe, Risk Assessor

Reviewed by _____

Matt Pontier, Staff Engineer

Approved by _____

Carole M. Farr, PG, Senior Principal Geologist

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Abbreviations

BGS	Background Soil
BTVs	Background Threshold Values
CASRN	Chemical Abstracts Service Registry Number
CCR	Coal Combustion Residuals
CCR Parameters	Constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations, Part 257
EAR	Environmental Assessment Report
EI	Environmental Investigation
ft bgs	Feet Below Ground Surface
IQR	Interquartile Range
NA	Not Available
%	Percent
QA/QC	Quality Assurance and Quality Control
SAR	Sampling and Analysis Report
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority
UTLs	Upper Tolerance Limits
WBF Plant	Watts Bar Fossil Plant

APPENDIX E.1 – STATISTICAL ANALYSIS OF BACKGROUND SOIL DATA

March 31, 2024

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this statistical analysis report on behalf of the Tennessee Valley Authority (TVA) to summarize the statistical analyses performed on background soil (BGS) data to support evaluations conducted for the Environmental Assessment Report (EAR) at the Watts Bar Fossil Plant (WBF Plant) located in Spring City, Tennessee. The BGS samples were collected as part of the Tennessee Department of Environment and Conservation (TDEC) Order Environmental Investigation (EI) on June 6 and July 8, 2019 from two background monitoring well borings, and between September 4 and 17, 2019 in the vicinity of the WBF Plant from locations where naturally occurring, *in situ*, native soils unaffected by Coal Combustion Residual (CCR) materials were present. Further details regarding the BGS sampling program and results are available in the Watts Bar Fossil Plant (*WBF Plant) BGS Investigation Sampling and Analysis Report* (SAR) (Appendix F.1), including the BGS investigation boring locations (Exhibit A.2), and a list of the BGS investigation borings and associated soil samples and analyses (Table B.1).

Twelve samples were excluded from the statistical analysis datasets for being collected in the saturated zone. The Constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04 (CCR Parameters) included in the analysis are presented below in Table E.1-1.

Table E.1-1 – CCR Parameters Evaluated in Statistical Analysis

Parameter	CASRN
CCR Rule Appendix III Parameters	
Boron	7440-42-8
Calcium	7440-70-2
Chloride	16887-00-6
Fluoride[1] (also Appendix IV)	16984-48-8
pH	Not Available (NA)
Sulfate	14808-79-8
TDS	NA
CCR Rule Appendix IV Parameters	
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Lead	7439-92-1
Lithium	7439-93-2
Mercury	7439-97-6
Molybdenum	7439-98-7
Radium-226+228	13982-63-3/ 15262-20-1
Selenium	7782-49-2
Thallium	7440-28-0
TDEC Appendix I Parameters	
Copper	7440-50-8
Nickel	7440-02-0
Silver	7440-22-4
Vanadium	7440-62-2
Zinc	7440-66-6
Other	
% Ash	NA

Notes: CASRN - Chemical Abstracts Service Registry Number; CCR Rule - Title 40, Code of Federal Regulations, Part 257; NA - Not available

[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV parameter. In this table, and in the results presented herein, fluoride has been grouped with the Appendix III parameters only to avoid duplication.

The following sections present the methods and results from general exploratory data analysis using summary statistics, data plots, outlier screening methods and the calculation of Background Threshold Values (BTVs).

2.0 METHODS

The statistical evaluation for the BGS data collected at the WBF Plant for the EI was conducted in two parts: 1) exploratory data analysis and 2) calculation of site-specific BTVs. The analyses relied on available background soil data collected as part of the BGS EI. Quality assurance and quality control (QA/QC) samples (e.g. field duplicates) were excluded from the statistical analysis.

2.1 EXPLORATORY DATA ANALYSIS

Exploratory data analysis is the initial step of statistical analysis. It utilizes simple summary statistics (e.g. mean, median, standard deviation, and percentiles) and graphical representations to identify important characteristics of an analytical dataset, such as the center of the data (mean, median), variation, distribution, spatial patterns, presence of outliers, and randomness.

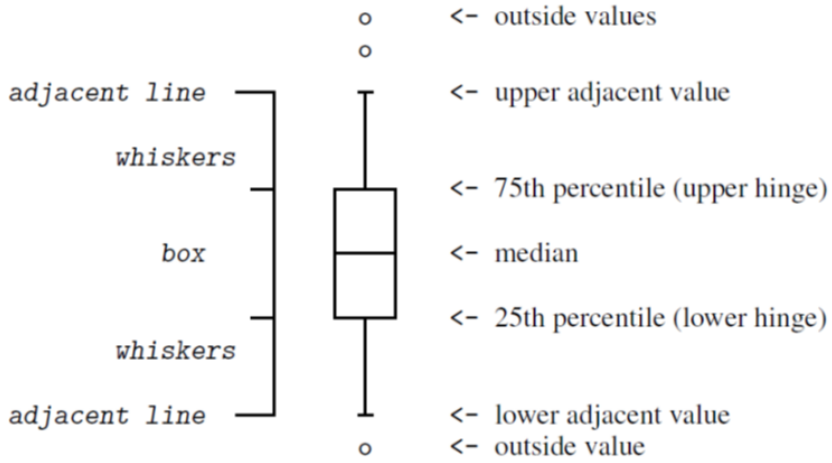
For the EI, surficial soil samples were typically collected at depths ranging from 0.0 to approximately 0.5 feet below ground surface (ft bgs). In addition to the CCR Parameters (Table E.1-1), these samples were analyzed for the presence of CCR Material (percent [%] Ash). Along with surficial samples, the field sampling personnel collected approximately two feet of soil from each 5-foot soil run (one foot in both directions from the midpoint of the 5-foot interval) for the total depth of the boring. For the statistical analysis, soil depths were aggregated into the following depth intervals: surficial (0 to approximately 0.5 ft bgs), approximately 0.5 to less than or equal to 10 ft bgs, and greater than 10 ft bgs.

2.1.1 Summary Statistics

Summary statistics were calculated for each CCR Parameter grouped by depth interval and the entire set of BGS samples (including all depth intervals and boring locations). Summary statistics include information such as the total numbers of available samples, the frequencies of detection, ranges of reporting limits, minimum and maximum detected concentrations, mean concentrations, standard deviations, median concentrations, and the 95th percentile concentrations. A summary statistics table is presented in Attachment E.1-A.

2.1.2 Exploratory Data Plots

Exploratory data plots (box plots) were constructed to support a visual review of the data. Box plots identify the center of the data, distribution, variability, and to visually identify potential outliers. The diagram below graphically depicts the basics of the construction of the box plots (StataCorp LLC 2017).



The box portion of the plot is the interquartile range (IQR), which represents the middle 50% of data, with the bottom of the box being the 25th percentile and the top of the box being the 75th percentile. The line inside the box is the median concentration. The top of the upper "whisker" represents the first observed concentration above the 75th percentile, whereas the bottom of the lower "whisker" represents the first observed concentration below the 25th percentile (upper adjacent value and lower adjacent value, respectively). Values that lie outside of the adjacent values represent outside concentrations (i.e. concentrations at the upper and lower ends of the distribution of the data). The method detection limit was used as the reported value in order to construct the box plot when analytical results were reported as non-detects.

Two sets of side-by-side box plots were constructed for the BGS CCR Parameter data: 1) results by depth interval and 2) results by BGS boring location. These box plots were useful in identifying differences in CCR Parameter concentrations between depth intervals and between boring locations and were especially useful for visually identifying potential outliers. Box plots for CCR Parameters aggregated by depth interval and by boring location are provided in Attachment E.1-B.

2.1.3 Outlier Screening

Outliers are data points that are abnormally high or low as compared to the rest of the measurements and may represent anomalous data or data errors but may also represent natural variation of CCR Parameter concentrations in environmental systems. Screening for outliers is a critical step because outliers can bias statistical estimates, statistical testing results, and inferences. The size of the datasets for each depth interval (a minimum of 10 samples) were sufficiently large to capture natural variation commonly seen in environmental datasets.

Outlier values were initially screened visually using the side-by-side box plots. If suspected visual outliers were identified, then Tukey's procedure was used to identify extreme outliers (Tukey 1977). This method relies on the IQR, which is defined as the 75th percentile value minus the 25th percentile value.

Values were identified as potential outliers as follows:

- **Lower extreme outliers** are less than the 25th percentile minus 3 x IQR
- **Upper extreme outliers** are greater than the 75th percentile plus 3 x IQR.

Multiple potential outliers were identified using Tukey's procedure as indicated in the Summary Statistics Tables in Attachment E.1-A; these values were flagged as potential outliers in the dataset. However, given the heterogeneity of naturally occurring inorganic compounds in soils, statistical outliers were not removed from the datasets prior to statistical analysis, but may be reevaluated if BTVs are used to inform future corrective actions.

2.2 ESTIMATES OF BACKGROUND CONDITIONS

BTVs were calculated as conservative estimates of CCR Parameter concentrations in BGS. Specifically, 95% upper tolerance limits (UTLs) with 95% coverage were calculated for each parameter at each soil depth interval defined for the statistical datasets and with all depths combined to establish conservative

estimates of background soil concentrations. The UTL represents the upper bound of a pre-specified proportion of the underlying data population with a specified level of confidence. For example, for a "95% UTL with 95% coverage", there is 95% confidence that, on average, 95% of the data are below the UTL. The upper one-sided UTL is commonly used in environmental monitoring and is constructed using background data (Ofungwu 2014). In the case of pH, 95% tolerance intervals with 95% coverage were calculated to bound the range of pH values. BTVs aggregated by soil depth interval and with all depths combined are presented in Attachment E.1-A.

2.2.1 Tests for Normality of Background Data

Prior to the calculation of UTLs, the data were evaluated for normality. Parametric methods to establish background conditions (UTLs) can be applied to data that are normally distributed or to data that fit another defined statistical distribution (e.g., gamma distribution), or to data that can be transformed to normal using mathematical transformations (e.g., lognormal transformation). Testing data for normality was done using formal statistical methods, known as goodness-of-fit-testing (e.g., Shapiro-Wilk or Lilliefors tests). If the data did not fit a defined statistical distribution or could not be transformed to normal, then non-parametric methods were used.

2.2.2 Parametric UTLs

Parametric UTLs were used when the background data were normally distributed, gamma distributed or transformed using the lognormal transformation. A background sample size or dataset consisting of at least eight observations was required to generate an adequate tolerance limit.

The calculation of the UTL is straightforward:

$$UTL = \overline{x} + \tau s$$

Where:

$\overline{x}$ = mean CCR parameter concentration in the background dataset

s = standard deviation of CCR parameter in the background dataset

τ = multiplier based on size of dataset, confidence (95%) and desired coverage (95%).

2.2.3 Non-parametric UTLs

When the background data do not fit the normal or gamma distribution or cannot be normalized via the lognormal transformation, non-parametric UTLs were used. The non-parametric UTL is an order statistic, typically the maximum or the second largest observed concentration in the background dataset. Unlike parametric methods, the desired coverage and confidence interval cannot be pre-specified for non-parametric tolerance limits. In the case of non-parametric methods, the level of confidence increases with increasing sample size. If non-parametric methods were used, the approximate level of confidence was reported.



UTLs, especially non-parametric UTLs, are sensitive to outliers and are biased high in the presence of outliers. For this initial analysis, no suspect outliers were removed from the data set. If the UTLs presented in this report are going to be used to inform corrective actions, then additional analysis to account for the presence of outliers is warranted.

3.0 RESULTS AND DISCUSSION

3.1 SUMMARY STATISTICS, EXPLORATORY DATA PLOTS, AND OUTLIER SCREENING

Summary statistics for each CCR Parameter are provided in Attachment E.1-A, with results aggregated by depth interval and with all depths combined. Summary statistics are sorted by CCR Parameter type (i.e., CCR Rule Appendix III Parameters, CCR Rule Appendix IV Parameters, TDEC Appendix I Parameters, and Other). Box plots for each CCR Parameter aggregated by depth and boring location are provided in Attachment E.1-B.

The number of values identified as potential outliers using Tukey's procedure for each depth interval and with all depths combined is identified in Attachment E.1-A. For these potential outliers, no definitive reasons were identified for the outlier values and the values identified were assumed to be representative of natural conditions and natural variation within native soil. These values were flagged as statistical outliers in the dataset and retained for subsequent calculations and analysis if needed for future evaluations (see columns labelled "Number of Statistical Outliers" and "Number of Outliers Removed" in Attachment E.1-A).

3.2 ESTIMATES OF BACKGROUND CONDITIONS

BTVs for the BGS investigation at the WBF Plant were calculated using UTLs (and Tolerance Intervals in the case of pH). The resulting BTV concentrations and the statistical distribution and methods used to calculate the UTLs are identified for each CCR Parameter aggregated by depth interval and with all depths combined in Attachment E.1-A.

4.0 REFERENCES

Ofungwu, J. (2014). Statistical Applications for Environmental Analysis and Risk Assessment. Hoboken, New Jersey: John Wiley and Sons, Inc.

StataCorp. (2017). Stata Graphics Reference Manual Stata: Release 15. Statistical Software. College Station, TX: StataCorp LLC.

Tukey, J.W. (1977). Exploratory data analysis. Reading, Massachusetts: Addison-Wesley, 1977.

ATTACHMENT E.1-A
SUMMARY STATISTICS TABLES

DRAFT

Summary Statistics - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Soil Depth (ft bgs)	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects							
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile	Number of Statistical Outliers	Number of Outliers Removed	Background Threshold Value	Statistical Distribution & Method
Percent Ash														
Ash	Surficial	7/10	(1.0 - 1.0)	30.0%	1.0	3.0	1.4	0.66	1.0	2.6	0	0	NA	NA
CCR Rule Appendix IV Parameters														
Boron	Surficial	10/10	--	0.0%	1.93	3.81	2.97	0.545	2.98	3.69	2	0	4.56	95% UTL (Normal) 95% Coverage
	0.5' to 10'	17/20	(1.46 - 1.78)	15.0%	1.75	55.9	5.51	11.7	2.59	11.7			55.9	95% UTL (NP-64.2%) 95% Coverage
	>10'	19/27	(1.71 - 1.88)	29.6%	1.62	3.17	2.14	0.493	1.97	2.88			3.25	95% UTL (Normal) 95% Coverage
	All Depth	46/57	(1.46 - 1.88)	19.3%	1.62	55.9	3.46	7.10	2.41	3.90			9.32	95% UTL (NP-78.5%) 95% Coverage
Calcium	Surficial	10/10	--	0.0%	997	33,900	5,680	10,200	1,730	22,900	5	0	68,600	95% (Lognormal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	31.8	14,700	2,650	4,540	1,030	14,200			34,700	95% (Lognormal) 95% Coverage
	>10'	27/27	--	0.0%	22.0	3,320	1,080	816	834	2,710			3,990	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	57/57	--	0.0%	22.0	33,900	2,440	5,180	1,030	10,700			14,700	95% UTL (NP-78.5%) 95% Coverage
Chloride	Surficial	3/10	(4.43 - 4.86)	70.0%	5.02	5.81	4.72	0.478	4.68	5.61	5	0	5.81	95% UTL (NP-40.1%) 95% Coverage
	0.5' to 10'	7/20	(4.17 - 4.87)	65.0%	4.76	10.3	4.88	1.42	4.69	6.91			10.3	95% UTL (NP-64.2%) 95% Coverage
	>10'	10/27	(4.78 - 5.32)	63.0%	4.51	19.8	6.00	3.49	5.02	13.5			19.8	95% UTL (NP-75%) 95% Coverage
	All Depth	20/57	(4.17 - 5.32)	64.9%	4.51	19.8	5.25	2.67	4.87	10.3			14.8	95% UTL (NP-78.5%) 95% Coverage
Fluoride	Surficial	7/10	(0.777 - 0.799)	30.0%	0.905	4.01	1.72	0.962	1.74	3.23	7	0	4.52	95% UTL (Normal) 95% Coverage
	0.5' to 10'	7/20	(0.759 - 0.853)	65.0%	0.912	14.6	2.11	3.32	0.832	8.63			9.17	95% WH Approximate Gamma UTL 95% Coverage
	>10'	18/27	(0.768 - 0.914)	33.3%	1.04	15.4	3.20	4.11	1.17	12.0			15.4	95% UTL (NP-75%) 95% Coverage
	All Depth	32/57	(0.759 - 0.914)	43.9%	0.905	15.4	2.56	3.52	1.05	10.8			14.6	95% UTL (NP-78.5%) 95% Coverage
pH (lab)	Surficial	10/10	--	0.0%	6.0	7.8	6.5	0.640	6.3	7.7	0	0	(6.0-7.8)	95% Tolerance Interval (NP-40.1%) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	4.9	8.4	6.2	0.930	5.9	8.2			(3.7-8.7)	95% Tolerance Interval (Gamma) 95% Coverage
	>10'	27/27	--	0.0%	4.9	8.3	6.4	0.940	6.2	8.0			(4.1-8.6)	95% Tolerance Interval (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	4.9	8.4	6.3	0.880	6.2	8.1			(4.9-8.3)	95% Tolerance Interval (NP-78.5%) 95% Coverage
pH (field)	Surficial	10/10	--	0.0%	5.22	7.55	6.23	0.703	6.21	7.33	0	0	(3.94-8.52)	95% Tolerance Interval (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	4.19	8.41	5.78	1.08	5.60	7.45			(3.00-8.56)	95% Tolerance Interval (Normal) 95% Coverage
	>10'	27/27	--	0.0%	4.34	7.68	6.05	0.959	5.91	7.57			(3.75-8.36)	95% Tolerance Interval (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	4.19	8.41	5.99	0.964	5.90	7.57			(3.95-8.03)	95% Tolerance Interval (Normal) 95% Coverage
Sulfate	Surficial	7/10	(7.98 - 8.51)	30.0%	10.1	16.8	11.2	2.92	10.8	16.0	1	0	19.7	95% UTL (Normal) 95% Coverage
	0.5' to 10'	18/20	(7.58 - 7.82)	10.0%	9.19	269	51.1	61.6	25.1	137			228	95% WH Approximate Gamma UTL 95% Coverage
	>10'	22/27	(8.44 - 8.82)	18.5%	9.97	138	37.4	34.4	21.6	96.9			184	95% UTL (NP-62.3%) 95% Coverage
	All Depth	47/57	(7.58 - 8.82)	17.5%	9.19	269	37.5	45.7	20.9	128			138	95% KM UTL (Lognormal) 95% Coverage
CCR Rule Appendix IV Parameters														
Antimony	Surficial	10/10	--	0.0%	0.108	0.198	0.153	0.0321	0.157	0.193	1	0	0.246	95% UTL (Normal) 95% Coverage
	0.5' to 10'	15/20	(0.0694 - 0.0779)	25.0%	0.0712	8.89	0.541	1.92	0.0947	0.602			8.89	95% UTL (NP-64.2%) 95% Coverage
	>10'	19/27	(0.07 - 0.0826)	29.6%	0.0875	0.229	0.105	0.0366	0.0969	0.171			0.194	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	44/57	(0.0694 - 0.0826)	22.8%	0.0712	8.89	0.267	1.15	0.108	0.189			0.229	95% UTL (NP-78.5%) 95% Coverage
Arsenic	Surficial	10/10	--	0.0%	2.53	5.63	4.00	1.02	3.88	5.53	2	0	6.96	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	2.06	12.7	4.16	2.21	3.86	6.19			9.52	95% (Lognormal) 95% Coverage
	>10'	27/27	--	0.0%	1.27	9.18	4.00	1.60	3.60	6.58			7.61	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	1.27	12.7	4.05	1.74	3.79	6.22			7.91	95% (Lognormal) 95% Coverage
Barium	Surficial	10/10	--	0.0%	50.4	194	119	49.4	126	181	2	0	263	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	34.9	755	174	164	120	375			640	95% WH Approximate Gamma UTL 95% Coverage
	>10'	27/27	--	0.0%	39.2	381	137	73.4	116	266			328	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	57/57	--	0.0%	34.9	755	147	112	119	309			411	95% (Lognormal) 95% Coverage
Beryllium	Surficial	10/10	--	0.0%	0.345	1.48	1.06	0.392	1.27	1.42	1	0	2.20	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	0.220	4.50	1.26	0.868	1.20	2.03			4.50	95% UTL (NP-64.2%) 95% Coverage
	>10'	27/27	--	0.0%	0.562	2.27	1.25	0.433	1.18	2.11			2.23	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	0.220	4.50	1.22	0.611	1.20	2.03			2.27	95% UTL (NP-78.5%) 95% Coverage
Cadmium	Surficial	10/10	--	0.0%	0.0353	0.362	0.167	0.114	0.132	0.327	1	0	0.499	95% UTL (Normal) 95% Coverage
	0.5' to 10'	15/20	(0.0184 - 0.0224)	25.0%	0.0305	3.29	0.234	0.704	0.0500	0.390			1.16	95% KM UTL (Lognormal) 95% Coverage
	>10'	24/27	(0.0192 - 0.0236)	11.1%	0.0214	0.346	0.112	0.0808	0.0933	0.234			0.295	95% UTL (Normal) 95% Coverage
	All Depth	49/57	(0.0184 - 0.0236)	14.0%	0.0214	3.29	0.165	0.427	0.0811	0.296			0.633	95% KM UTL (Lognormal) 95% Coverage

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Summary Statistics - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Soil Depth (ft bgs)	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects							
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile	Number of Statistical Outliers	Number of Outliers Removed	Background Threshold Value	Statistical Distribution & Method
Chromium	Surficial	10/10	--	0.0%	10.2	18.9	16.1	2.63	16.9	18.7	3	0	23.8	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	9.96	43.1	21.3	8.46	20.0	41.1			44.8	95% WH Approximate Gamma UTL 95% Coverage
	>10'	27/27	--	0.0%	14.1	43.7	21.0	5.88	19.6	30.6			43.7	95% UTL (NP-75%) 95% Coverage
	All Depth	57/57	--	0.0%	9.96	43.7	20.3	6.72	18.9	33.3			43.1	95% UTL (NP-78.5%) 95% Coverage
Cobalt	Surficial	10/10	--	0.0%	3.76	13.2	9.20	2.78	9.84	12.4	2	0	17.3	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	1.38	39.1	12.5	8.56	11.8	28.8			40.1	95% WH Approximate Gamma UTL 95% Coverage
	>10'	27/27	--	0.0%	3.72	19.8	11.1	3.64	10.8	16.2			19.3	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	1.38	39.1	11.3	5.80	10.8	19.8			28.2	95% UTL (NP-78.5%) 95% Coverage
Fluoride	Surficial	7/10	(0.777 - 0.799)	30.0%	0.905	4.01	1.72	0.962	1.74	3.23	7	0	4.52	95% UTL (Normal) 95% Coverage
	0.5' to 10'	7/20	(0.759 - 0.853)	65.0%	0.912	14.6	2.11	3.32	0.832	8.63			9.17	95% WH Approximate Gamma UTL 95% Coverage
	>10'	18/27	(0.768 - 0.914)	33.3%	1.04	15.4	3.20	4.11	1.17	12.0			15.4	95% UTL (NP-75%) 95% Coverage
	All Depth	32/57	(0.759 - 0.914)	43.9%	0.905	15.4	2.56	3.52	1.050	10.8			14.6	95% UTL (NP-78.5%) 95% Coverage
Lead	Surficial	10/10	--	0.0%	9.35	22.3	15.7	3.79	15.5	21.2	0	0	26.7	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	3.79	28.1	13.4	5.39	13.5	20.2			26.3	95% UTL (Normal) 95% Coverage
	>10'	27/27	--	0.0%	3.43	19.0	12.4	3.77	12.8	16.9			20.9	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	3.43	28.1	13.3	4.49	13.6	19.8			22.5	95% UTL (Normal) 95% Coverage
Lithium	Surficial	10/10	--	0.0%	4.99	20.2	12.5	4.30	13.1	18.3	0	0	25.1	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	6.03	27.9	17.2	6.39	17.2	25.9			32.5	95% UTL (Normal) 95% Coverage
	>10'	27/27	--	0.0%	2.89	27.7	16.6	5.99	16.8	26.2			30.1	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	2.89	27.9	16.1	6.03	15.9	26.0			28.3	95% UTL (Normal) 95% Coverage
Mercury	Surficial	10/10	--	0.0%	0.0215	0.0766	0.0381	0.0157	0.0332	0.0649	1	0	0.0837	95% UTL (Normal) 95% Coverage
	0.5' to 10'	16/20	(0.0146 - 0.0163)	20.0%	0.0214	0.0799	0.0336	0.0167	0.0307	0.0681			0.0827	95% WH Approximate Gamma UTL 95% Coverage
	>10'	23/27	(0.0142 - 0.0197)	14.8%	0.0207	0.302	0.0404	0.0526	0.0320	0.0548			0.302	95% UTL (NP-75%) 95% Coverage
	All Depth	49/57	(0.0142 - 0.0197)	14.0%	0.0207	0.302	0.0376	0.0382	0.0320	0.0693			0.0799	95% UTL (NP-78.5%) 95% Coverage
Molybdenum	Surficial	10/10	--	0.0%	0.494	1.09	0.704	0.160	0.687	0.955	1	0	1.17	95% UTL (Normal) 95% Coverage
	0.5' to 10'	18/20	(0.182 - 0.187)	10.0%	0.287	4.41	0.780	0.871	0.544	1.16			3.03	95% KM UTL (Lognormal) 95% Coverage
	>10'	26/27	(0.184 - 0.184)	3.7%	0.351	1.25	0.660	0.206	0.634	0.949			1.13	95% UTL (Normal) 95% Coverage
	All Depth	54/57	(0.182 - 0.187)	5.3%	0.287	4.41	0.710	0.542	0.659	1.01			1.67	95% KM UTL (Lognormal) 95% Coverage
Radium-226+228	Surficial	10/10	--	0.0%	2.05	4.27	2.78	0.645	2.70	3.78	0	0	4.66	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	1.68	4.29	3.07	0.602	3.08	4.20			4.51	95% UTL (Normal) 95% Coverage
	>10'	27/27	--	0.0%	1.41	4.62	2.98	0.692	2.93	3.94			4.54	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	1.41	4.62	2.98	0.649	2.96	4.21			4.29	95% UTL (Normal) 95% Coverage
Selenium	Surficial	10/10	--	0.0%	0.405	1.30	0.812	0.319	0.678	1.29	1	0	1.74	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	0.195	6.58	0.971	1.35	0.641	1.77			3.57	95% (Lognormal) 95% Coverage
	>10'	26/27	(0.138 - 0.138)	3.7%	0.219	0.972	0.587	0.232	0.563	0.936			1.11	95% UTL (Normal) 95% Coverage
	All Depth	56/57	(0.138 - 0.138)	1.8%	0.195	6.58	0.761	0.825	0.641	1.28			1.93	95% KM UTL (Lognormal) 95% Coverage
Thallium	Surficial	10/10	--	0.0%	0.139	0.527	0.295	0.112	0.267	0.490	1	0	0.622	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	0.120	6.91	0.614	1.49	0.250	0.852			6.91	95% UTL (NP-64.2%) 95% Coverage
	>10'	24/27	(0.321 - 0.355)	11.1%	0.0892	0.439	0.272	0.0769	0.298	0.370			0.446	95% UTL (Normal) 95% Coverage
	All Depth	54/57	(0.321 - 0.355)	5.3%	0.0892	6.91	0.396	0.876	0.275	0.513			0.533	95% UTL (NP-78.5%) 95% Coverage

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Summary Statistics - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Soil Depth (ft bgs)	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects							
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile	Number of Statistical Outliers	Number of Outliers Removed	Background Threshold Value	Statistical Distribution & Method
TDEC Appendix I Parameters														
Copper	Surficial	10/10	--	0.0%	4.17	23.2	12.0	5.16	11.4	20.1	0	0	27.0	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	2.45	27.6	14.3	6.23	14.9	23.6			29.2	95% UTL (Normal) 95% Coverage
	>10'	27/27	--	0.0%	4.66	27.0	14.9	4.36	14.5	21.4			24.7	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	2.45	27.6	14.2	5.23	14.3	23.2			24.8	95% UTL (Normal) 95% Coverage
Nickel	Surficial	10/10	--	0.0%	4.41	17.3	12.3	3.89	13.4	16.3	3	0	23.7	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	2.95	49.4	17.5	11.5	15.4	42.8			54.5	95% WH Approximate Gamma UTL 95% Coverage
	>10'	27/27	--	0.0%	5.44	49.8	17.7	8.12	17.5	26.4			38.1	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	57/57	--	0.0%	2.95	49.8	16.7	9.05	15.1	30.5			49.4	95% UTL (NP-78.5%) 95% Coverage
Silver	Surficial	5/10	(0.0316 - 0.0354)	50.0%	0.0345	0.0552	0.0368	0.00725	0.0350	0.0495	5	0	0.0579	95% UTL (Normal) 95% Coverage
	0.5' to 10'	5/20	(0.0292 - 0.0356)	75.0%	0.0307	8.68	0.466	1.88	0.0323	0.503			8.68	95% UTL (NP-64.2%) 95% Coverage
	>10'	6/27	(0.0305 - 0.0375)	77.8%	0.0373	0.0996	0.0351	0.0134	0.0352	0.0461			0.0996	95% UTL (NP-75%) 95% Coverage
	All Depth	16/57	(0.0292 - 0.0375)	71.9%	0.0307	8.68	0.186	1.14	0.0342	0.0586			0.0996	95% UTL (NP-78.5%) 95% Coverage
Vanadium	Surficial	10/10	--	0.0%	14.7	27.4	22.4	3.70	23.6	26.6	0	0	33.2	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	16.4	42.2	26.2	6.77	25.7	35.8			42.4	95% UTL (Normal) 95% Coverage
	>10'	27/27	--	0.0%	16.6	43.7	26.9	6.52	25.5	37.8			41.6	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	14.7	43.7	25.9	6.34	24.6	37.5			39.9	95% WH Approximate Gamma UTL 95% Coverage
Zinc	Surficial	10/10	--	0.0%	22.5	74.8	50.8	17.2	56.2	73.3	1	0	101	95% UTL (Normal) 95% Coverage
	0.5' to 10'	20/20	--	0.0%	7.80	73.2	50.0	18.6	55.4	72.4			94.6	95% UTL (Normal) 95% Coverage
	>10'	27/27	--	0.0%	18.0	127	54.9	20.1	53.2	73.3			100	95% UTL (Normal) 95% Coverage
	All Depth	57/57	--	0.0%	7.80	127	52.5	18.9	55.0	73.3			90.8	95% UTL (Normal) 95% Coverage

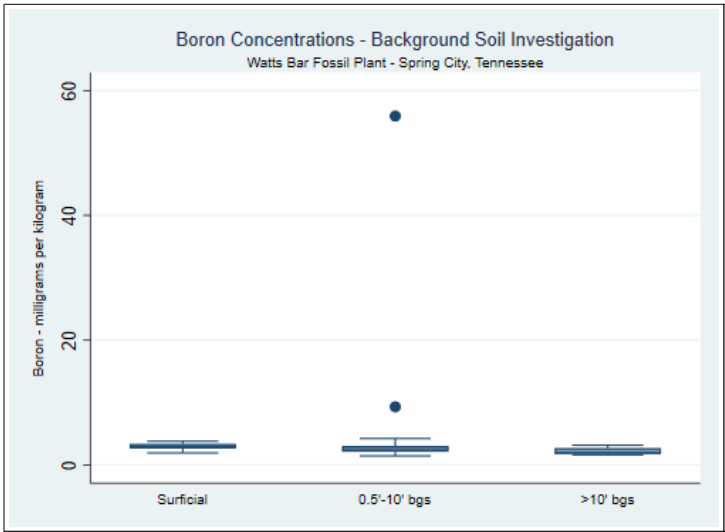
Notes:
CCR Rule - Title 40, Code of Federal Regulations, Part 257
ft bgs - feet below ground surface
KM - Kaplan-Meier, For Parameters with non-detects reported at the method detection limit, the mean, standard deviation, and background threshold values were calculated using Kaplan-Meier methods
'--' / NA - Not Applicable
NP-% - Non-parametric method and associated confidence level of the estimate
TDEC - Tennessee Department of Environment and Conservation
UTL - Upper Tolerance Limit
WH - Background Threshold Limits based on the gamma distribution utilize Wilson Hiferty (WH) estimates
% - Percent

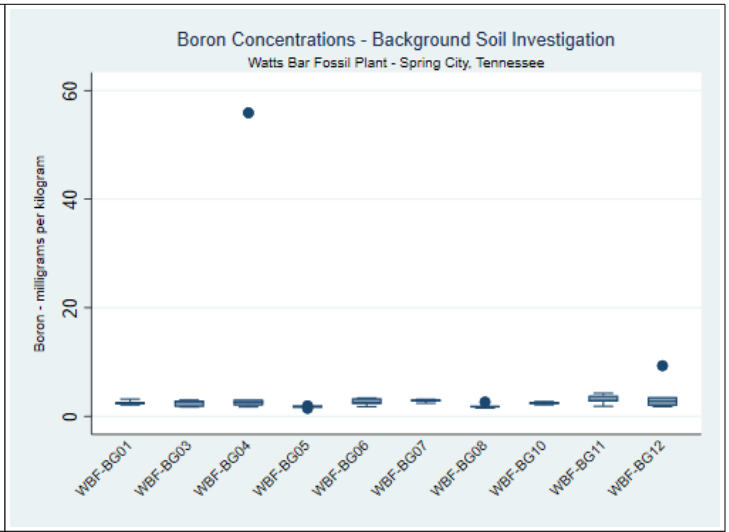
Except for Ash, pH & Radium 226 + 228, all units milligrams per kilogram (mg/kg)
Units for Ash are percent (%)
Units for pH are Standard Units (S.U.)
Units for Radium 226+228 are picocuries per gram (pCi/g)
All non-detects reported at the laboratory reporting limit
Surficial soil samples were collected in 0 to 0.5 feet below ground surface (bgs) soil depth interval

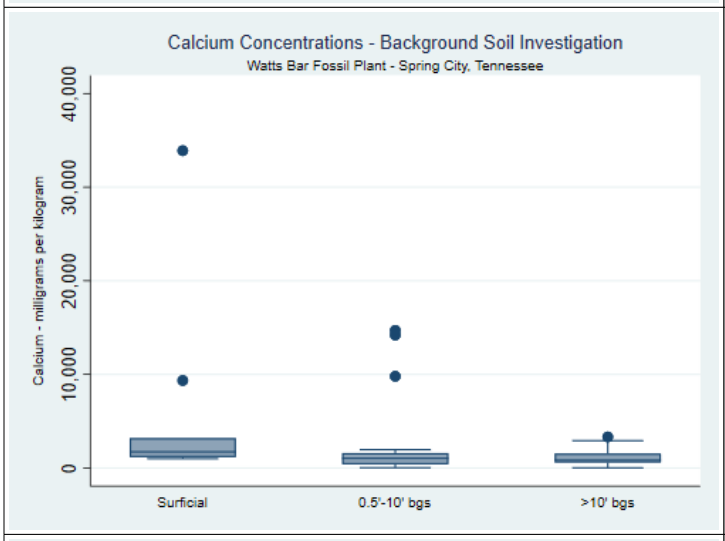
ATTACHMENT E.1-B
BOX PLOTS

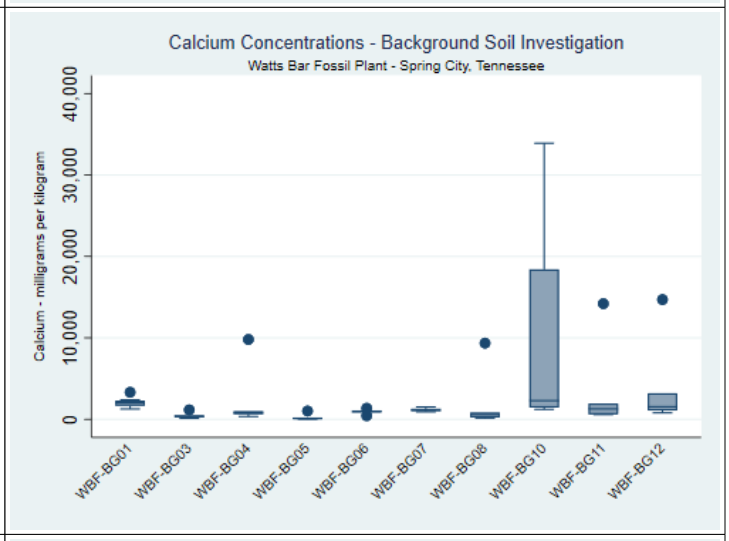
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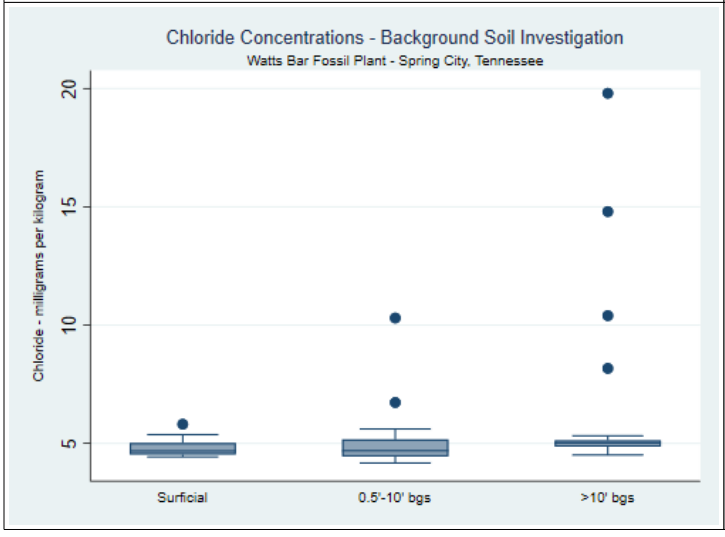
Box Plots
CCR Rule Appendix III Parameters
Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

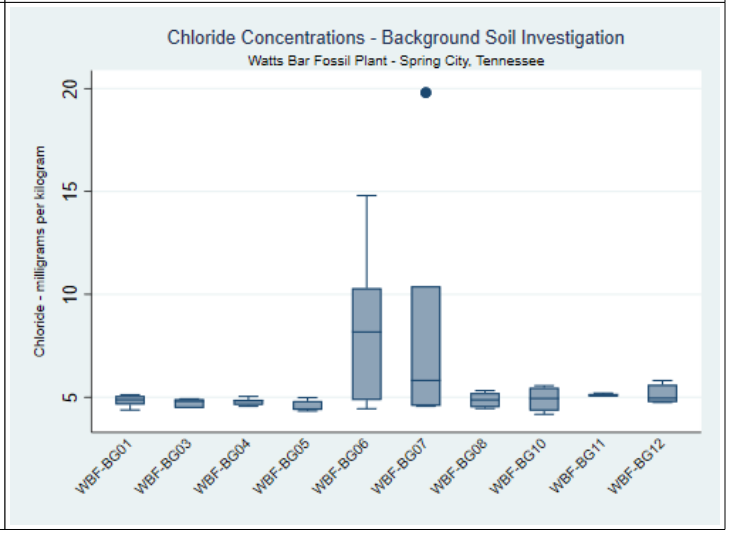




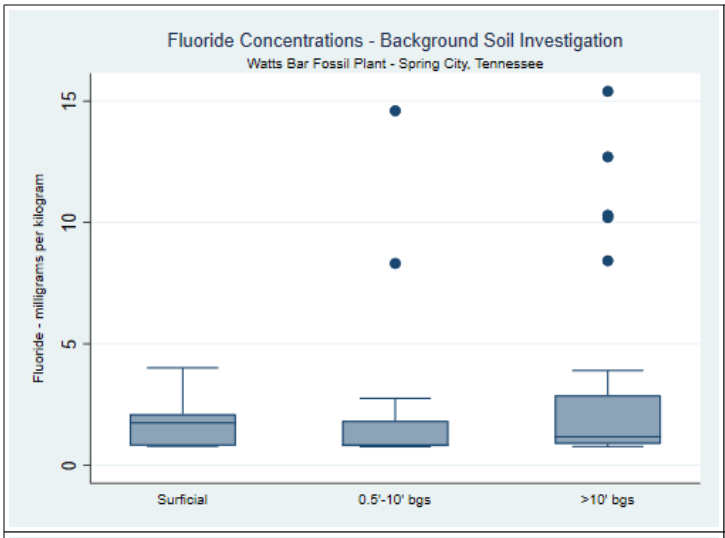


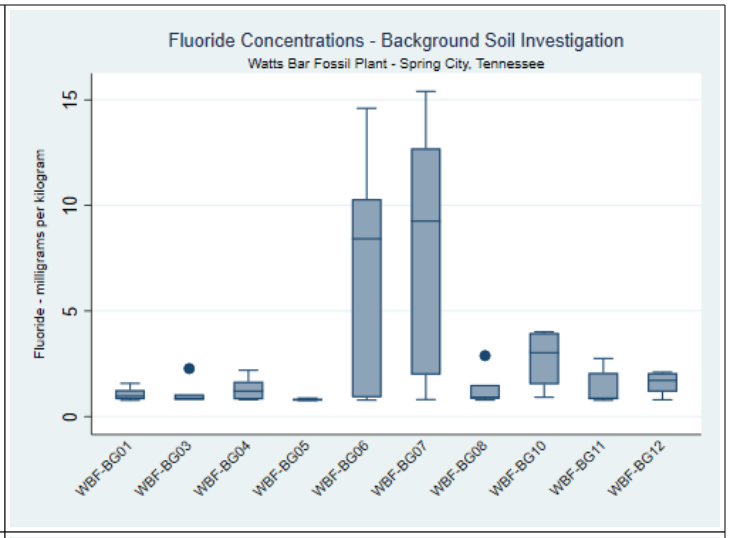


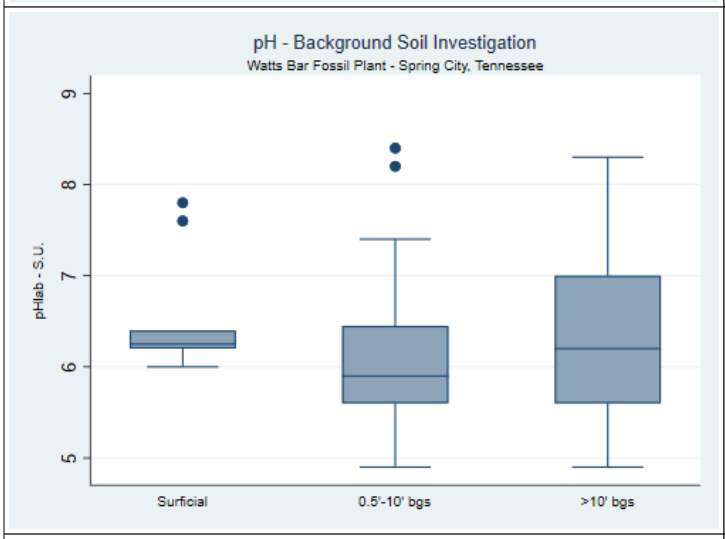


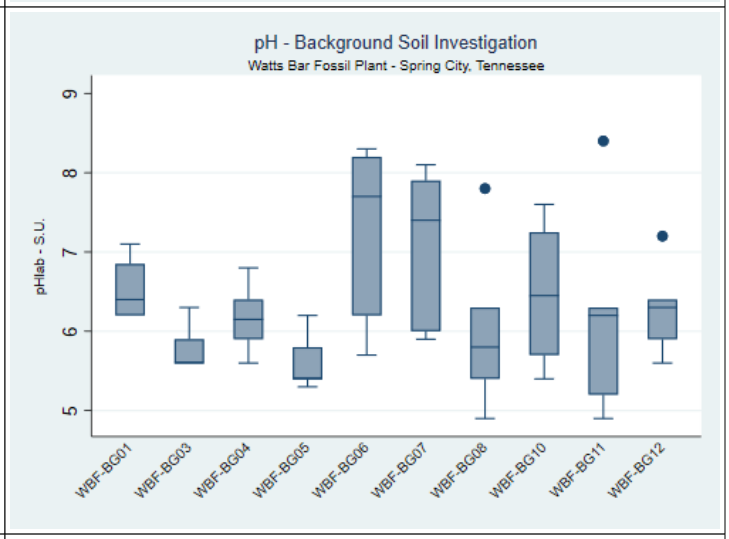


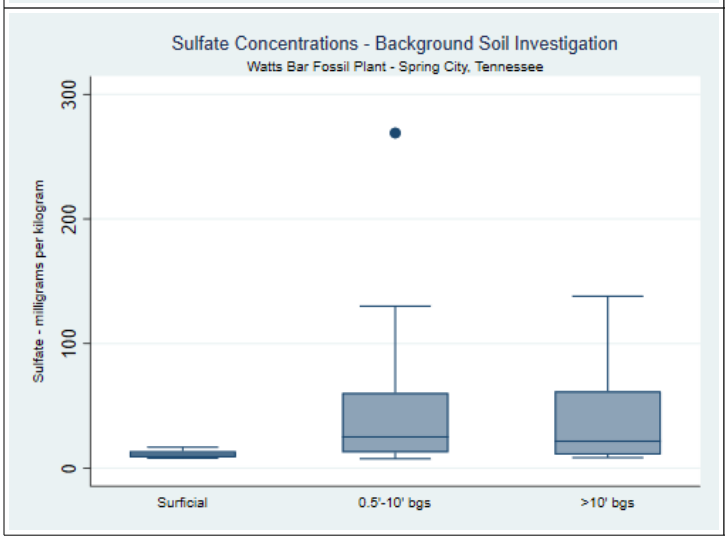
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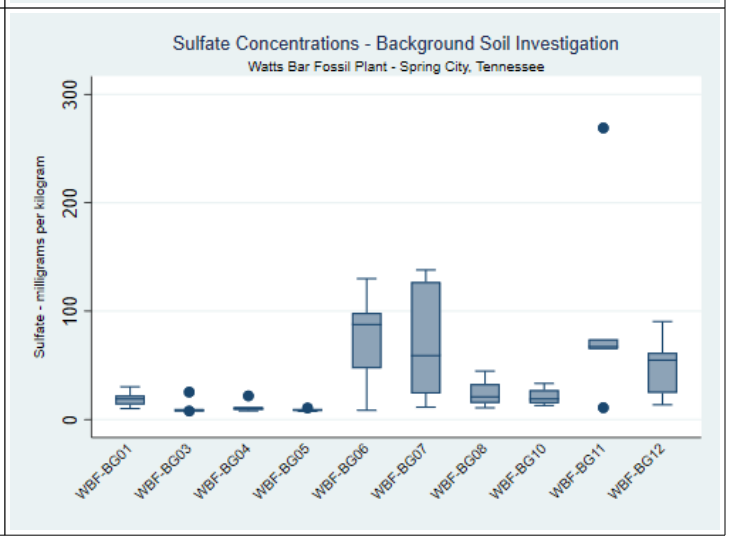

Fluoride Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Fluoride - milligrams per kilogram
0
5
10
15
Surficial
0.5'-10' bgs
>10' bgs


Fluoride Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Fluoride - milligrams per kilogram
0
5
10
15
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12


pH - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
pHlab - S.U.
5
6
7
8
9
Surficial
0.5'-10' bgs
>10' bgs

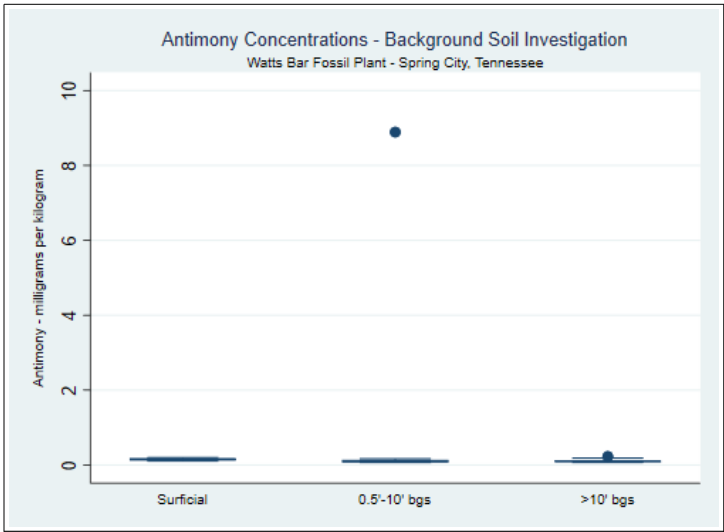

pH - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
pHlab - S.U.
5
6
7
8
9
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

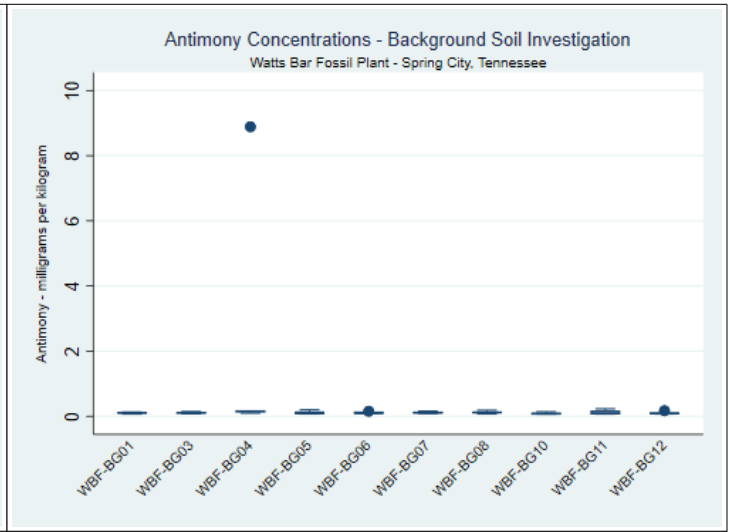

Sulfate Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Sulfate - milligrams per kilogram
0
100
200
300
Surficial
0.5'-10' bgs
>10' bgs

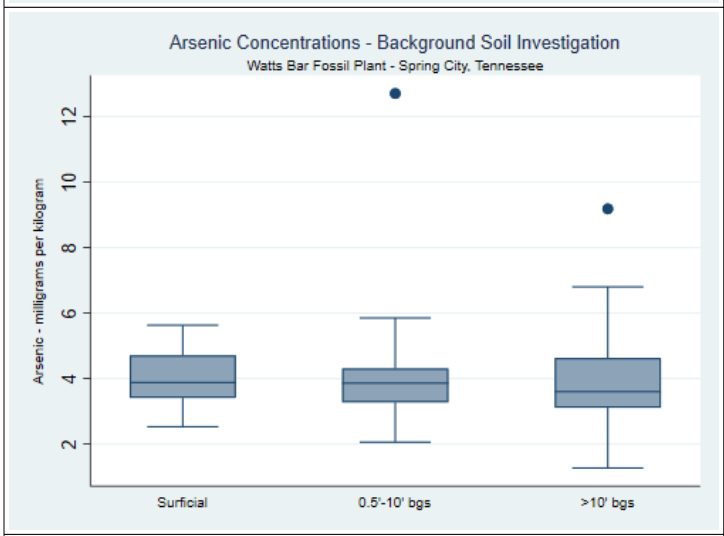

Sulfate Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Sulfate - milligrams per kilogram
0
100
200
300
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

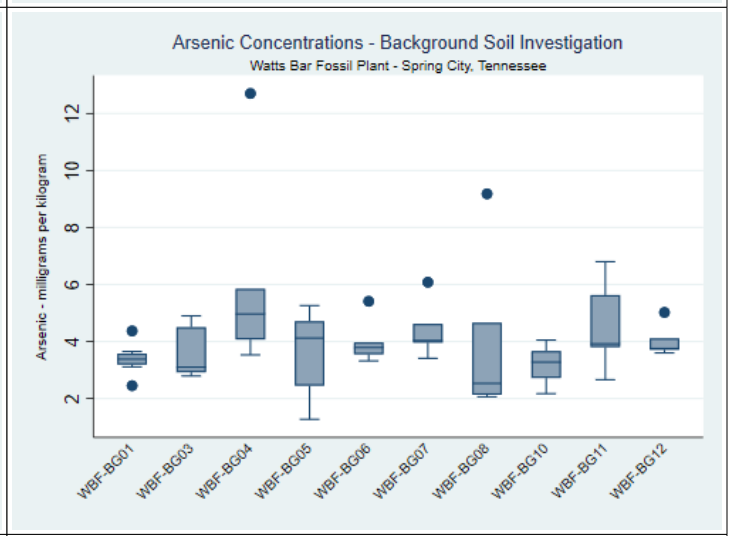
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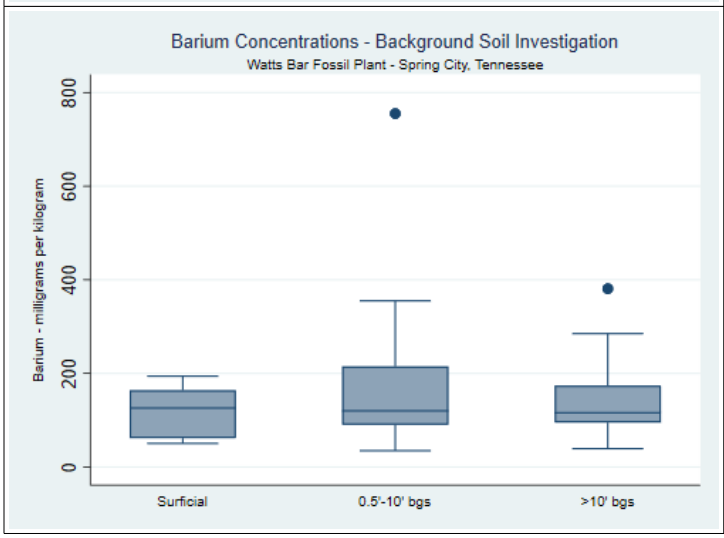
Box Plots - CCR Rule Appendix IV Parameters
CCR Rule Appendix IV Parameters
Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

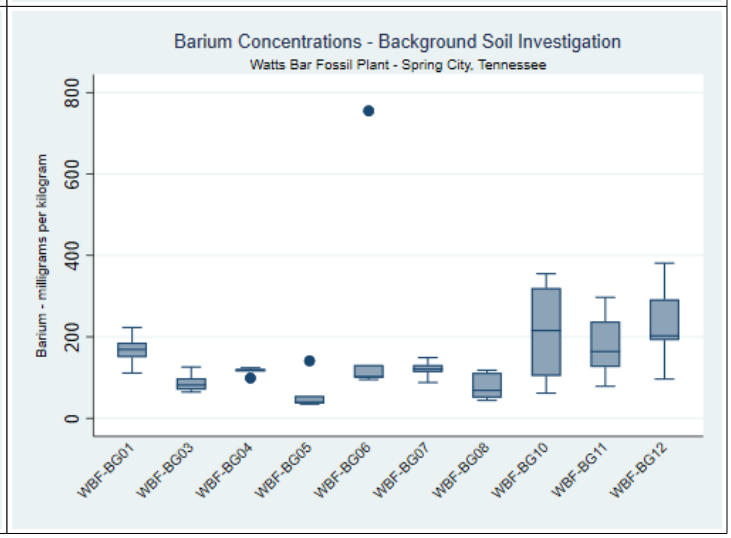




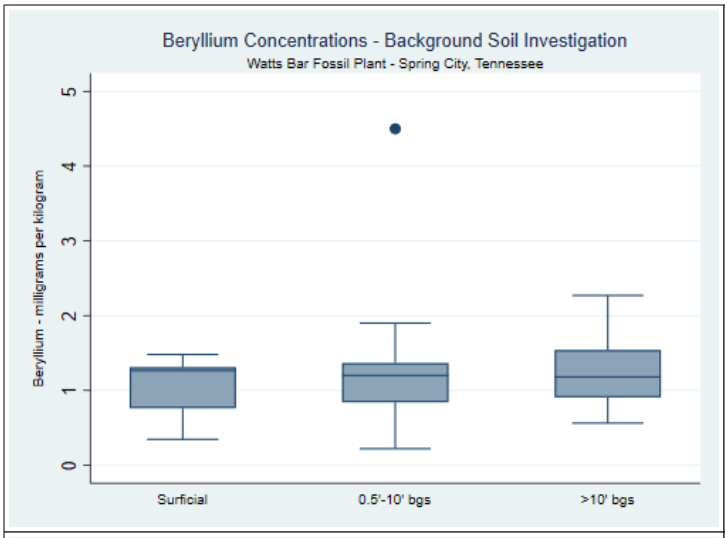


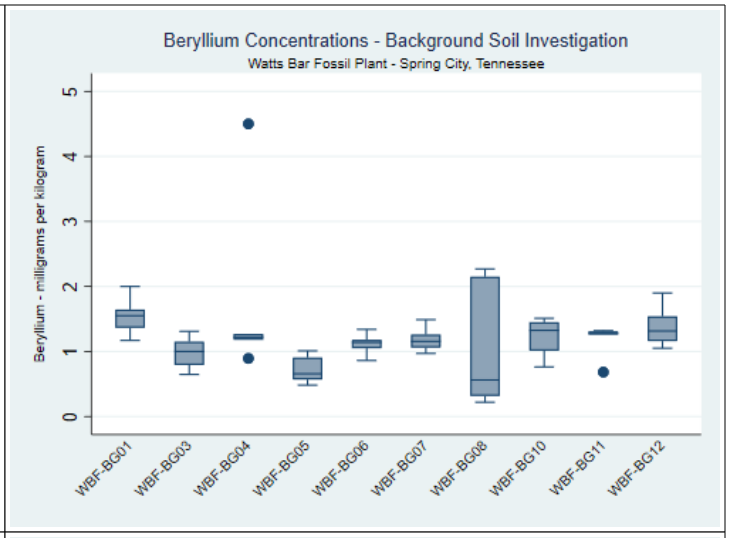


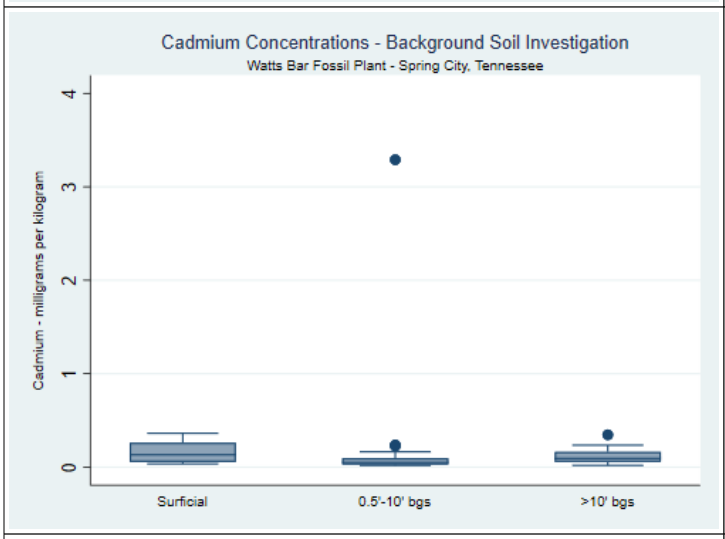


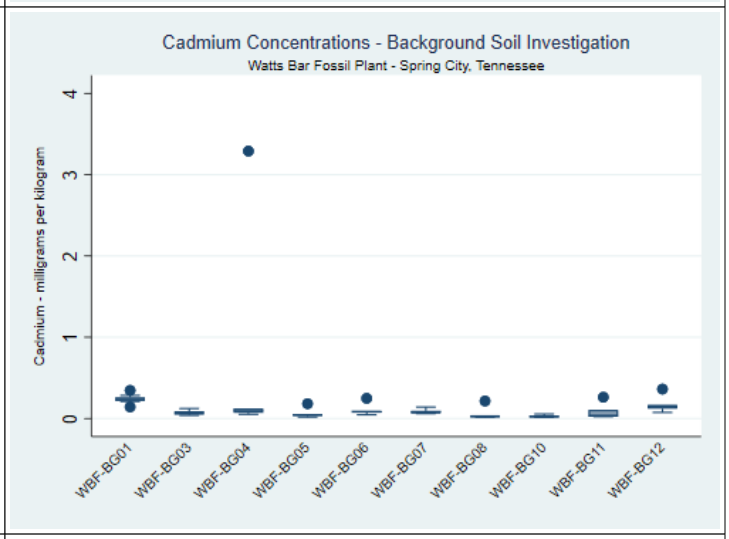


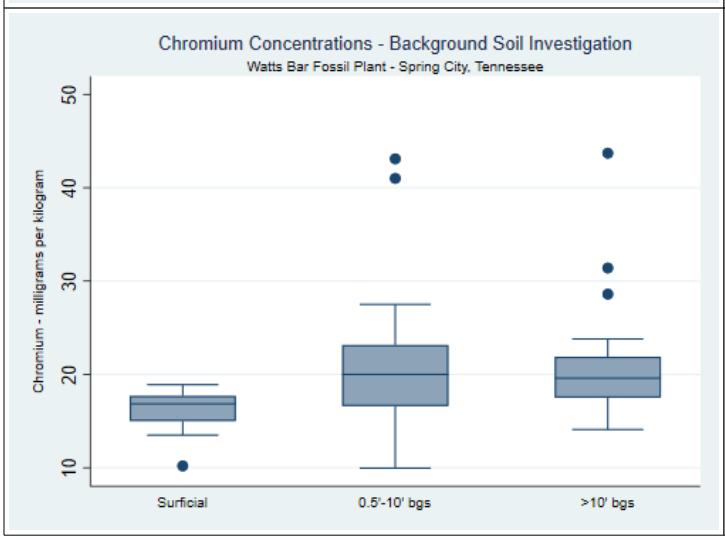
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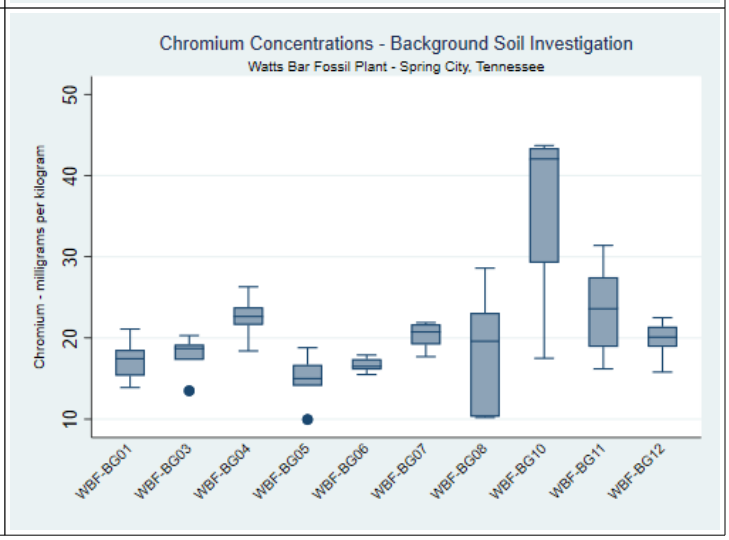

Beryllium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Beryllium - milligrams per kilogram
0
1
2
3
4
5
Surficial
0.5'-10' bgs
>10' bgs


Beryllium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Beryllium - milligrams per kilogram
0
1
2
3
4
5
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

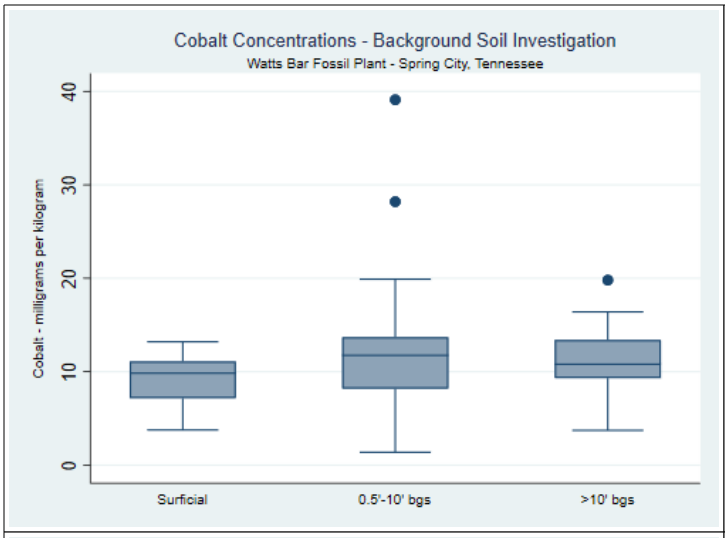

Cadmium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Cadmium - milligrams per kilogram
0
1
2
3
4
Surficial
0.5'-10' bgs
>10' bgs

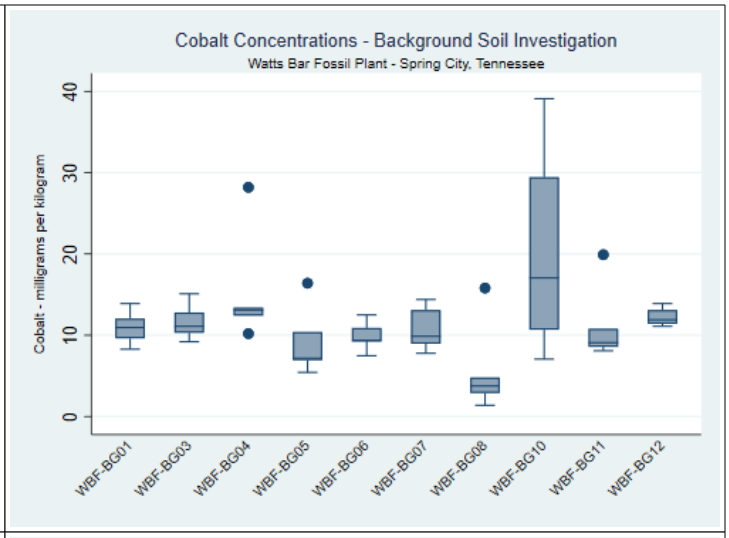

Cadmium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Cadmium - milligrams per kilogram
0
1
2
3
4
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

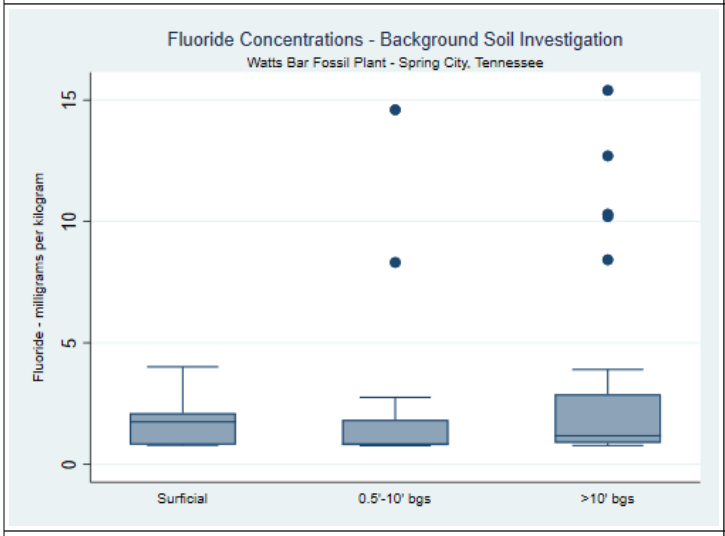

Chromium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Chromium - milligrams per kilogram
10
20
30
40
50
Surficial
0.5'-10' bgs
>10' bgs

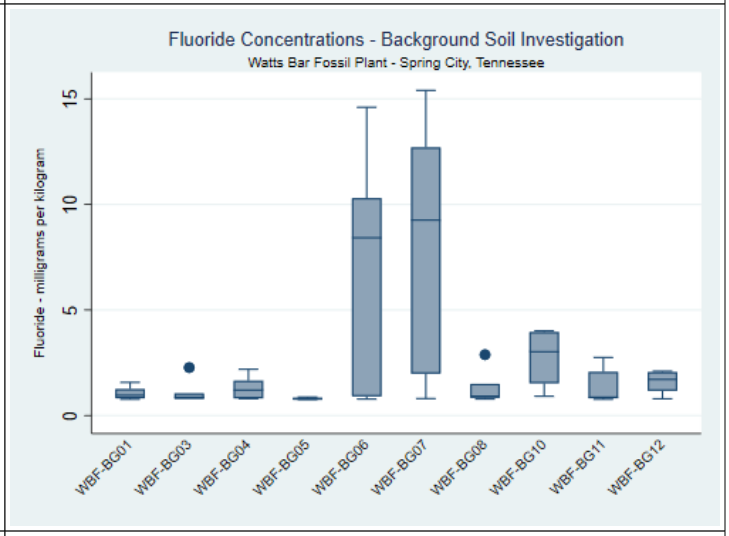

Chromium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Chromium - milligrams per kilogram
10
20
30
40
50
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

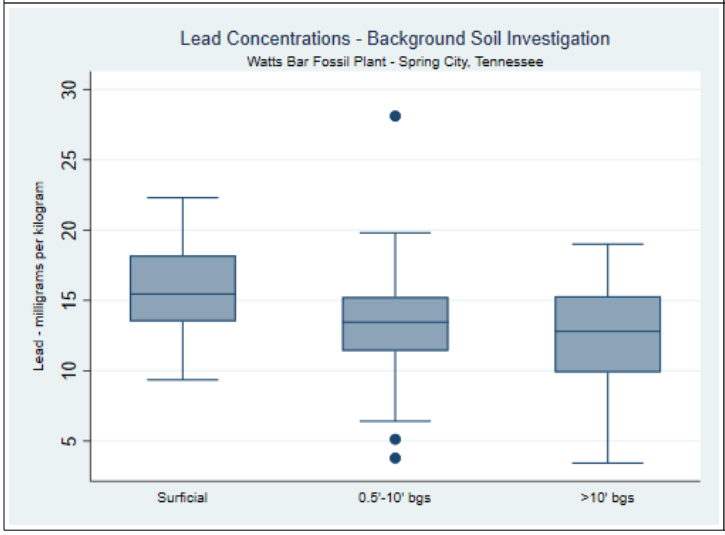
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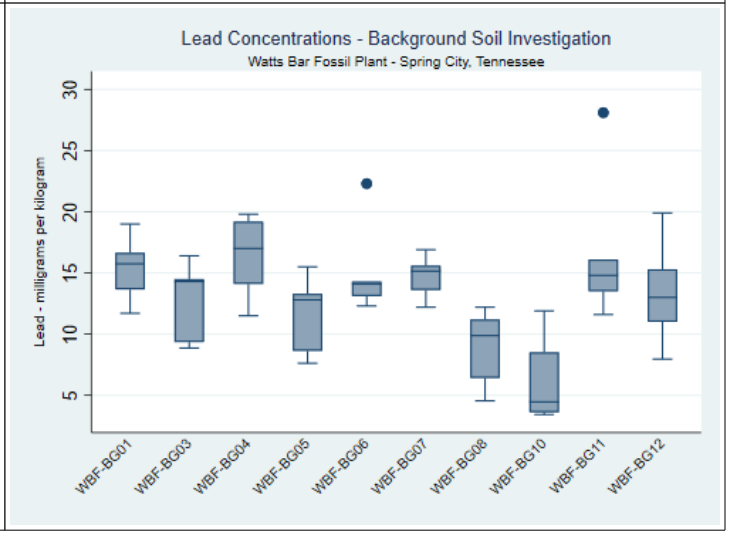

Cobalt Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Cobalt - milligrams per kilogram
0
10
20
30
40
Surficial
0.5'-10' bgs
>10' bgs


Cobalt Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Cobalt - milligrams per kilogram
0
10
20
30
40
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

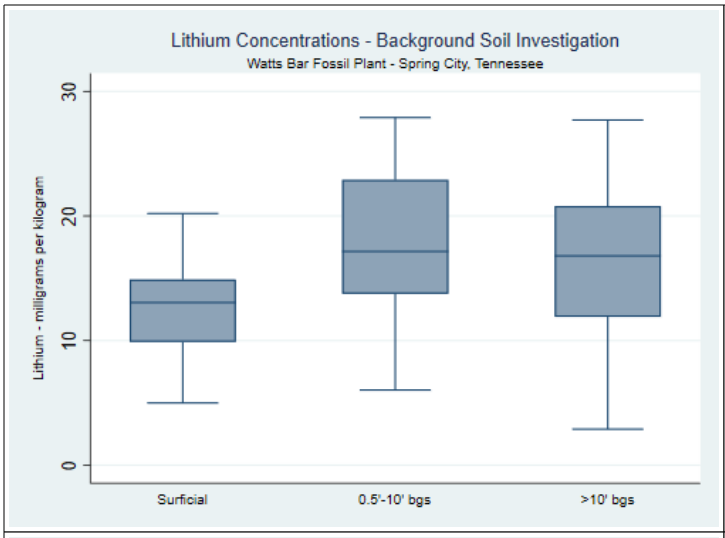

Fluoride Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Fluoride - milligrams per kilogram
0
5
10
15
Surficial
0.5'-10' bgs
>10' bgs

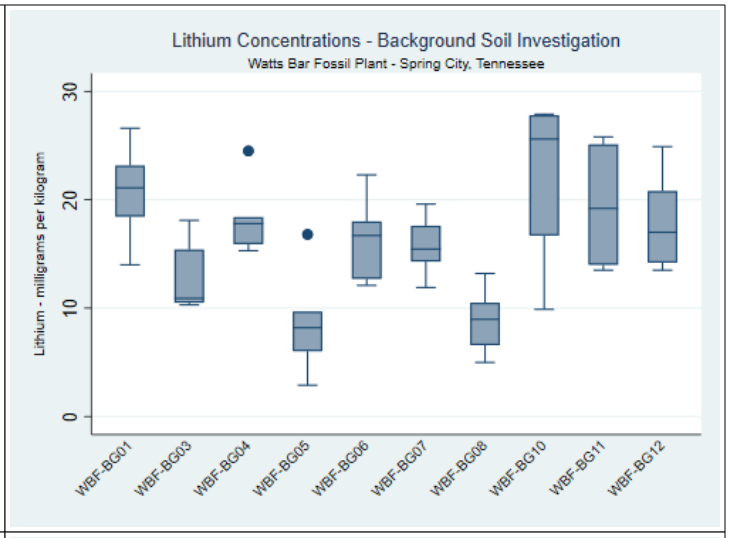

Fluoride Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Fluoride - milligrams per kilogram
0
5
10
15
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

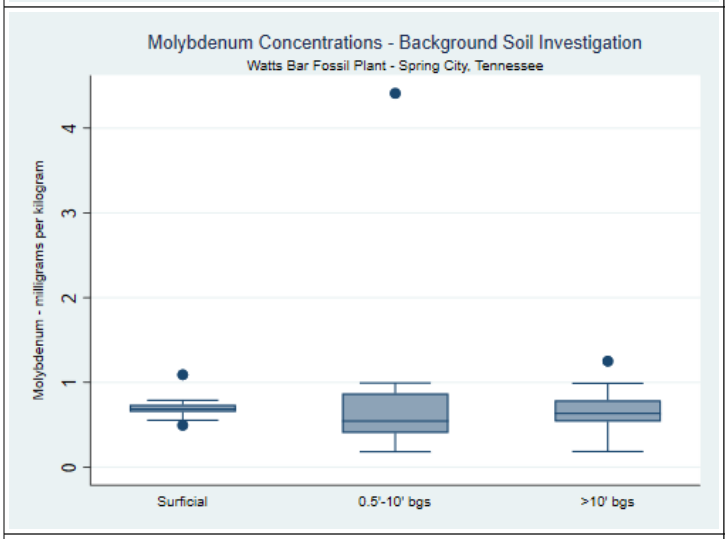

Lead Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Lead - milligrams per kilogram
5
10
15
20
25
30
Surficial
0.5'-10' bgs
>10' bgs

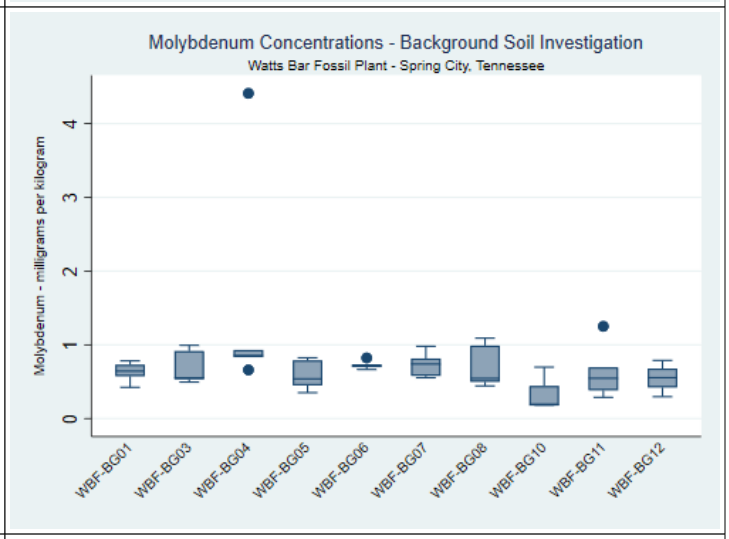

Lead Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Lead - milligrams per kilogram
5
10
15
20
25
30
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

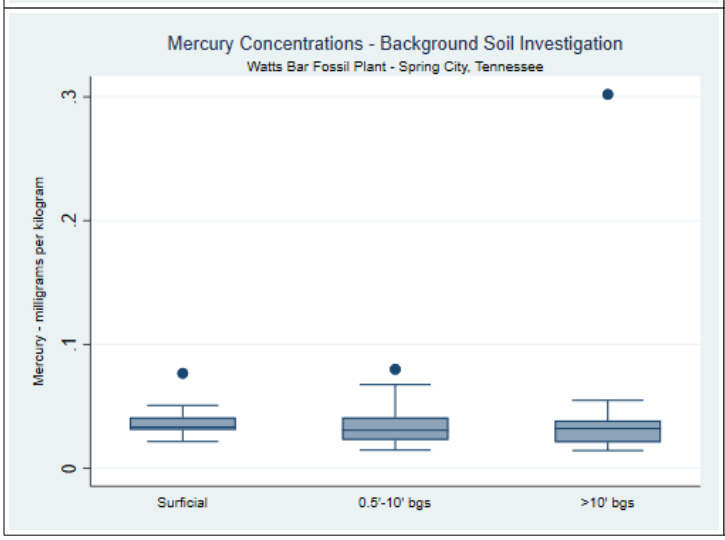
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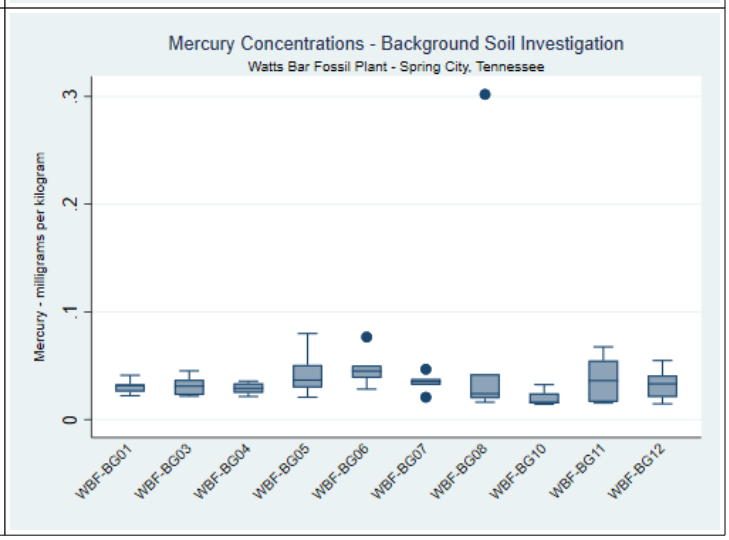

Lithium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Lithium - milligrams per kilogram
0
10
20
30
Surficial
0.5'-10' bgs
>10' bgs


Lithium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Lithium - milligrams per kilogram
0
10
20
30
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

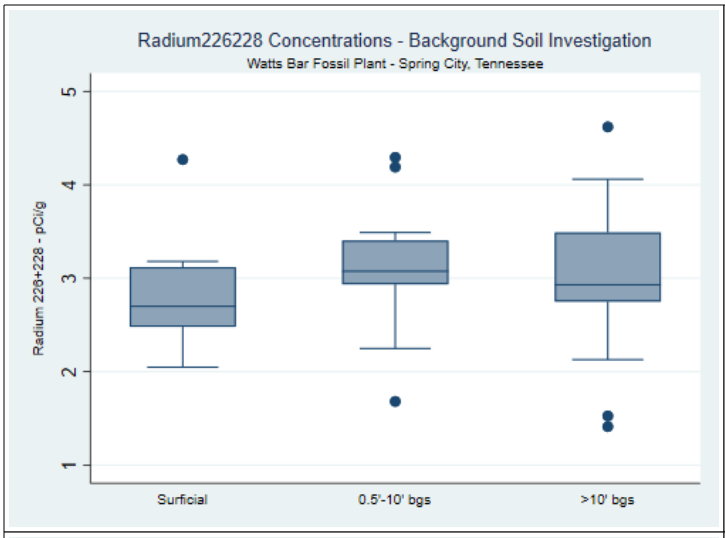

Molybdenum Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Molybdenum - milligrams per kilogram
0
1
2
3
4
Surficial
0.5'-10' bgs
>10' bgs

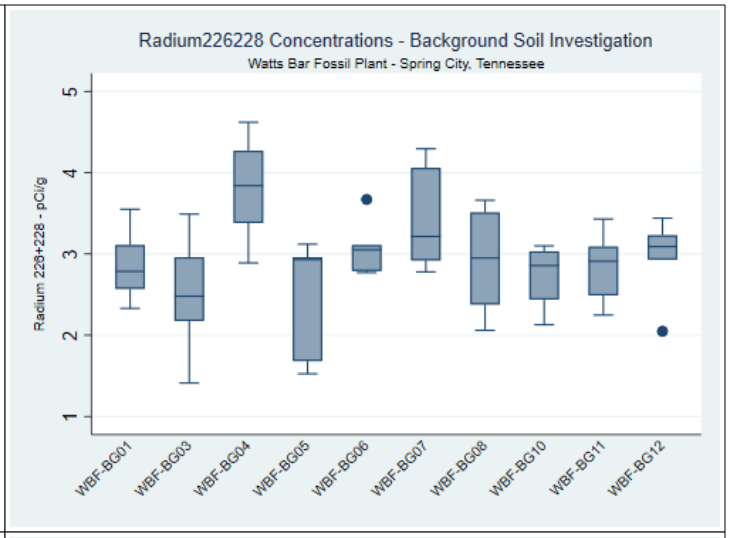

Molybdenum Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Molybdenum - milligrams per kilogram
0
1
2
3
4
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

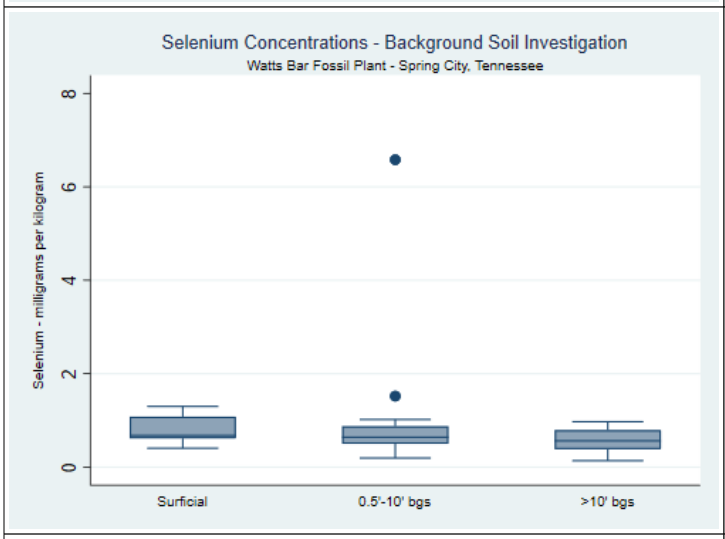

Mercury Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Mercury - milligrams per kilogram
0
.1
.2
.3
Surficial
0.5'-10' bgs
>10' bgs

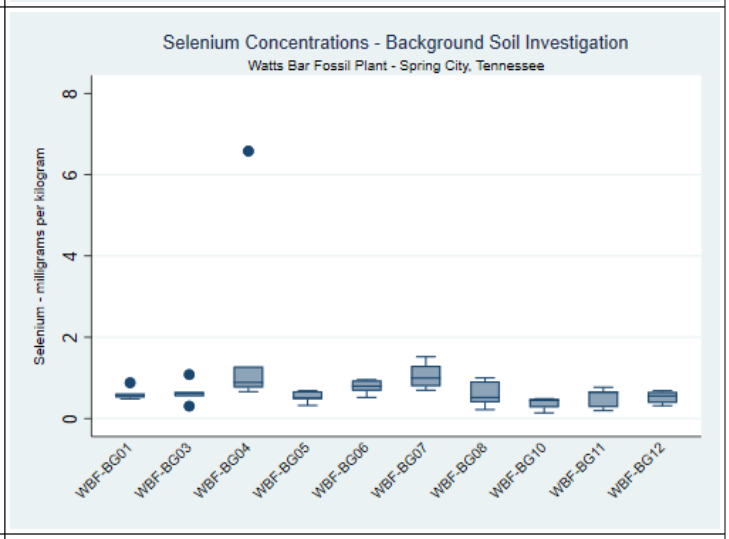

Mercury Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Mercury - milligrams per kilogram
0
.1
.2
.3
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

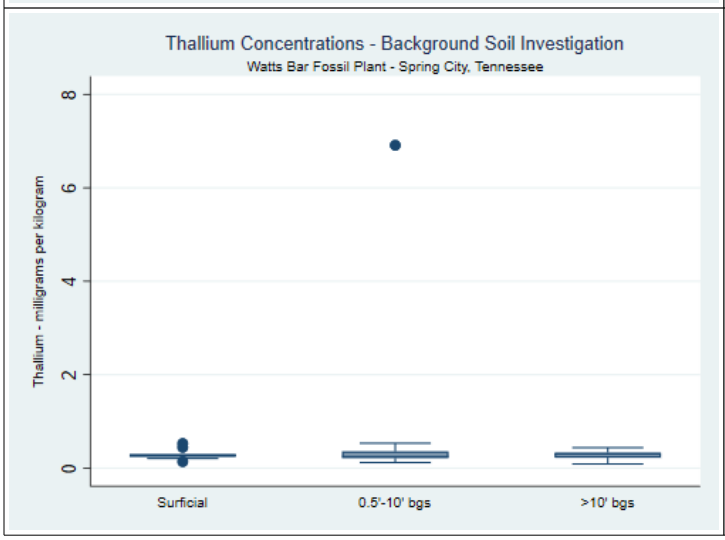
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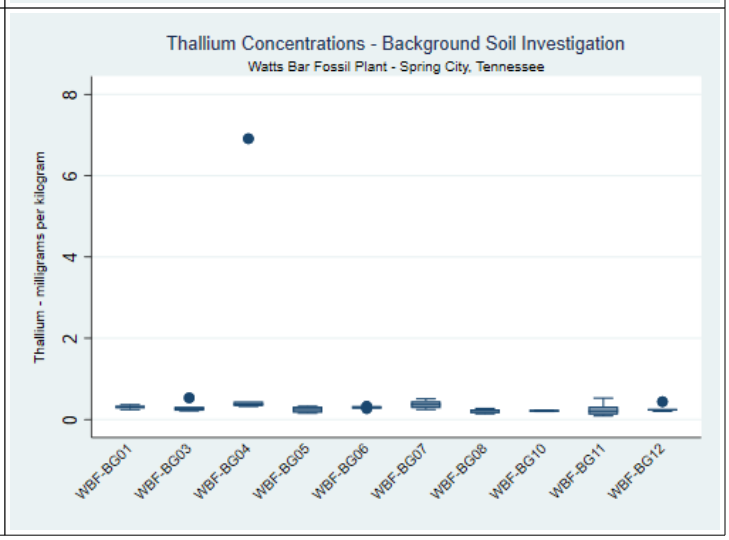

Radium226228 Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Radium 226+228 - pCi/g
1
2
3
4
5
Surficial
0.5'-10' bgs
>10' bgs


Radium226228 Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Radium 226+228 - pCi/g
1
2
3
4
5
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12


Selenium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Selenium - milligrams per kilogram
0
2
4
6
8
Surficial
0.5'-10' bgs
>10' bgs

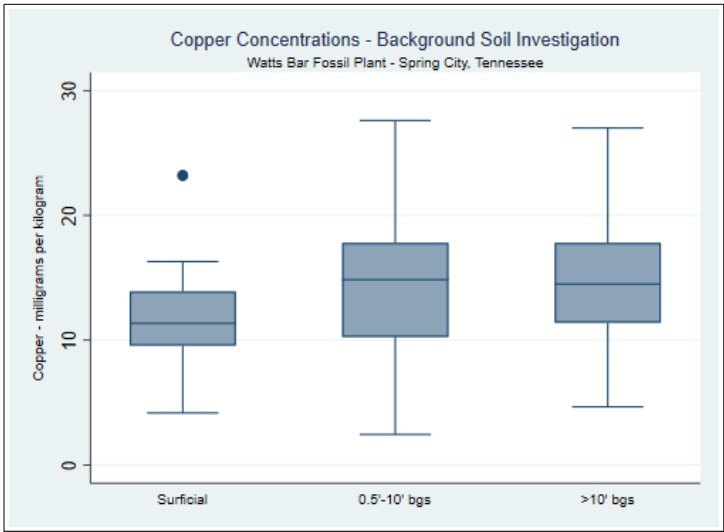

Selenium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Selenium - milligrams per kilogram
0
2
4
6
8
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

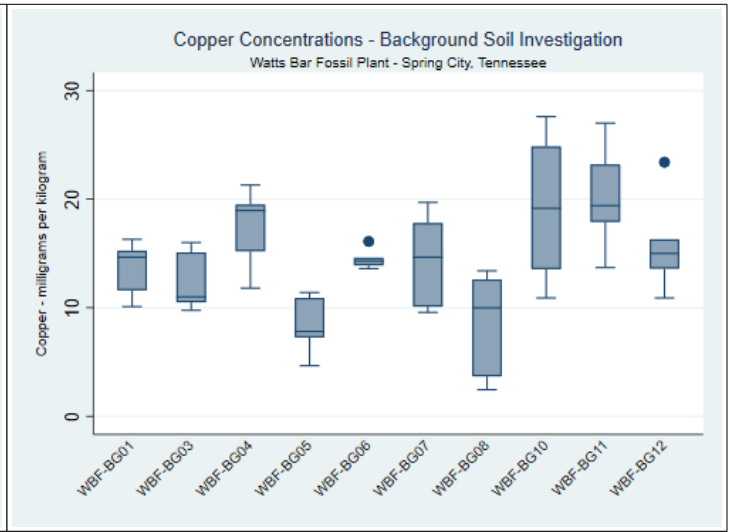

Thallium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Thallium - milligrams per kilogram
0
2
4
6
8
Surficial
0.5'-10' bgs
>10' bgs

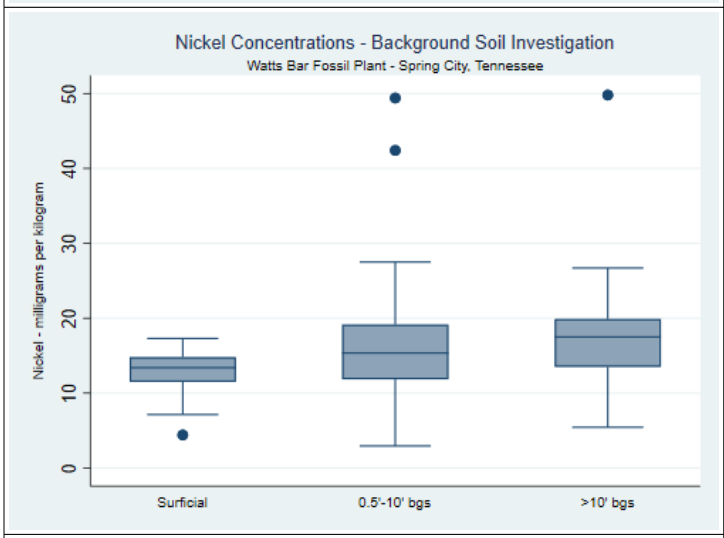

Thallium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Thallium - milligrams per kilogram
0
2
4
6
8
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

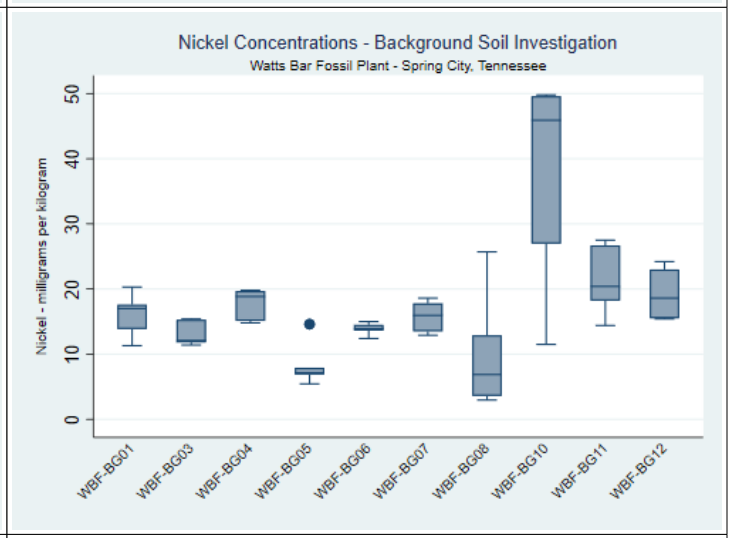
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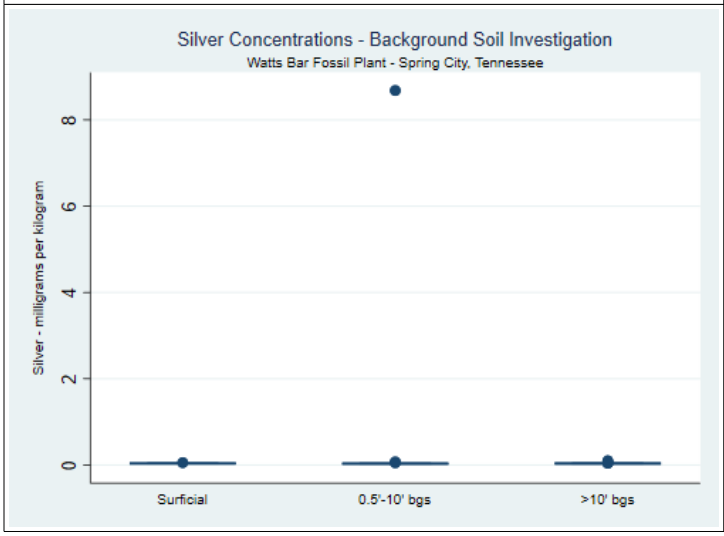
Box Plots - TDEC Appendix I Parameters
TDEC Appendix I Parameters
Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

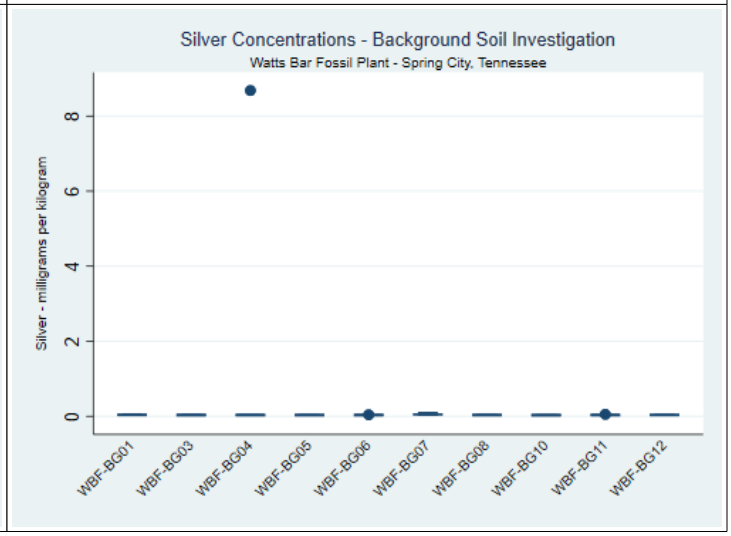




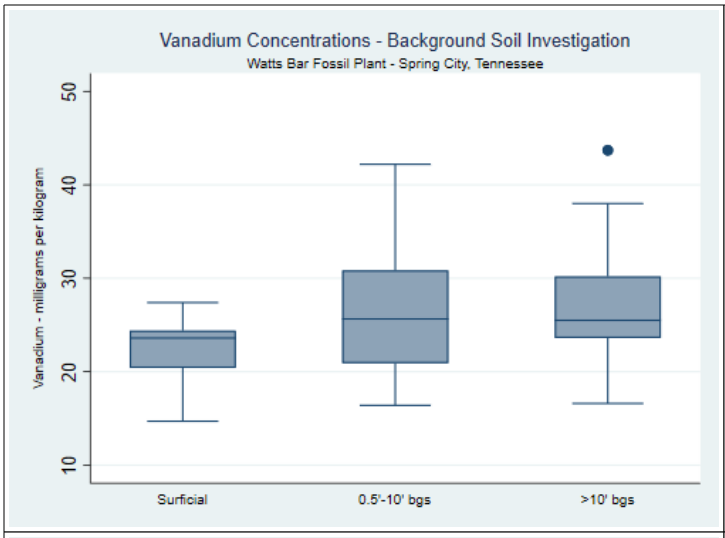


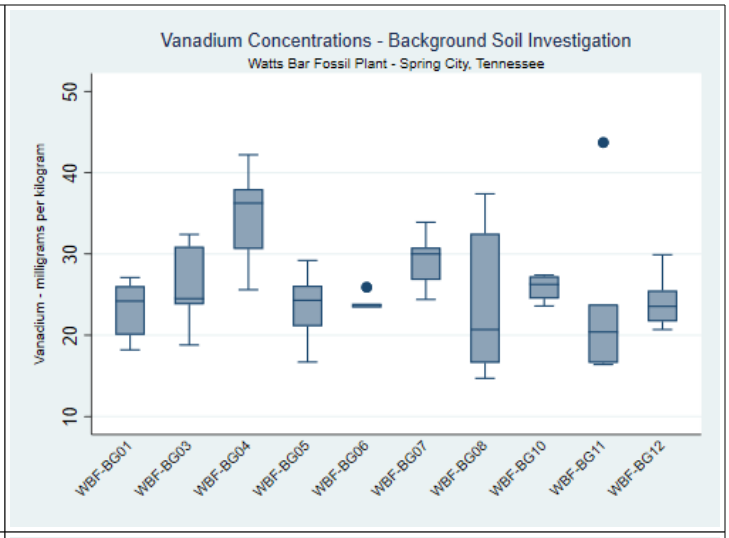


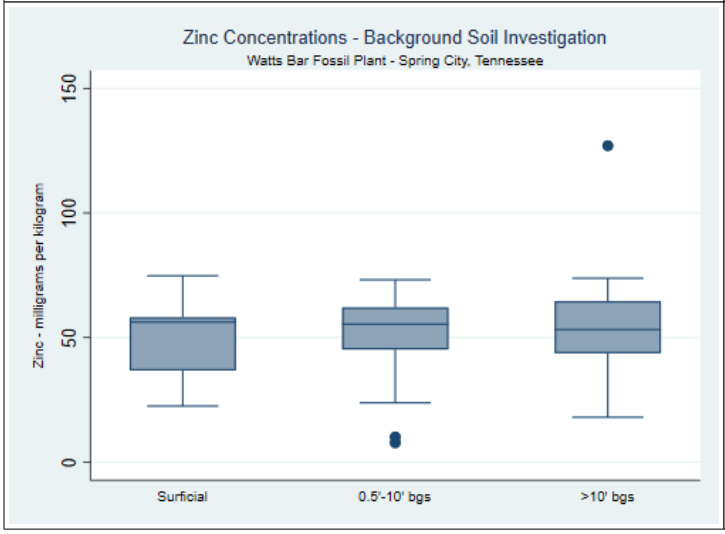


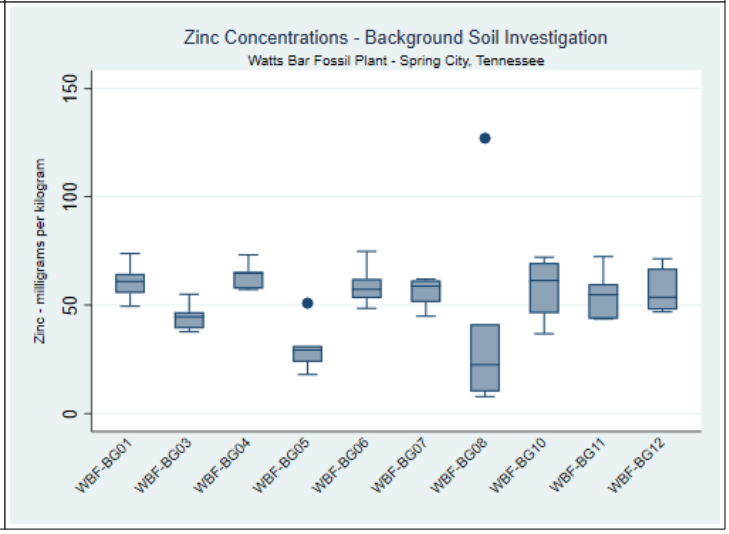


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Vanadium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Vanadium - milligrams per kilogram
10
20
30
40
50
Surficial
0.5'-10' bgs
>10' bgs


Vanadium Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Vanadium - milligrams per kilogram
10
20
30
40
50
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12


Zinc Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Zinc - milligrams per kilogram
0
50
100
150
Surficial
0.5'-10' bgs
>10' bgs


Zinc Concentrations - Background Soil Investigation
Watts Bar Fossil Plant - Spring City, Tennessee
Zinc - milligrams per kilogram
0
50
100
150
WBF-BG01
WBF-BG03
WBF-BG04
WBF-BG05
WBF-BG06
WBF-BG07
WBF-BG08
WBF-BG10
WBF-BG11
WBF-BG12

APPENDIX E.2

STATISTICAL ANALYSIS OF CCR MATERIAL CHARACTERISTICS DATA

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Appendix E.2 - Statistical Analysis of CCR Material Characteristics Data

TDEC Commissioner's Order:
Environmental Assessment Report
Watts Bar Fossil Plant
Spring City, Tennessee

March 31, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

Revision Log

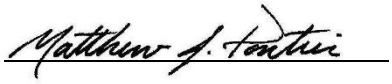
Revision	Description	Date
0	Submittal to TDEC	November 7, 2023
1	Addresses January 31, 2024 TDEC Review Comments and Issued for TDEC	March 31, 2024

Sign-off Sheet

This document entitled Appendix E.2 - Statistical Analysis of CCR Material Characteristics Data was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by 

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Approved by 

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Abbreviations

CASRN	Chemical Abstracts Service Registry Number
CCR	Coal Combustion Residuals
CCR Parameters	Constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations, Part 257
EAR	Environmental Assessment Report
IQR	Interquartile Range
NA	Not Available
%	Percent
SPLP	Synthetic Precipitate Leaching Procedure
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority
WBF Plant	Watts Bar Fossil Plant

APPENDIX E.2 - STATISTICAL ANALYSIS OF CCR MATERIAL CHARACTERISTICS DATA

March 31, 2024

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this appendix on behalf of the Tennessee Valley Authority (TVA) to document the statistical analyses performed on data collected to characterize coal combustion residual (CCR) materials to support evaluations conducted for the Environmental Assessment Report (EAR) at the Watts Bar Fossil Plant (WBF Plant) located in Spring City, Tennessee. The CCR material characterization samples were collected in July 2019 within the CCR management units at the WBF Plant. Further details regarding the CCR material sampling and laboratory data results are presented in the WBF Plant *CCR Material Characteristics Sampling and Analysis Report* (Appendix G.5).

For the Environmental Investigation, CCR material and pore water samples were collected for characterization related to the leachability of constituents listed in Appendices III and IV of 40 CFR 257 and five additional inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04 (CCR Parameters) from material within two WBF Plant CCR management units: the Ash Pond and Slag Disposal Area. The Synthetic Precipitate Leaching Procedure (SPLP) was used to characterize leachability of CCR Parameters in CCR material. Temporary well/boring locations and the number of samples collected in each WBF Plant CCR management unit are presented in Table E.2-1. Table E.2-2 presents the list of CCR Parameters evaluated in this statistical evaluation.

Table E.2-1 – CCR Material Characteristics Sample Locations - WBF Plant

WBF Plant CCR Management Unit	Temporary Well/Boring Location	Number of Samples	
		CCR Material/SPLP	Pore Water
Ash Pond	WBF-TW01; WBF-TW02	8	0
Slag Disposal Area	WBF-TW03; WBF-TW-04; WBF-TW05	13	3

APPENDIX E.2 - STATISTICAL ANALYSIS OF CCR MATERIAL CHARACTERISTICS DATA

March 31, 2024

Table E.2-2 – CCR Parameters Evaluated in Statistical Analysis

CCR Parameter	CASRN
CCR Rule Appendix III Parameters	
Boron	7440-42-8
Calcium	7440-70-2
Chloride	16887-00-6
Fluoride[1] (also Appendix IV)	16984-48-8
pH	NA
Sulfate	14808-79-8
Total Dissolved Solids	NA
CCR Rule Appendix IV Parameters	
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Lead	7439-92-1
Lithium	7439-93-2
Mercury	7439-97-6
Molybdenum	7439-98-7
Radium-226+228	13982-63-3/ 15262-20-1
Selenium	7782-49-2
Thallium	7440-28-0
Additional TDEC Appendix I Parameters	
Copper	7440-50-8
Nickel	7440-02-0
Silver	7440-22-4
Vanadium	7440-62-2
Zinc	7440-66-6
Other	
Iron	7439-89-6
Manganese	7439-96-5
Total Organic Carbon	NA

Notes:
CASRN: Chemical Abstracts Service Registry Number; CCR Rule - Title 40, Code of Federal Regulations, Part 257; NA – Not Available; TDEC - Tennessee Department of Environment and Conservation
[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV CCR parameter. In this table, and in the results figures and tables for this report, fluoride has been grouped with the Appendix III CCR parameters only to avoid duplication.

The following sections present the methods and results used to evaluate the CCR material and pore water data, including: 1) general exploratory data analysis (summary statistics, data plots and outlier screening), 2) a regression analysis to evaluate correlation between SPLP results to CCR Parameter concentrations in CCR material, and 3) a comparison of SPLP results to pore water concentrations.

2.0 METHODS

The statistical evaluation was conducted in three parts: 1) exploratory data analysis, 2) regression analysis, and 3) comparison of SPLP results to CCR Parameter concentrations in pore water.

2.1 EXPLORATORY DATA ANALYSIS

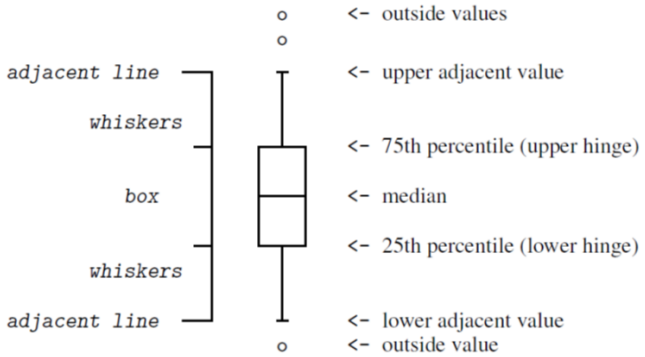
Exploratory data analysis is the initial step of statistical analysis. It utilizes simple summary statistics (e.g. mean, median, standard deviation and percentiles) and graphical representations to identify characteristics of an analytical dataset, such as the center of the data (mean, median), variation, distribution, patterns, presence of outliers, and randomness.

2.1.1 Summary Statistics

Summary statistics were calculated for CCR material, SPLP, and pore water for each CCR Parameter grouped by WBF Plant CCR management unit. Summary statistics include information such as the total numbers of available samples, the frequencies of detection, ranges of reporting limits, minimum and maximum detected concentrations, mean concentrations, standard deviations, median concentrations, and the 95th percentile concentrations. Summary statistics were also calculated for total metal and dissolved metal concentrations in pore water. Summary statistics tables are presented in Attachment E.2-A.

2.1.2 Exploratory Data Plots

Box plots were constructed of CCR Parameter concentrations in CCR material to support a visual review of the data. Box plots were used to identify the center of the data, distribution, variability, and to visually identify potential outliers. The diagram below graphically depicts the basics of the construction of the box plots (StataCorp LLC 2017).



The box portion of the plot is the interquartile range (IQR), which represents the middle 50 percent (%) of data, with the bottom of the box being the 25th percentile and the top of the box being the 75th percentile. The line inside the box is the median concentration. The top of the upper “whisker” represents the first observed concentration above the 75th percentile, whereas the bottom of the lower “whisker” represents

the first observed concentration below the 25th percentile (upper adjacent value and lower adjacent value, respectively). Values that lie outside of the adjacent values represent outside (potential outliers) concentrations (i.e. concentrations at the upper and lower ends of the distribution of the data). The method detection limit was used as the reported value in order to construct the box plot when analytical results were reported as non-detects.

Side-by-side box plots were constructed for the CCR materials data and aggregated by temporary well/boring location and WBF Plant CCR management unit. These box plots were useful in identifying differences in CCR Parameter concentrations between each WBF Plant CCR management unit and are especially useful for visually identifying potential outliers. Box plots are presented in Attachment E.2-B.

2.1.3 Outlier Screening

Outliers are data points that are abnormally high or low as compared to other measurements and may represent anomalous data or data errors. Outliers may also represent natural variation of CCR Parameter concentrations in environmental systems. Screening for outliers is a critical step because outliers can bias statistical estimates, statistical testing results, and inferences.

Outlier values were initially screened visually using side-by-side box plots. If suspected visual outliers were identified, then Tukey's procedure was used to identify extreme outliers (Tukey 1977). This method relies on the IQR, which is defined as the 75th percentile value minus the 25th percentile value. Values were identified as potential outliers as follows:

- **Lower extreme outliers** are less than the 25th percentile minus 3 x IQR
- **Upper extreme outliers** are greater than the 75th percentile plus 3 x IQR.

Finally, when the potential outlier(s) were identified visually and by Tukey's procedure, then statistical testing for outliers (Dixon or Rosner's Test) was conducted to determine if the data points were statistically significant outliers.

Following confirmation of the outliers as statistically significant, a desktop evaluation was conducted to verify that the data points were not errors (e.g., laboratory or transcriptional error). Field forms, data validation reports, and other variables in the dataset that could influence analytical results were also evaluated. If a verifiable error was discovered, the outlier was removed and, if possible, replaced with a corrected value.

In the absence of a verifiable error, additional lines of evidence were reviewed to determine final outlier disposition (e.g., frequency of detection, spatial and temporal variability). If an outlier was identified as suitable for removal from further statistical analysis, a clear and defensible rationale based on multiple lines of evidence was provided. In addition, values that were identified as outliers and removed from further evaluation in the present statistical analysis were retained in the historical database and will be reevaluated for inclusion or exclusion in future statistical analyses of this dataset. The results of the outlier screening for the WBF Plant CCR material dataset are provided in Section 3.1.

2.2 REGRESSION ANALYSIS

The linear relationship between the concentrations of CCR Parameters in SPLP results and concentrations in CCR material was evaluated using regression analysis. Scatter plots were constructed to compare SPLP and CCR material results for the CCR Parameters. Using linear regression, the Pearson's correlation coefficient was estimated, and a regression line was fit to the data and added to the scatter plots. As part of the analysis, the SPLP results for the CCR Parameters were compared to the range of pore water concentrations from the Slag Disposal Area (pore water was not collected and analyzed at the Ash Pond). Analyses were conducted on data where CCR parameters were detected in greater than 50% of the samples in both the SPLP and CCR material datasets. Scatter plots, regression results, and range of pore water concentrations are presented in Attachment E.2-C.

3.0 RESULTS AND DISCUSSION

3.1 SUMMARY STATISTICS, EXPLORATORY DATA PLOTS, AND OUTLIER SCREENING

Summary statistics tables are presented in Attachment E.2-A, and box plots are presented in Attachment E.2-B.

No outliers were identified in the CCR material or SPLP datasets. The pore water dataset was not screened for outliers due to the small size of the dataset.

3.2 REGRESSION ANALYSIS

The purpose of the regression analysis was to evaluate whether the total concentrations of metals in CCR material could be used as a reliable predictor of leachable concentrations as represented by SPLP concentrations. Scatter plots, regression results, and range of pore water concentrations are presented in Attachment E.2-C. The correlation coefficient (R-squared) is a numerical measure that measures the strength of association between two variables (in this case, between total concentration and SPLP results for CCR material). Correlation coefficients range from zero to one; a high correlation coefficient (closer to one) demonstrates a strong relationship between the two variables, whereas a low correlation coefficient (closer to zero) demonstrates a weak relationship. The slope of the regression line indicates the direction of correlation. A positive slope indicates that SPLP concentrations increased as CCR Parameter concentrations in CCR material increased. Conversely, a negative slope indicates that as CCR Parameter concentrations increased, the SPLP concentrations decreased.

The statistical relationships between SPLP concentrations and CCR material concentrations were inconsistent and highly variable. One would expect SPLP concentrations to increase with increasing CCR constituent concentrations in CCR material (e.g. regression line with a positive slope). However, this relationship was inconsistent between different CCR constituents and between WBF Plant CCR management units. In some cases, even when there was a statistically significant correlation (e.g., arsenic in the Slag Disposal Area), the wide range of variability around the regression line limits the

predictive value of the relationship. In addition, the relationship between the CCR parameter concentrations in SPLP and CCR parameter concentrations directly measured in pore water were inconsistent and variable.

The results indicate that the total concentrations of metals in CCR material is not a reliable predictor of the magnitude of the potentially leached concentrations measured using SPLP and that direct measurement of pore water concentrations is the most accurate way of characterizing potential leachability from CCR material.

4.0 REFERENCES

StataCorp. (2017). Stata Graphics Reference Manual Stata: Release 15. Statistical Software. College Station, Texas: StataCorp LLC.

Tukey, J.W. (1977). *Exploratory Data Analysis*. Reading, Massachusetts: Addison-Wesley. 1977.

ATTACHMENT E.2–A
SUMMARY STATISTICS

DRAFT

Summary Statistics - CCR Material Characteristics
Watts Barr Fossil Plant - Spring City, Tennessee

Parameter	Soil Depth	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters										
Boron	Ash Pond	8/8	--	0%	38.4	117	70.8	28.7	67.9	111
	Slag Disposal Area	13/13	--	0%	2.01	300	63.1	81.8	35.1	190
Calcium	Ash Pond	8/8	--	0%	4,030	27,600	8,900	7,760	6,500	21,300
	Slag Disposal Area	13/13	--	0%	387	18,400	4,780	4,880	3,010	12,700
Chloride	Ash Pond	2/8	(4.53 - 5.95)	75.0%	6.17	30.8	8.02	8.63	5.12	22.2
	Slag Disposal Area	4/13	(4.15 - 5.64)	69.2%	6.74	11.2	5.60	2.37	4.97	10.3
Fluoride	Ash Pond	8/8	--	0%	1.92	5.85	4.39	1.18	4.46	5.66
	Slag Disposal Area	8/13	(0.730 - 0.934)	38.5%	1.11	6.80	2.23	2.14	1.24	6.27
pH (lab)	Ash Pond	8/8	--	0%	7.40	9.90	8.20	0.949	7.85	9.76
	Slag Disposal Area	13/13	--	0%	4.40	10.2	6.79	1.83	7.00	9.72
Sulfate	Ash Pond	8/8	--	0%	113	1580	594	498	458	1340
	Slag Disposal Area	13/13	--	0%	23.3	1050	327	333	175	879
CCR Rule Appendix IV Parameters										
Antimony	Ash Pond	8/8	--	0%	1.80	3.52	2.59	0.636	2.47	3.40
	Slag Disposal Area	12/13	(0.0819 - 0.0819)	7.69%	0.104	6.71	1.91	1.94	0.754	4.83
Arsenic	Ash Pond	8/8	--	0%	68.5	258	138	64.2	129	234
	Slag Disposal Area	13/13	--	0%	5.81	205	84.0	71.7	109	185
Barium	Ash Pond	8/8	--	0%	161	313	216	49.9	208	294
	Slag Disposal Area	13/13	--	0%	69.4	337	194	68.0	186	285
Beryllium	Ash Pond	8/8	--	0%	1.85	6.06	3.25	1.34	3.26	5.24
	Slag Disposal Area	13/13	--	0%	0.411	5.74	2.35	1.51	1.76	4.51
Cadmium	Ash Pond	8/8	--	0%	1.21	3.35	1.90	0.715	1.70	2.98
	Slag Disposal Area	12/13	(0.0224 - 0.0224)	7.69%	0.0283	5.64	1.36	1.71	0.208	4.68
Chromium	Ash Pond	8/8	--	0%	28.9	59.1	40.0	10.9	37.6	55.0
	Slag Disposal Area	13/13	--	0%	4.58	75.8	44.6	19.2	44.9	69.7
Cobalt	Ash Pond	8/8	--	0%	9.60	20.9	13.7	3.33	13.5	18.7
	Slag Disposal Area	13/13	--	0%	7.67	18.3	12.6	3.18	12.4	17.2
Lead	Ash Pond	8/8	--	0%	28.9	63.4	46.1	12.3	47.5	61.00
	Slag Disposal Area	13/13	--	0%	5.06	92.6	32.4	26.2	24.1	70.1
Lithium	Ash Pond	8/8	--	0%	20.9	39.2	29.1	7.21	28.3	38.6
	Slag Disposal Area	13/13	--	0%	3.29	37.8	25.2	9.77	29.2	37.3
Mercury	Ash Pond	8/8	--	0%	0.206	0.698	0.451	0.192	0.408	0.693
	Slag Disposal Area	10/13	(0.0156 - 0.140)	23.1%	0.0209	1.13	0.306	0.311	0.230	0.818

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Summary Statistics - CCR Material Characteristics Watts Barr Fossil Plant - Spring City, Tennessee										
Parameter	Soil Depth	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Molybdenum	Ash Pond	8/8	--	0%	8.75	16.3	11.2	2.39	10.3	15.0
	Slag Disposal Area	13/13	--	0%	0.489	14.9	6.50	4.41	6.12	12.9
Radium-226+228	Ash Pond	8/8	--	0%	4.50	6.89	5.59	0.896	5.65	6.81
	Slag Disposal Area	13/13	--	0%	0.945	9.09	4.90	2.31	5.16	8.86
Selenium	Ash Pond	8/8	--	0%	3.32	9.23	6.00	2.43	6.06	8.81
	Slag Disposal Area	12/13	(0.812 - 0.812)	7.69%	1.06	11.5	4.99	3.84	4.58	10.7
Thallium	Ash Pond	8/8	--	0%	2.65	9.30	5.07	2.31	4.730	8.61
	Slag Disposal Area	13/13	--	0%	0.243	10.9	3.99	3.56	4.48	9.50
TDEC Appendix I Parameters										
Copper	Ash Pond	8/8	--	0%	29.4	65.4	44.4	13.7	45.3	62.8
	Slag Disposal Area	13/13	--	0%	16.7	111	40.9	27.3	46.1	83.5
Nickel	Ash Pond	8/8	--	0%	23.8	57.8	35.4	11.4	37.2	51.4
	Slag Disposal Area	13/13	--	0%	15.3	57.0	30.4	13.1	25.8	50.6
Silver	Ash Pond	8/8	--	0%	0.0745	0.243	0.144	0.0567	0.155	0.220
	Slag Disposal Area	10/13	(0.0299 - 0.0357)	23.1%	0.0309	0.201	0.0975	0.0628	0.0757	0.187
Vanadium	Ash Pond	8/8	--	0%	50.5	121	75.5	23.3	73.0	109
	Slag Disposal Area	13/13	--	0%	7.55	226	78.0	61.1	49.2	181
Zinc	Ash Pond	8/8	--	0%	111	264	157	52.3	146	236
	Slag Disposal Area	13/13	--	0%	6.95	423	119	119	66.1	296
Additional Parameters										
Iron	Ash Pond	8/8	--	0%	28,000	42,100	33,500	5,520	32,700	41,800
	Slag Disposal Area	13/13	--	0%	28,300	106,000	53,700	20,100	51,600	87,400
Manganese	Ash Pond	8/8	--	0%	118	687	306	199	254	627
	Slag Disposal Area	13/13	--	0%	35.5	1180	311	332	161	883
TOC	Ash Pond	8/8	--	0%	30500	137,000	77,300	40,900	75,000	132,000
	Slag Disposal Area	12/13	(948 - 948)	7.69%	4100	312,000	60,400	82,400	25,500	207,000

Notes:
CCR Rule - Title 40, Code of Federal Regulations, Part 257
TDEC - Tennessee Department of Environment and Conservation
% - percent
"--" : Not Applicable
TOC - Total Organic Carbon

Except for pH & Radium 226 + 228, all units are milligrams per kilogram (mg/kg).
Units for pH are Standard Units (S.U.).
Units for Radium 226+228 are picocuries per gram (pCi/g).
All non-detects reported at the method detection limit.
For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM).

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Summary Statistics - CCR Material Characteristics - Synthetic Precipitate Leaching Procedure (SPLP)
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	CCR Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects and Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters										
Boron	Ash Pond	8/8	--	0%	178	807	457	217	400	760
	Slag Disposal Area	13/13	--	0%	47.0	1120	291	311	194	884
Calcium	Ash Pond	8/8	--	0%	9,170	45,900	23,400	13,000	19,800	43,900
	Slag Disposal Area	13/13	--	0%	878	49,300	15,500	12,600	14,800	33,500
CCR Rule Appendix IV Parameters										
Antimony	Ash Pond	8/8	--	0%	1.93	6.37	4.93	1.44	5.35	6.21
	Slag Disposal Area	12/13	(0.378 - 0.378)	7.69%	0.416	15.6	4.72	5.59	1.52	14.6
Arsenic	Ash Pond	8/8	--	0%	6.72	101	47.3	30.8	42.3	90.3
	Slag Disposal Area	13/13	--	0%	0.428	95.7	19.7	28.9	2.86	70.2
Barium	Ash Pond	8/8	--	0%	2.87	31.0	13.7	11.2	8.83	29.7
	Slag Disposal Area	11/13	(1.49 - 1.60)	15.4%	5.18	146	32.6	37.1	17.6	90.1
Beryllium	Ash Pond	1/8	(0.155 - 0.245)	87.5%	0.234	0.234	0.166	0.0276	0.184	0.241
	Slag Disposal Area	3/13	(0.155 - 0.182)	76.9%	0.319	0.356	0.198	0.0796	0.182	0.355
Cadmium	Ash Pond	0/8	(0.125 - 0.125)	100%	--	--	--	--	0.125	0.125
	Slag Disposal Area	1/13	(0.125 - 0.125)	92.3%	1.70	1.70	0.246	0.420	0.125	0.755
Chromium	Ash Pond	1/8	(1.53 - 1.53)	87.5%	2.86	2.86	1.7	0.440	1.53	2.40
	Slag Disposal Area	2/13	(1.53 - 5.40)	84.6%	1.56	1.65	1.57	0.0492	2.20	4.37
Cobalt	Ash Pond	2/8	(0.075 - 0.256)	75.0%	0.196	0.356	0.128	0.096	0.158	0.321
	Slag Disposal Area	9/13	(0.0750 - 0.0750)	30.8%	0.088	163	16.6	43.2	0.152	80.9
Lead	Ash Pond	6/8	(0.128 - 0.128)	25.0%	0.241	1.31	0.494	0.383	0.402	1.16
	Slag Disposal Area	9/13	(0.128 - 0.128)	30.8%	0.144	27.3	2.36	7.21	0.220	11.6
Lithium	Ash Pond	2/8	(3.14 - 3.14)	75.0%	6.00	14.8	4.96	3.84	3.14	11.7
	Slag Disposal Area	7/13	(3.14 - 3.39)	46.2%	4.09	17.1	5.07	3.68	4.09	11.5
Mercury	Ash Pond	0/8	(0.101 - 0.101)	100%	--	--	--	--	0.101	0.101
	Slag Disposal Area	0/13	(0.101 - 0.101)	100%	--	--	--	--	0.101	0.101
Molybdenum	Ash Pond	8/8	--	0%	6.89	283	94.2	88.1	62.5	232
	Slag Disposal Area	7/13	(0.610 - 0.610)	46.2%	2.75	87.6	17.6	24.6	2.75	57.7
Radium-226+228	Ash Pond	0/8	(0 - 0.216)	100%	--	--	--	--	0.0398	0.17
	Slag Disposal Area	1/13	(0 - 0.337)	92.3%	0.52	0.52	0.04	0.139	0.141	0.41

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Summary Statistics - CCR Material Characteristics - Synthetic Precipitate Leaching Procedure (SPLP)
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	CCR Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects and Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Selenium	Ash Pond	5/8	(2.62 - 2.62)	37.5%	5.91	28.8	9.86	8.89	6.26	25.5
	Slag Disposal Area	7/13	(1.51 - 2.62)	46.2%	2.76	56.5	9.98	15.6	2.76	40.5
Thallium	Ash Pond	2/8	(0.128 - 0.375)	75.0%	0.401	1.25	0.302	0.369	0.163	0.953
	Slag Disposal Area	7/13	(0.128 - 0.148)	46.2%	0.19	13.2	1.19	3.47	0.190	5.51
TDEC Appendix I Parameters										
Copper	Ash Pond	7/8	(0.627 - 0.627)	12.5%	0.855	23.7	5.32	7.45	1.89	18.8
	Slag Disposal Area	5/13	(0.627 - 1.46)	61.5%	0.916	35.8	3.81	9.29	1.13	17.1
Nickel	Ash Pond	1/8	(0.423 - 1.81)	87.5%	8.72	8.72	1.46	2.74	1.21	6.30
	Slag Disposal Area	8/13	(0.336 - 0.849)	38.5%	0.354	308	31.3	82.3	0.849	169
Silver	Ash Pond	0/8	(0.121 - 0.121)	100%	--	--	--	--	0.121	0.121
	Slag Disposal Area	0/13	(0.121 - 0.177)	100%	--	--	--	--	0.177	0.177
Vanadium	Ash Pond	8/8	--	0%	3.08	130	44.8	40.8	46.1	105
	Slag Disposal Area	11/13	(0.991 - 0.991)	15.4%	0.978	150	27.4	42.3	2.49	99.0
Zinc	Ash Pond	6/8	(3.22 - 3.22)	25.0%	3.36	29.4	11.0	9.72	6.42	27.7
	Slag Disposal Area	5/13	(3.22 - 3.22)	61.5%	3.58	33.6	7.40	8.90	3.22	26.0
Additional Parameters										
Iron	Ash Pond	6/8	(14.1 - 14.1)	25.0%	54.5	727	207	215	197	558
	Slag Disposal Area	10/13	(19.5 - 19.5)	23.1%	20.8	20,900	1,760	5,540	31.8	9,150
Manganese	Ash Pond	6/8	(1.35 - 1.35)	25.0%	4.16	18.4	6.19	5.13	4.62	14.9
	Slag Disposal Area	11/13	(1.35 - 1.35)	15.4%	1.95	2,540	252	669	9.19	1,250

Notes:
CCR Rule - Title 40, Code of Federal Regulations, Part 257
TDEC - Tennessee Department of Environment and Conservation
% - percent
"--" : Not Applicable

Except for Radium 226 + 228, all units are micrograms per liter (µg/L).
Units for Radium 226+228 are picocuries per liter (pCi/L).
All non-detects reported at the method detection limit.
For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM).

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Summary Statistics - CCR Material Characteristics - Pore Water - Total Metals
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	CCR Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters										
Boron	Slag Disposal Area	3/3	--	0%	269	6,220	4,160	3,370	6,000	6,200
Calcium	Slag Disposal Area	3/3	--	0%	470,000	484,000	479,000	7,570	482,000	484,000
Chloride	Slag Disposal Area	3/3	--	0%	6,690	10,600	8,850	1,990	9,260	10,500
Fluoride	Slag Disposal Area	2/3	(65.8 - 65.8)	33.3%	76.6	137	93.1	31.3	76.6	131
pH (field)	Slag Disposal Area	3/3	--	0%	5.90	9.41	7.37	1.83	6.79	9.15
Sulfate	Slag Disposal Area	3/3	--	0%	913,000	1,430,000	1,170,000	259,000	1,160,000	1,400,000
TDS	Slag Disposal Area	3/3	--	0%	1,840,000	2,490,000	2,080,000	359,000	1,900,000	2,430,000
CCR Rule Appendix IV Parameters										
Antimony	Slag Disposal Area	0/3	(0.378 - 4.15)	100%	--	--	--	--	0.378	3.77
Arsenic	Slag Disposal Area	3/3	--	0%	17.4	71.6	49.2	28.3	58.7	70.3
Barium	Slag Disposal Area	3/3	--	0%	37.6	165	82.6	71.4	45.3	153
Beryllium	Slag Disposal Area	0/3	(0.620 - 0.976)	100%	--	--	--	--	0.942	0.973
Cadmium	Slag Disposal Area	1/3	(0.125 - 0.125)	66.7%	0.466	0.466	0.239	0.161	0.125	0.432
Chromium	Slag Disposal Area	1/3	(1.53 - 1.53)	66.7%	2.58	2.58	1.88	0.495	1.53	2.48
Cobalt	Slag Disposal Area	2/3	(0.369 - 0.369)	33.3%	1.15	3.93	1.82	1.53	1.150	3.65
Lead	Slag Disposal Area	1/3	(0.165 - 0.391)	66.7%	1.76	1.76	0.697	0.752	0.391	1.62
Lithium	Slag Disposal Area	2/3	(50.4 - 50.4)	33.3%	124	245	140	80.2	124	233
Mercury	Slag Disposal Area	0/3	(0.101 - 0.101)	100%	--	--	--	--	0.101	0.101
Molybdenum	Slag Disposal Area	2/3	(0.791 - 0.791)	33.3%	135	1360	499	612	135	1240
Radium-226+228	Slag Disposal Area	2/3	(0.337 - 0.337)	33.3%	0.848	1.01	0.73	0.285	0.848	0.99
Selenium	Slag Disposal Area	1/3	(1.51 - 1.51)	66.7%	3.68	3.68	2.23	1.02	1.51	3.46
Thallium	Slag Disposal Area	0/3	(0.148 - 0.791)	100%	--	--	--	--	0.148	0.727
TDEC Appendix I Parameters										
Copper	Slag Disposal Area	0/3	(1.15 - 2.58)	100%	--	--	--	--	1.82	2.50
Nickel	Slag Disposal Area	2/3	(4.34 - 4.34)	33.3%	3.09	9.25	5.14	2.90	4.34	8.76
Silver	Slag Disposal Area	0/3	(0.177 - 0.177)	100%	--	--	--	--	0.177	0.177
Vanadium	Slag Disposal Area	1/3	(0.991 - 0.991)	66.7%	84.5	84.5	28.8	39.4	0.991	76.2
Zinc	Slag Disposal Area	1/3	(9.01 - 13.4)	66.7%	23.6	23.6	13.9	6.88	13.4	22.6

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Summary Statistics - CCR Material Characteristics - Pore Water - Total Metals Watts Bar Fossil Plant - Spring City, Tennessee										
Parameter	CCR Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Additional Water Quality Parameters										
Iron	Slag Disposal Area	3/3	--	0%	488	94,900	47,200	47,200	46,200	90,000
Manganese	Slag Disposal Area	3/3	--	0%	61.6	31,600	12,200	17,000	4,990	28,900
TOC	Slag Disposal Area	3/3	--	0%	837	1,810	1,270	497	1,150	1,740

Notes:
CCR Rule - Title 40, Code of Federal Regulations, Part 257
TDEC - Tennessee Department of Environment and Conservation
% - percent
TDS: Total Dissolved Solids
TOC: Total Organic Carbon
"--" - Not Applicable

Except for pH & Radium 226 + 228, all units micrograms per liter (µg/L).
Units for pH are Standard Units (S.U.).
Units for Radium 226+228 are picocuries per liter (pCi/L).
All non-detects reported at the laboratory detection limit.
For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM).

Summary Statistics - CCR Material Characteristics - Pore Water - Dissolved Metals
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Chemical Abstracts Service Registry Number (CASRN)	Soil Depth	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
						Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters											
Boron	7440-42-8	Slag Disposal Area	3/3	--	0%	260	6,420	4,210	3,430	5,940	6,370
Calcium	7440-70-2	Slag Disposal Area	3/3	--	0%	477,000	504,000	490,000	13,500	490,000	503,000
CCR Rule Appendix IV Parameters											
Antimony	7440-36-0	Slag Disposal Area	0/3	(0.378 - 4.28)	100%	--	--	--	--	0.634	3.92
Arsenic	7440-38-2	Slag Disposal Area	3/3	--	0%	18.9	71.9	47.7	26.8	52.2	69.9
Barium	7440-39-3	Slag Disposal Area	3/3	--	0%	39.7	158	81.0	66.7	45.4	147
Beryllium	7440-41-7	Slag Disposal Area	0/3	(0.356 - 0.853)	100%	--	--	--	--	0.474	0.815
Cadmium	7440-43-9	Slag Disposal Area	1/3	(0.125 - 0.125)	66.7%	0.227	0.227	0.159	0.0481	0.125	0.217
Chromium	7440-47-3	Slag Disposal Area	0/3	(1.53 - 1.53)	100%	--	--	--	--	1.53	1.53
Cobalt	7440-48-4	Slag Disposal Area	2/3	(0.131 - 0.131)	33.3%	1.07	4.04	1.75	1.67	1.07	3.74
Lead	7439-92-1	Slag Disposal Area	0/3	(0.128 - 0.186)	100%	--	--	--	--	0.128	0.18
Lithium	7439-93-2	Slag Disposal Area	2/3	(54.9 - 54.9)	33.3%	119	235	136	74.5	119	223
Mercury	7439-97-6	Slag Disposal Area	0/3	(0.101 - 0.101)	100%	--	--	--	--	0.101	0.101
Molybdenum	7439-98-7	Slag Disposal Area	3/3	--	0%	0.920	1340	493	737	139	1220
Selenium	7782-49-2	Slag Disposal Area	1/3	(1.51 - 1.51)	66.7%	4.82	4.82	2.61	1.56	1.51	4.49
Thallium	7440-28-0	Slag Disposal Area	0/3	(0.148 - 0.768)	100%	--	--	--	--	0.148	0.706
TDEC Appendix I Parameters											
Copper	7440-50-8	Slag Disposal Area	1/3	(1.08 - 1.34)	66.7%	1.11	1.11	1.10	0.0150	1.11	1.32
Nickel	7440-02-0	Slag Disposal Area	1/3	(0.686 - 4.95)	66.7%	10.7	10.7	4.02	4.72	4.95	10.1
Silver	7440-22-4	Slag Disposal Area	0/3	(0.177 - 0.177)	100%	--	--	--	--	0.177	0.177
Vanadium	7440-62-2	Slag Disposal Area	1/3	(0.991 - 0.991)	66.7%	75.3	75.3	25.8	35.0	0.991	67.9
Zinc	7440-66-6	Slag Disposal Area	1/3	(3.57 - 13.1)	66.7%	25.0	25.0	10.7	10.1	13.1	23.8
Additional Water Quality Parameters											
Iron	7440-42-8	Slag Disposal Area	3/3	--	0%	50.4	101,000	49,500	50,500	47,400	95,600
Manganese	7440-70-2	Slag Disposal Area	3/3	--	0%	52.7	32,800	12,700	17,600	5,300	30,100

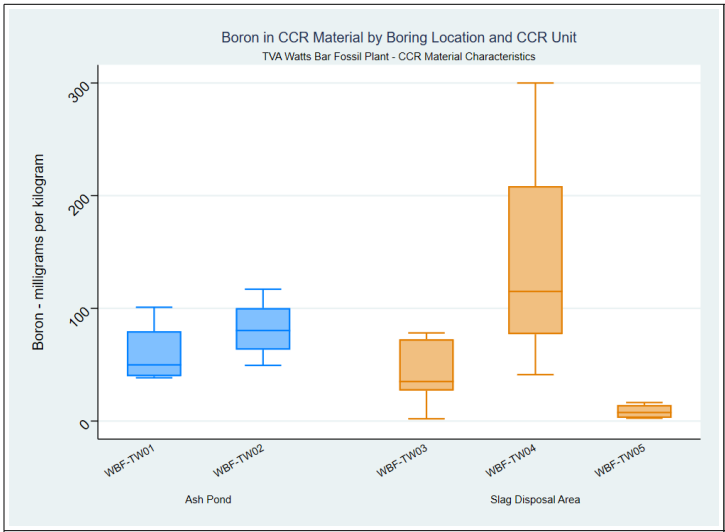
Notes:
CCR Rule - Title 40, Code of Federal Regulations, Part 257
TDEC - Tennessee Department of Environment and Conservation
% - percent
"--" : Not Applicable

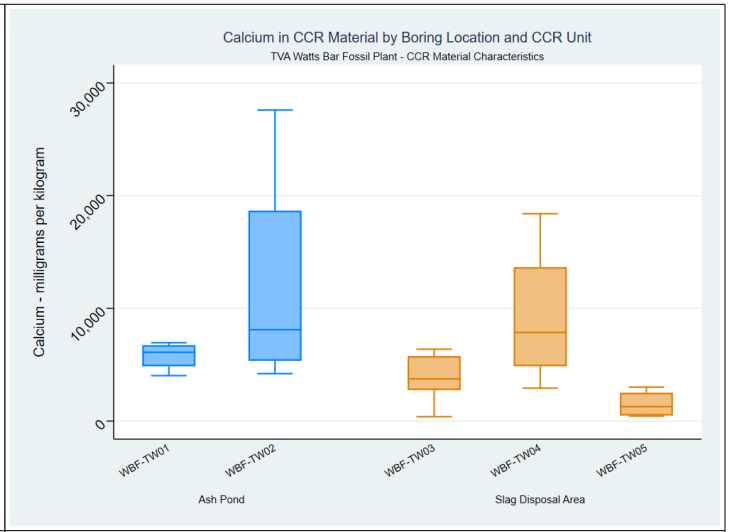
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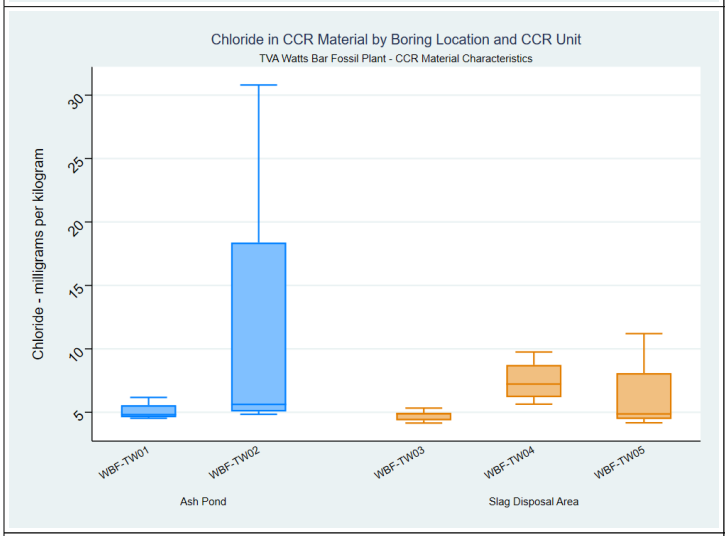
ATTACHMENT E.2-B
BOX PLOTS

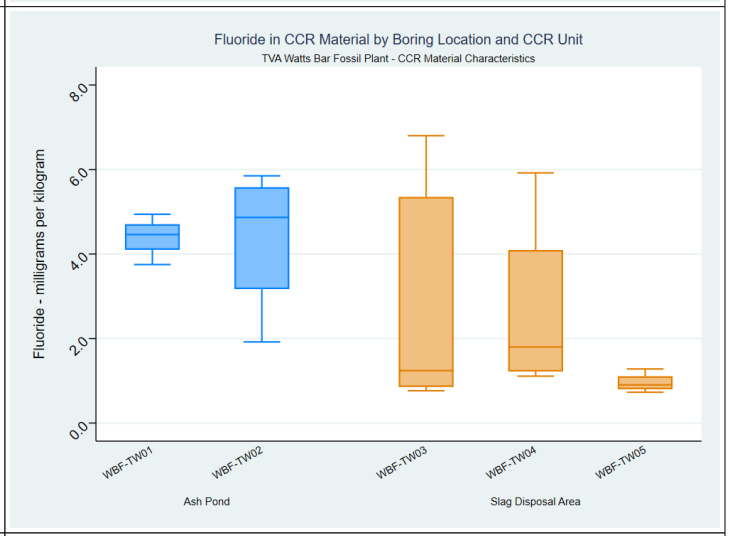
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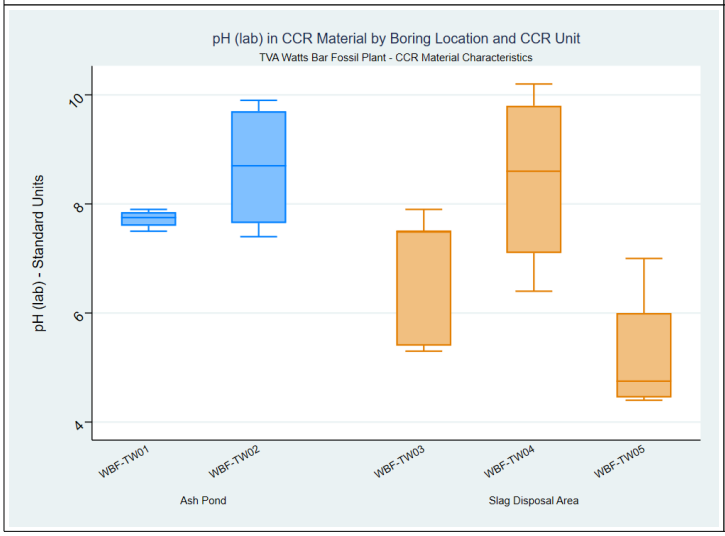
Box Plots
CCR Rule Appendix III Parameters
CCR Material Characteristics Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

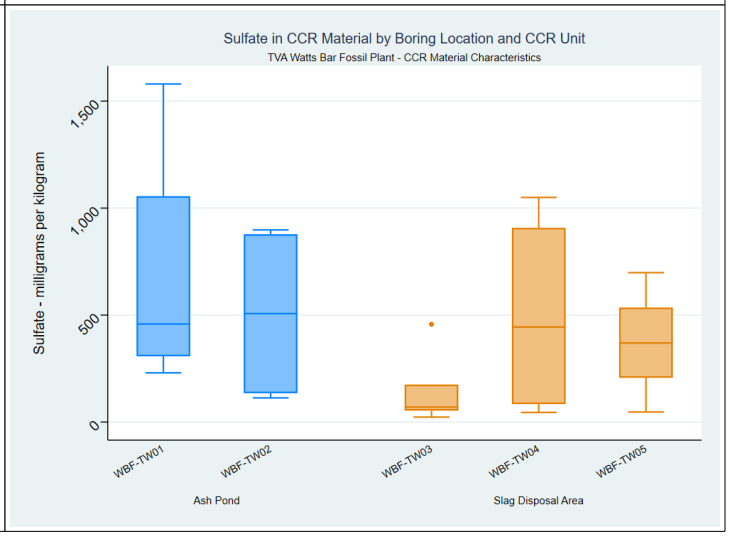






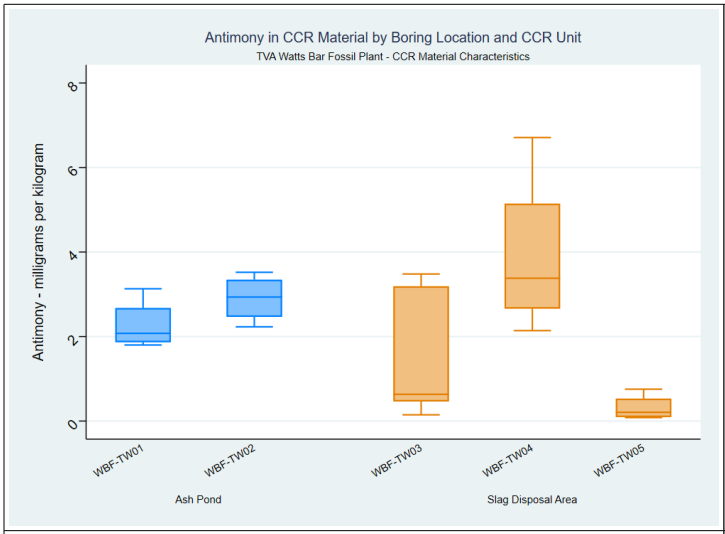


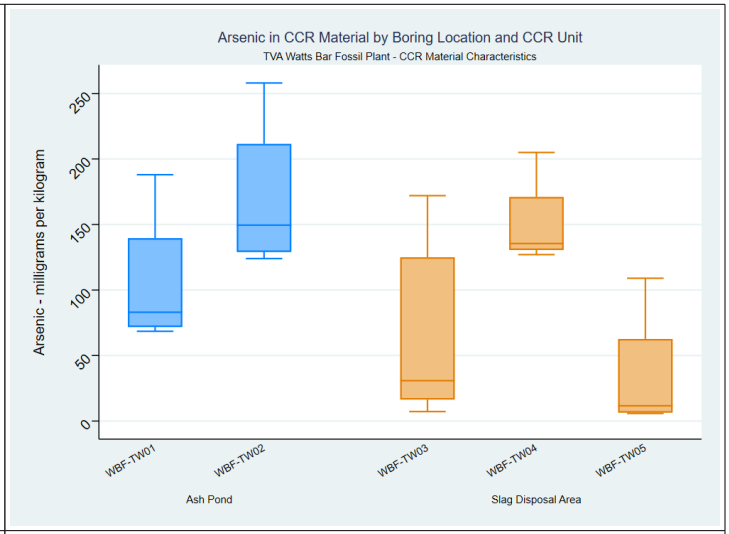


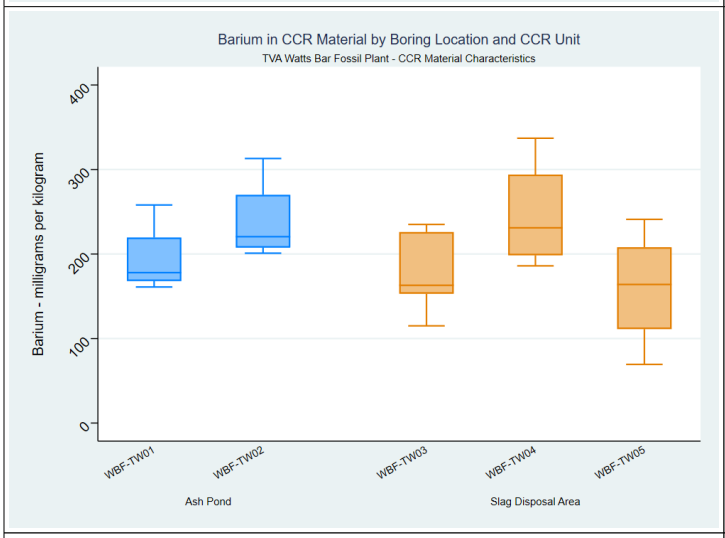


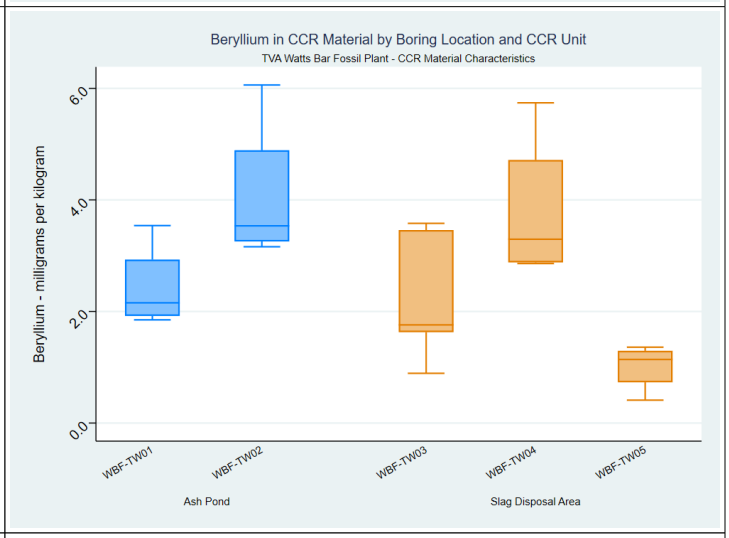
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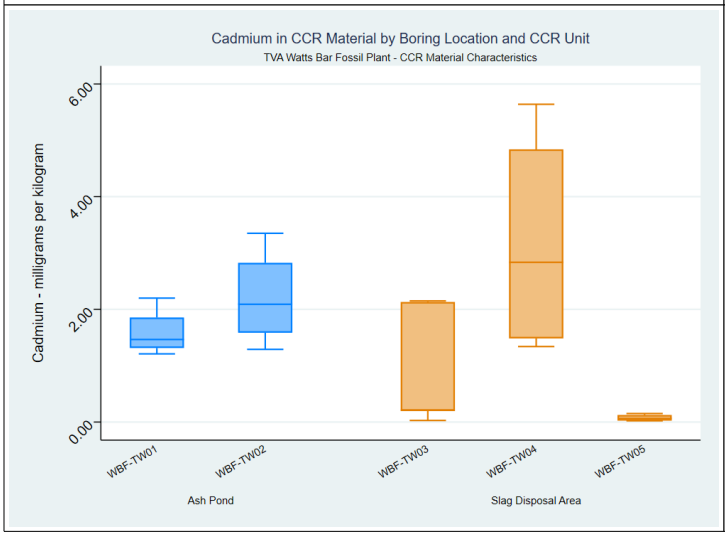
Box Plots
CCR Rule Appendix IV Parameters
CCR Material Characteristics Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

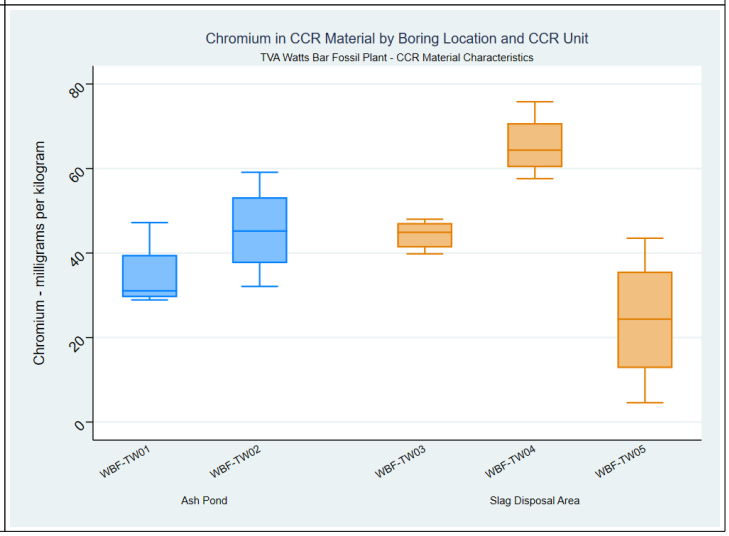




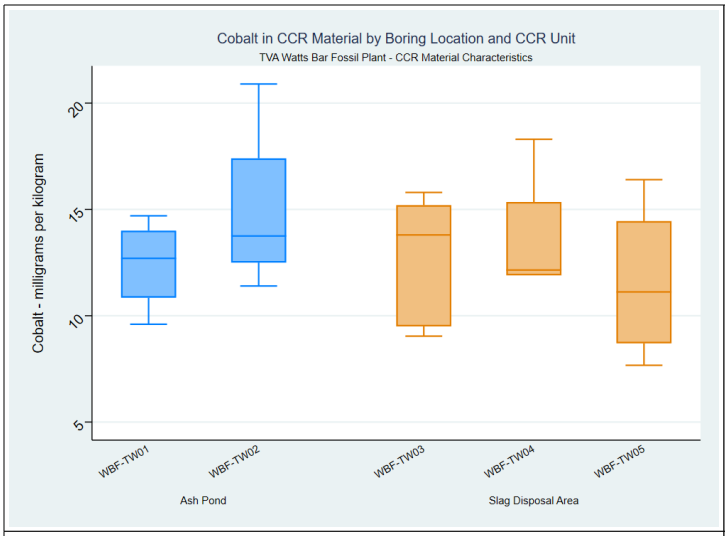


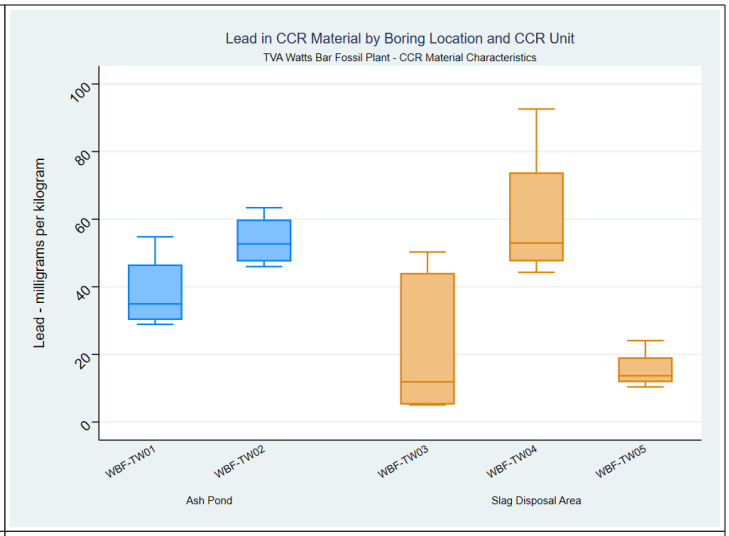


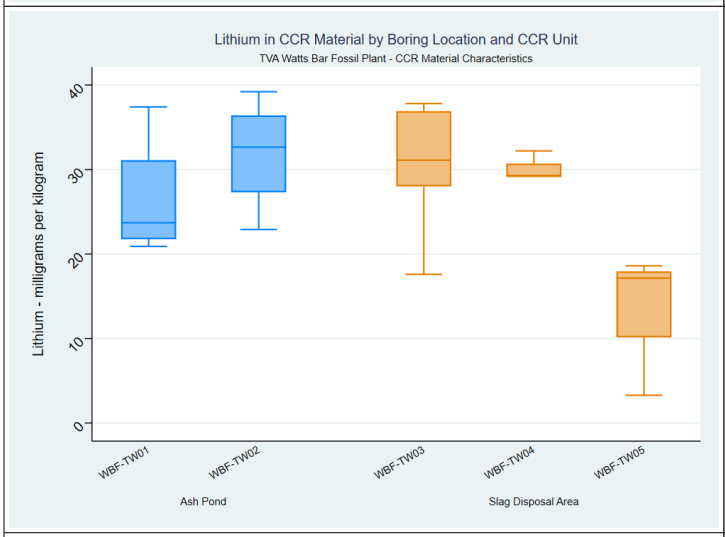


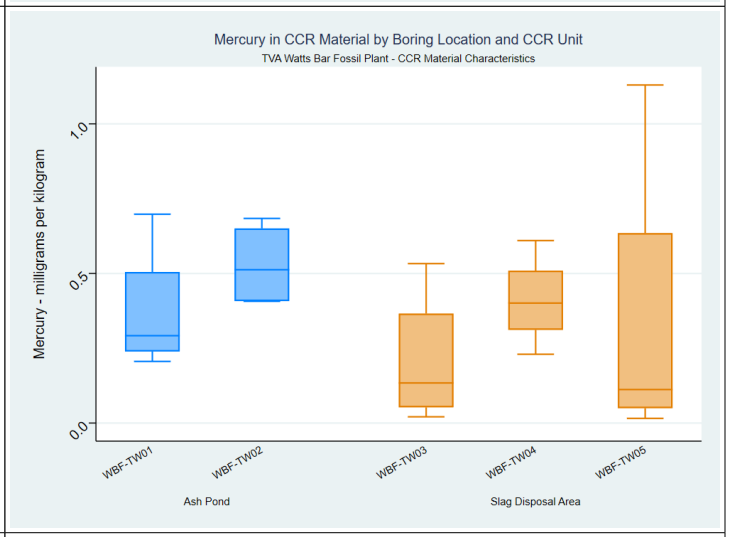


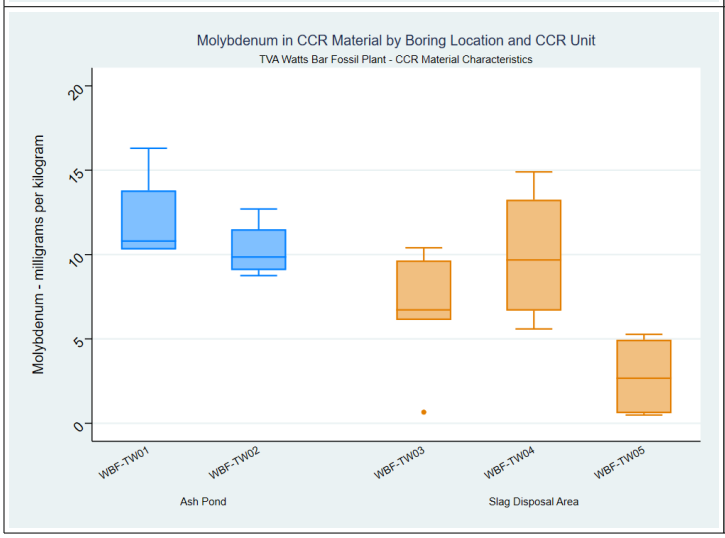
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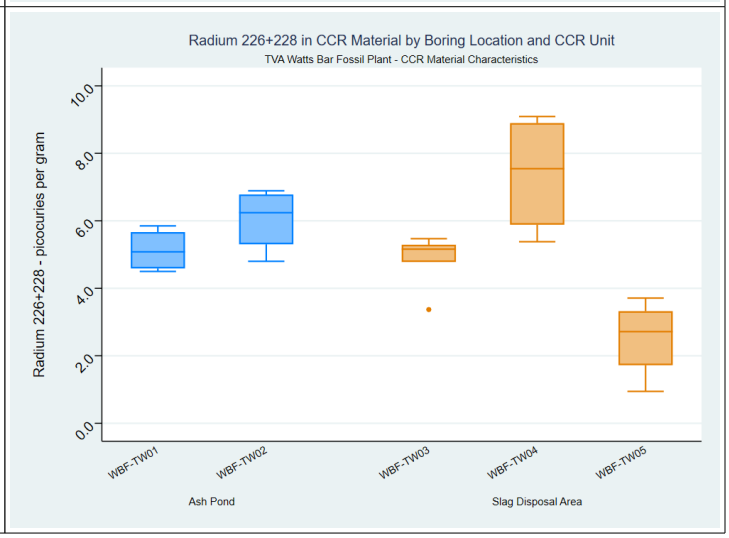

Cobalt in CCR Material by Boring Location and CCR Unit
TVA Watts Bar Fossil Plant - CCR Material Characteristics
Cobalt - milligrams per kilogram
5
10
15
20
WBF-TW01
WBF-TW02
WBF-TW03
WBF-TW04
WBF-TW05
Ash Pond
Slag Disposal Area


Lead in CCR Material by Boring Location and CCR Unit
TVA Watts Bar Fossil Plant - CCR Material Characteristics
Lead - milligrams per kilogram
0
20
40
60
80
100
WBF-TW01
WBF-TW02
WBF-TW03
WBF-TW04
WBF-TW05
Ash Pond
Slag Disposal Area

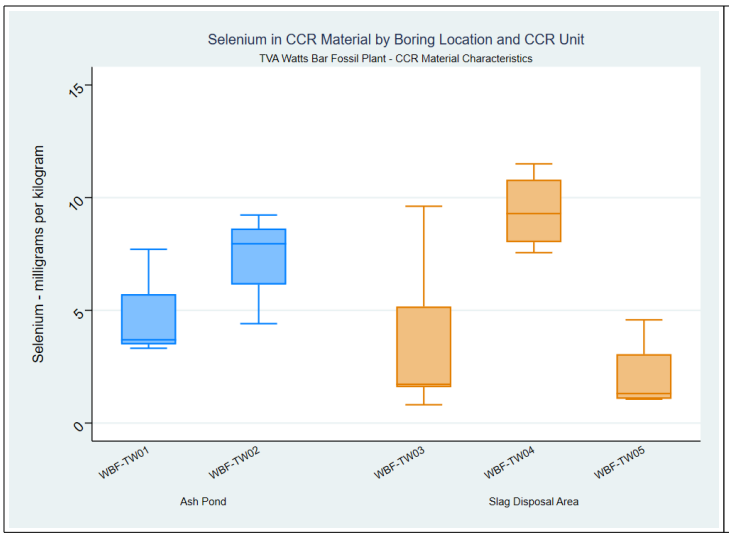

Lithium in CCR Material by Boring Location and CCR Unit
TVA Watts Bar Fossil Plant - CCR Material Characteristics
Lithium - milligrams per kilogram
0
10
20
30
40
WBF-TW01
WBF-TW02
WBF-TW03
WBF-TW04
WBF-TW05
Ash Pond
Slag Disposal Area

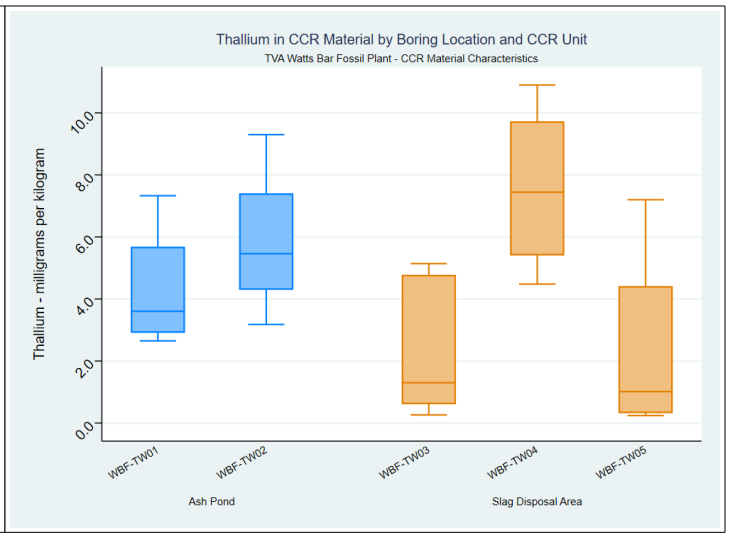

Mercury in CCR Material by Boring Location and CCR Unit
TVA Watts Bar Fossil Plant - CCR Material Characteristics
Mercury - milligrams per kilogram
0.0
0.5
1.0
WBF-TW01
WBF-TW02
WBF-TW03
WBF-TW04
WBF-TW05
Ash Pond
Slag Disposal Area


Molybdenum in CCR Material by Boring Location and CCR Unit
TVA Watts Bar Fossil Plant - CCR Material Characteristics
Molybdenum - milligrams per kilogram
0
5
10
15
20
WBF-TW01
WBF-TW02
WBF-TW03
WBF-TW04
WBF-TW05
Ash Pond
Slag Disposal Area


Radium 226+228 in CCR Material by Boring Location and CCR Unit
TVA Watts Bar Fossil Plant - CCR Material Characteristics
Radium 226+228 - picocuries per gram
0.0
2.0
4.0
6.0
8.0
10.0
WBF-TW01
WBF-TW02
WBF-TW03
WBF-TW04
WBF-TW05
Ash Pond
Slag Disposal Area

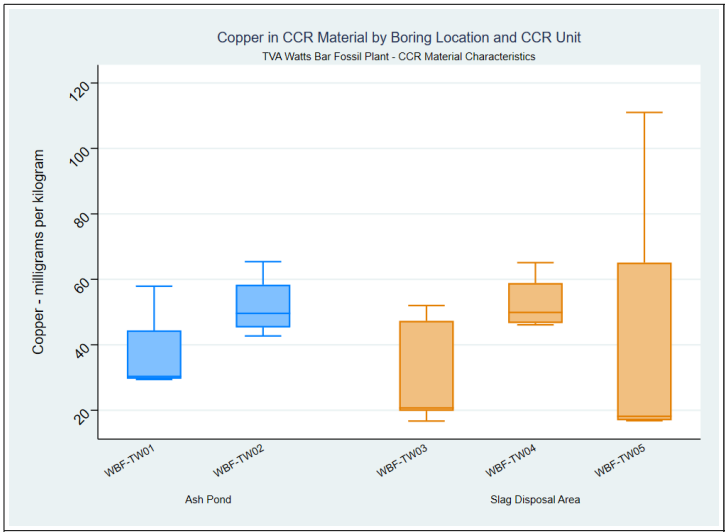
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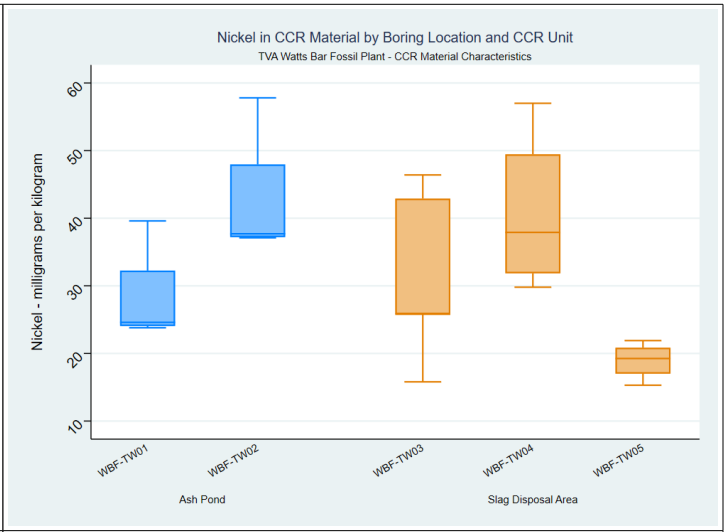

Selenium in CCR Material by Boring Location and CCR Unit
TVA Watts Bar Fossil Plant - CCR Material Characteristics
Selenium - milligrams per kilogram
0
5
10
15
WBF-TW01
WBF-TW02
WBF-TW03
WBF-TW04
WBF-TW05
Ash Pond
Slag Disposal Area

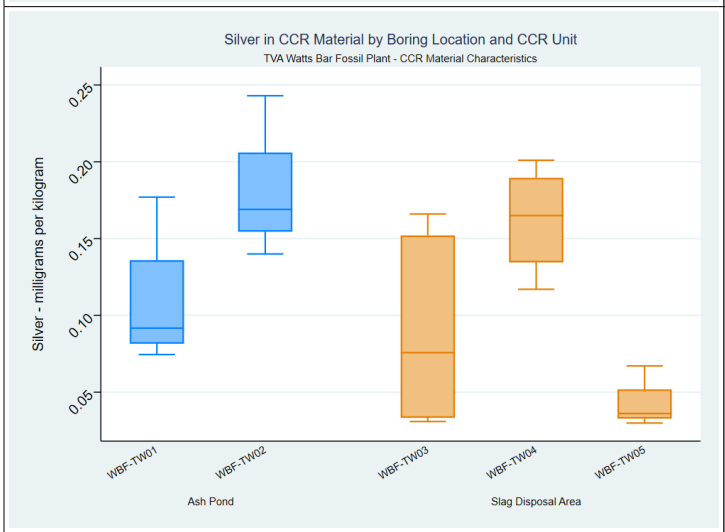

Thallium in CCR Material by Boring Location and CCR Unit
TVA Watts Bar Fossil Plant - CCR Material Characteristics
Thallium - milligrams per kilogram
0.0
2.0
4.0
6.0
8.0
10.0
WBF-TW01
WBF-TW02
WBF-TW03
WBF-TW04
WBF-TW05
Ash Pond
Slag Disposal Area

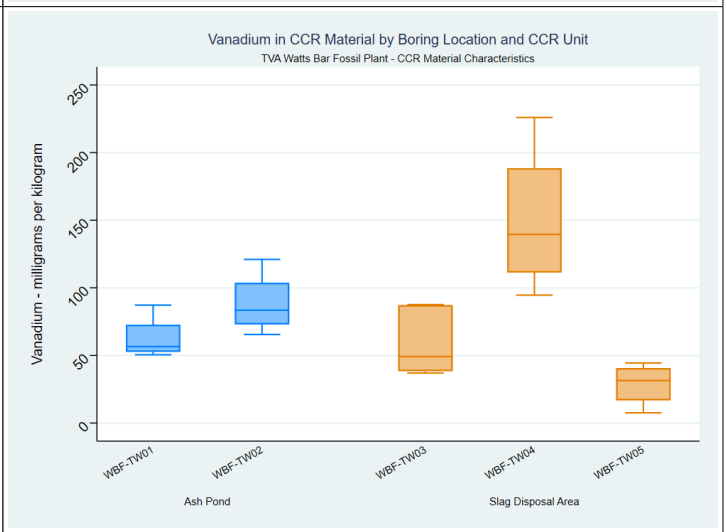
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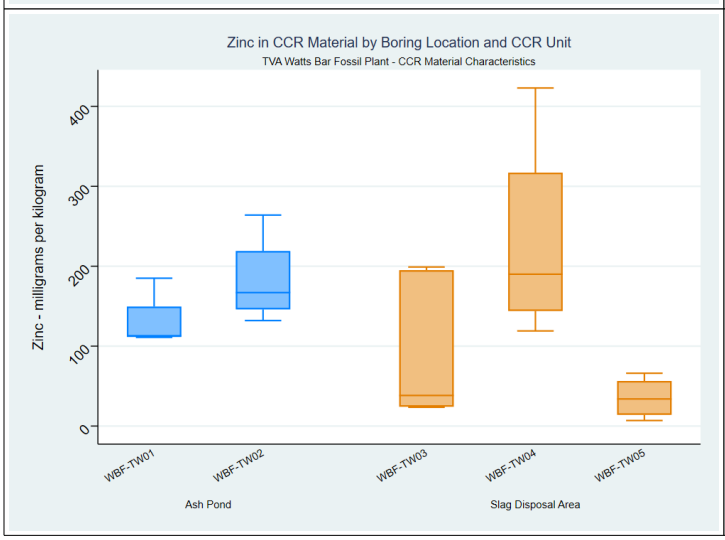
Box Plots
TDEC Appendix I Parameters
CCR Material Characteristics Investigation
Watts Bar Fossil Plant - Spring City, Tennessee









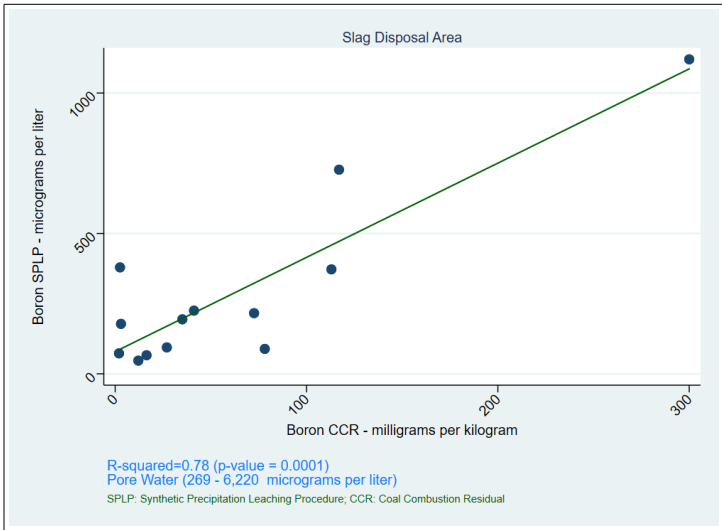


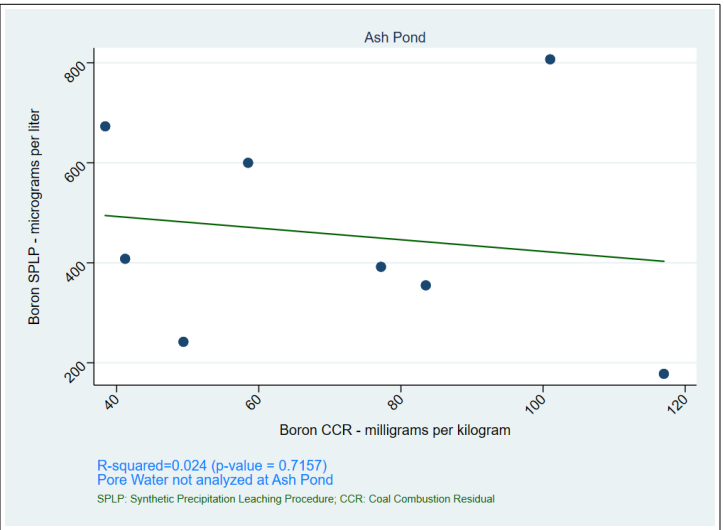
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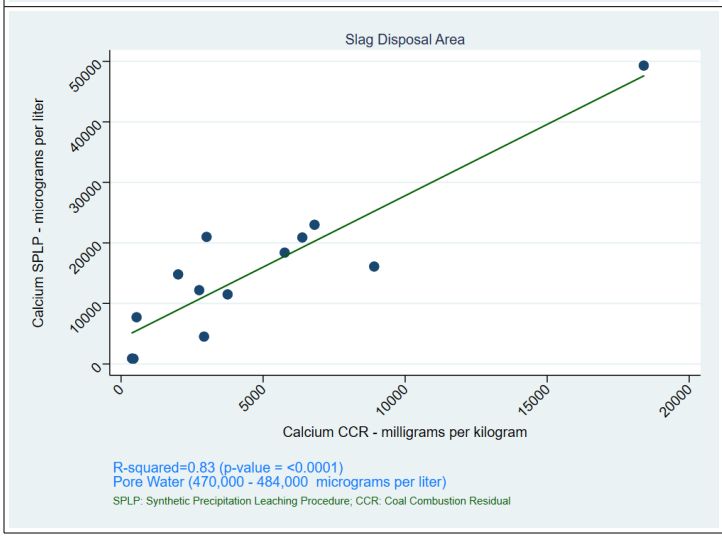
ATTACHMENT E.2-C
SCATTER PLOTS AND REGRESSION

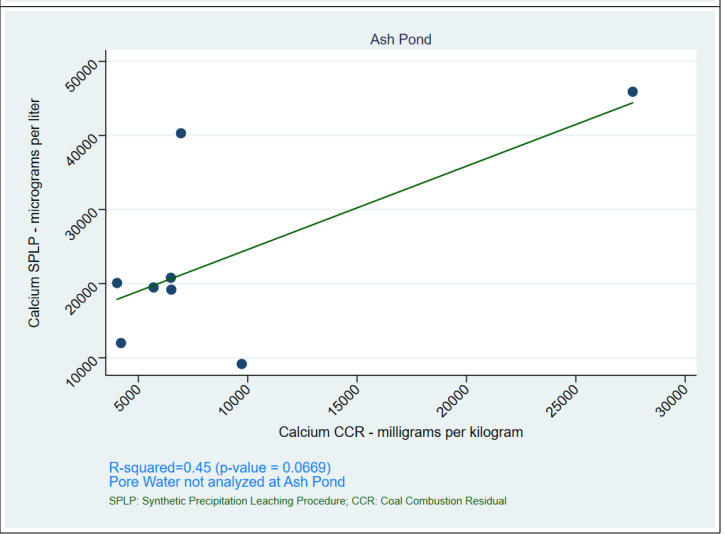
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Scatter Plots (SPLP and CCR Material)
CCR Rule Appendix III Parameters
CCR Material Characteristics Investigation
Watts Bar Fossil Plant - Spring City, Tennessee



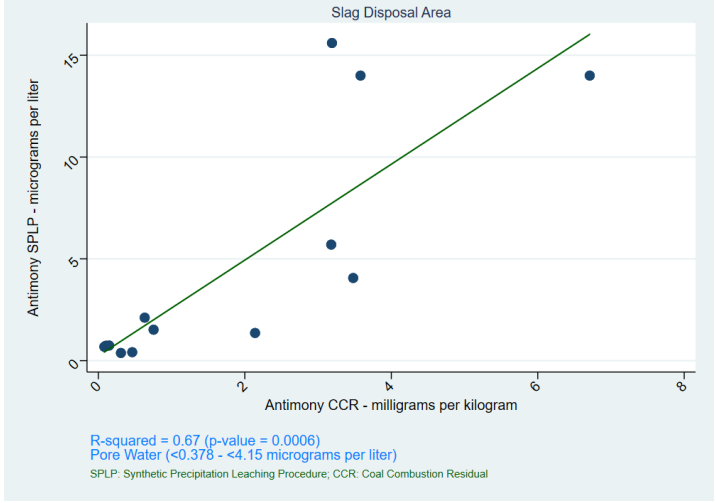


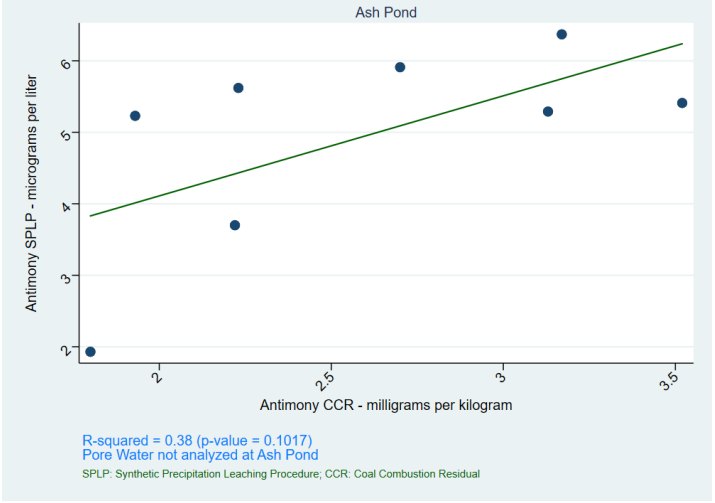


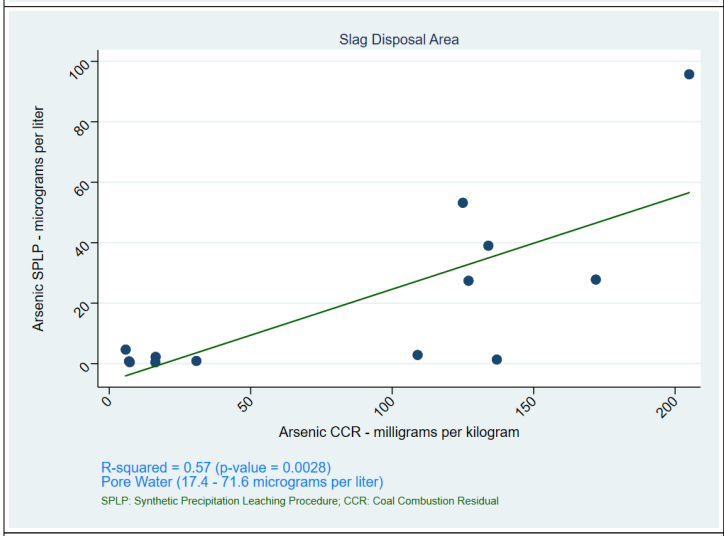


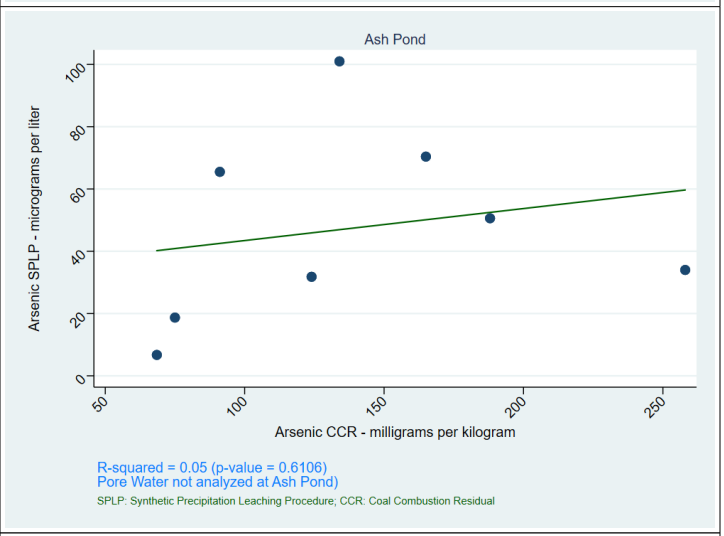
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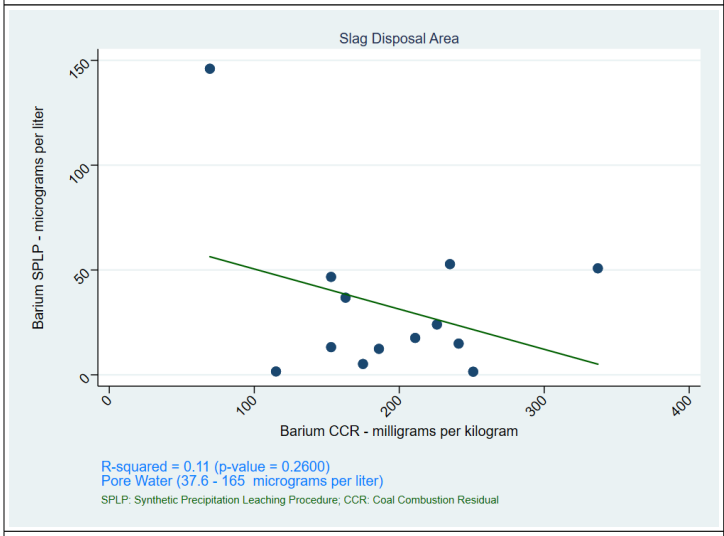
Scatter Plots (SPLP and CCR Material)
CCR Rule Appendix IV Parameters
CCR Material Characteristics Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

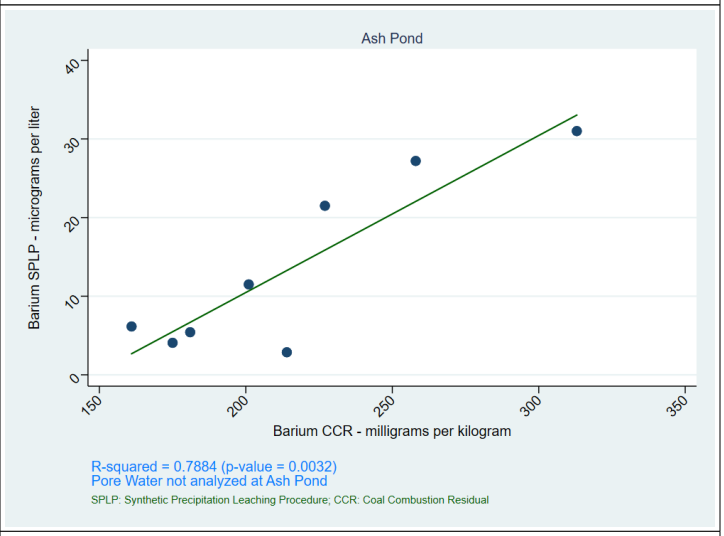




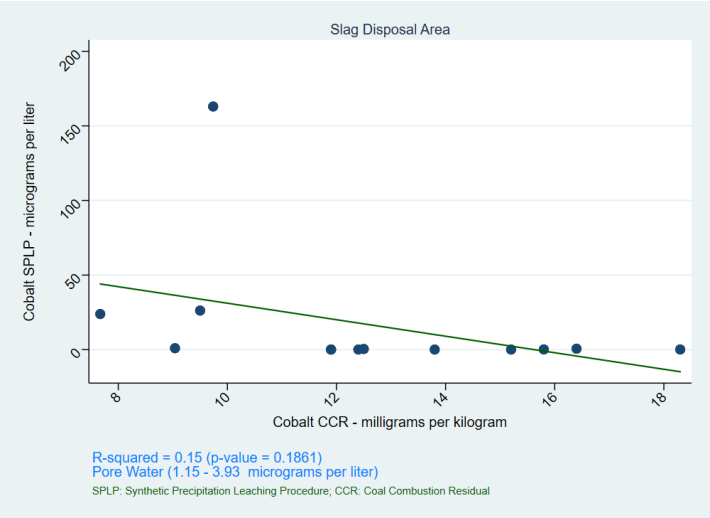
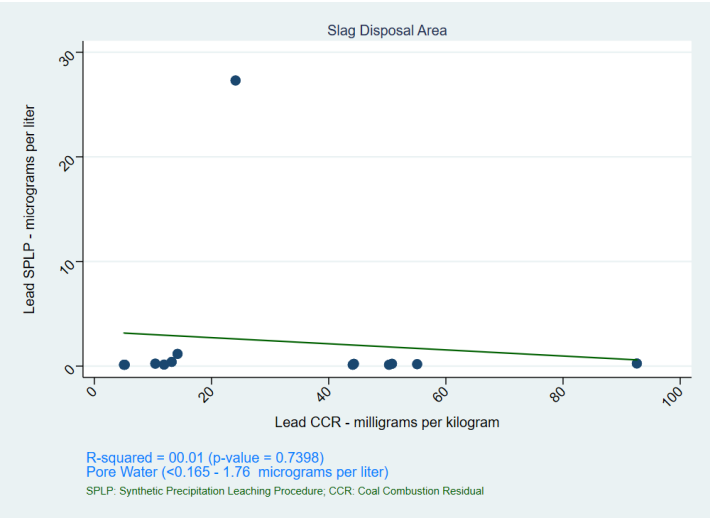
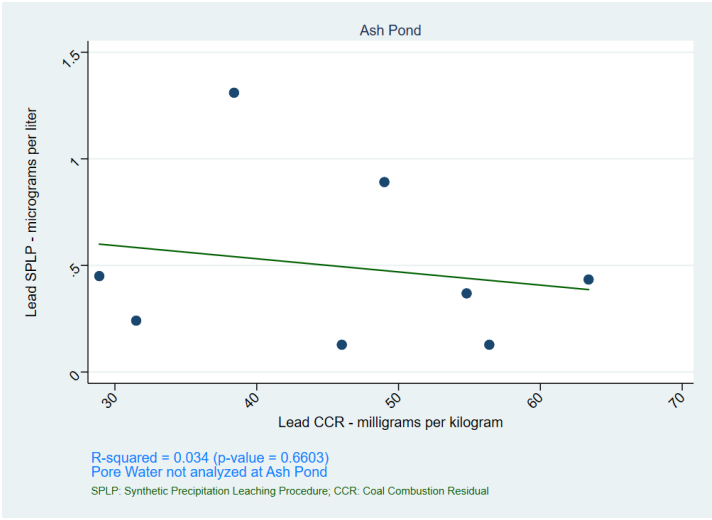
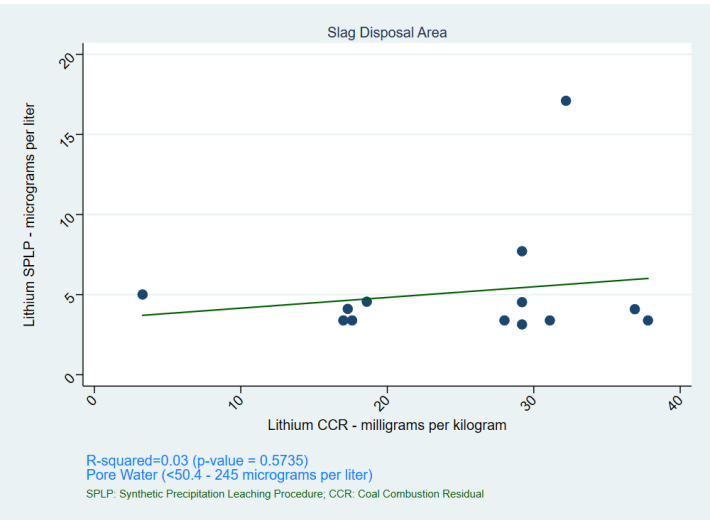


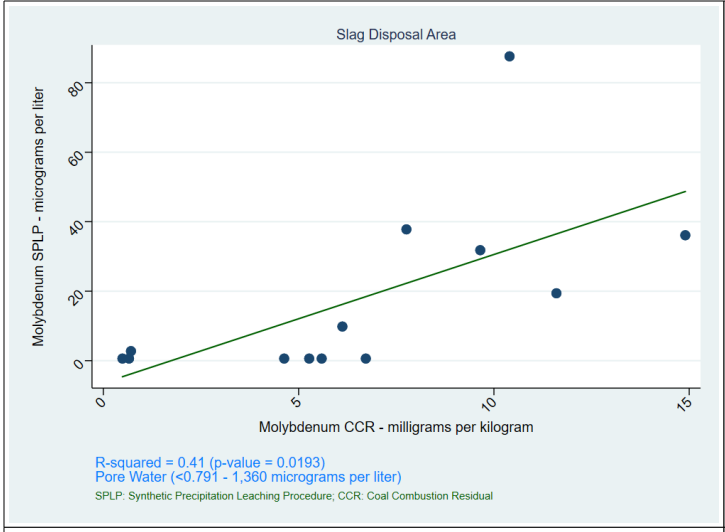




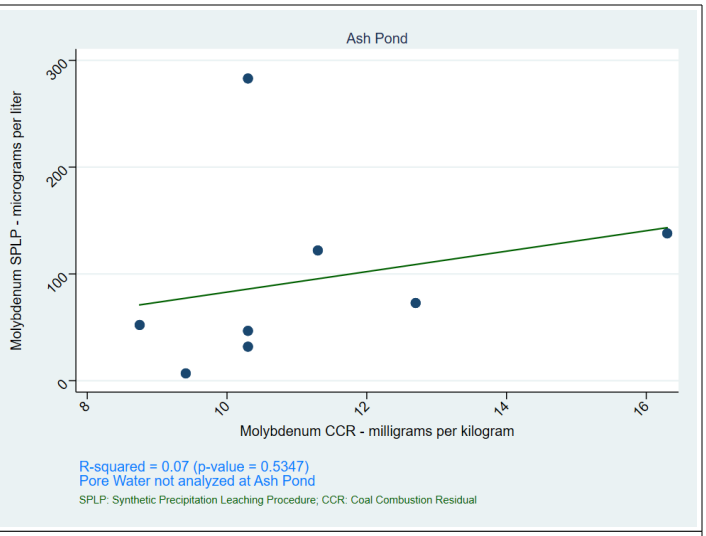


Beryllium/Slag Disposal Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Beryllium/Ash Pond, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
Cadmium/Slag Disposal Area, Insufficient Data, >	Cadmium/Ash Pond, Insufficient Data, > 50%

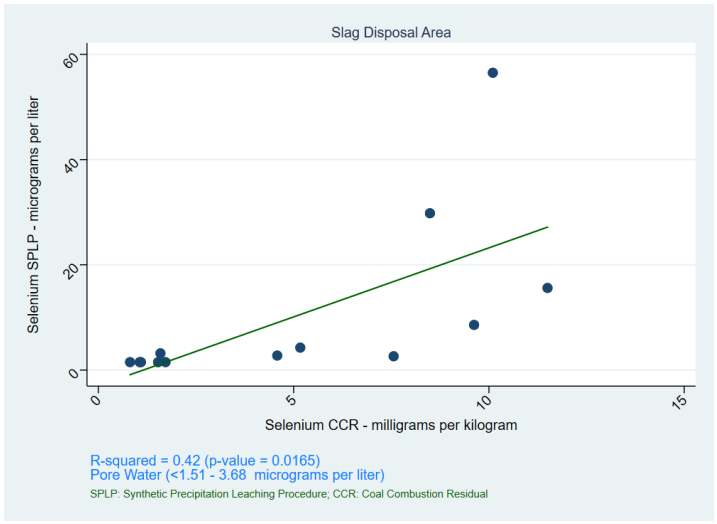
50% non-Detects in SPLP or CCR Material Data Sets	non-Detects in SPLP or CCR Material Data Sets
Chromium/Slag Disposal Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Chromium/Ash Pond, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
	Cobalt/Ash Pond, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
	
	Lithium/Ash Pond, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
Mercury/Slag Disposal Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Mercury/Ash Pond, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets



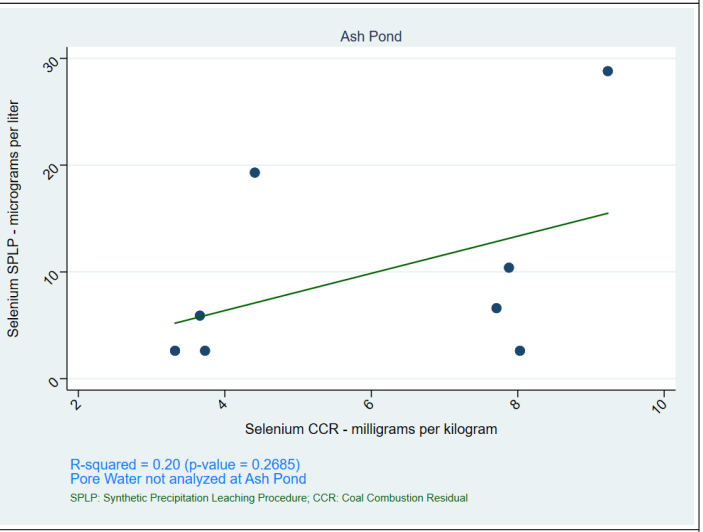
R-squared = 0.41 (p-value = 0.0193)
Pore Water (<0.791 - 1,360 micrograms per liter)
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual



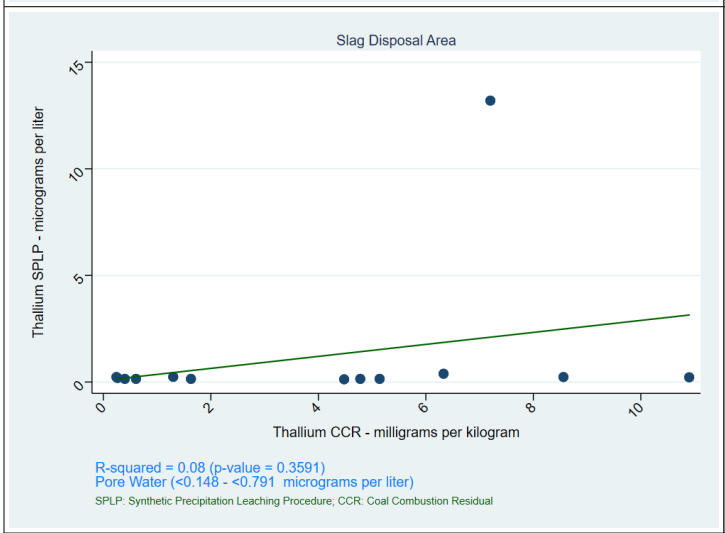
R-squared = 0.07 (p-value = 0.5347)
Pore Water not analyzed at Ash Pond
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual



R-squared = 0.42 (p-value = 0.0165)
Pore Water (<1.51 - 3.68 micrograms per liter)
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual



R-squared = 0.20 (p-value = 0.2685)
Pore Water not analyzed at Ash Pond
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual



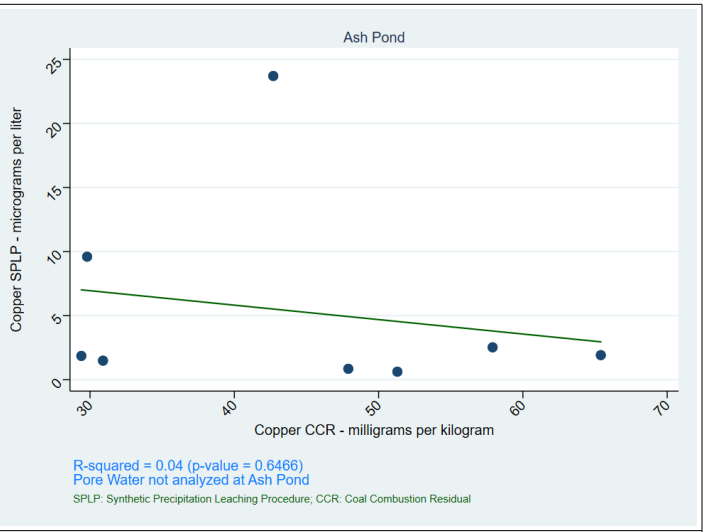
R-squared = 0.08 (p-value = 0.3591)
Pore Water (<0.148 - <0.791 micrograms per liter)
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual

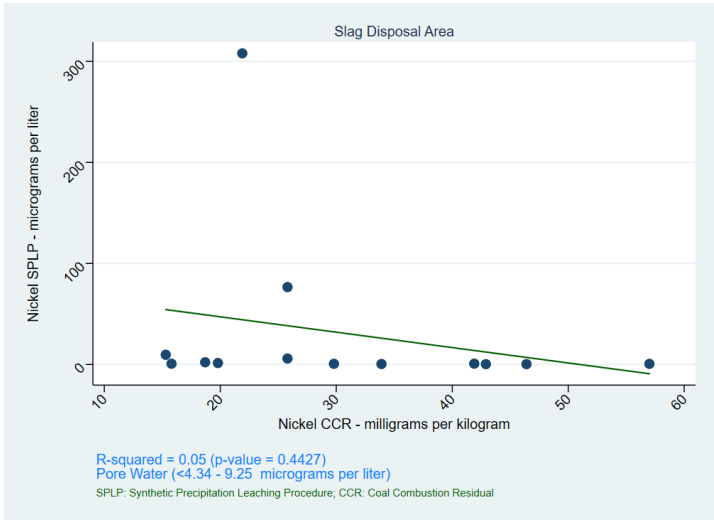
Thallium/Ash Pond, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets

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Scatter Plots (SPLP and CCR Material)
TDEC Appendix I Parameters
CCR Material Characteristics Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

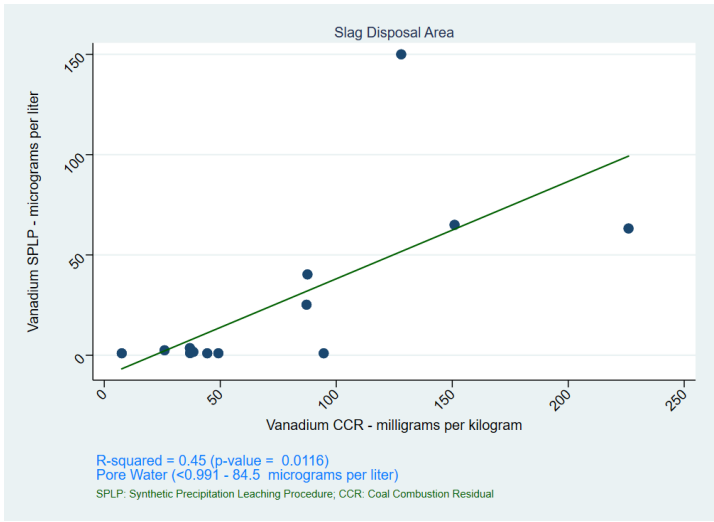
Copper/Slag Disposal Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets



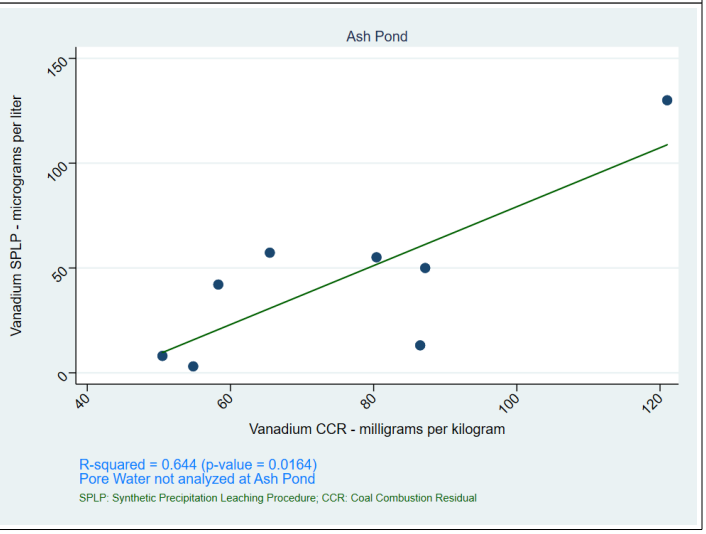


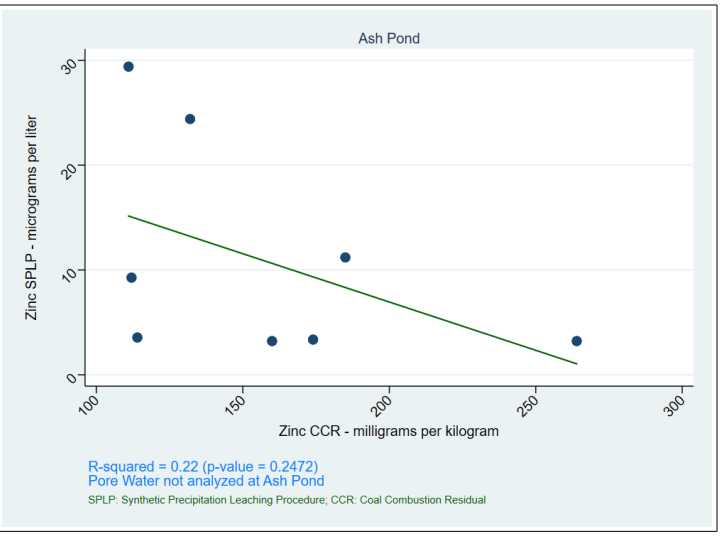
Nickel/Ash Pond, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets

Silver/Slag Disposal Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets



Silver/Ash Pond, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets



Zinc/Slag Disposal Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	

APPENDIX E.3

STATISTICAL ANALYSIS OF GROUNDWATER ANALYTICAL RESULTS

DRAFT

Appendix E.3 - Statistical Analysis of Groundwater Analytical Results

TDEC Commissioner's Order:
Environmental Assessment Report
Watts Bar Fossil Plant
Spring City, Tennessee

March 31, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

REVISION LOG

Revision	Description	Date
0	Submittal to TDEC	November 7, 2023
1	Addresses January 31, 2024 TDEC Review Comments and Issued for TDEC	March 31, 2024

Sign-off Sheet

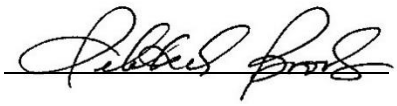
This document entitled Appendix E.3 - Statistical Analysis of Groundwater Analytical Results was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by 

Melissa Whitfield Aslund, PhD, Environmental Scientist

Reviewed by 

Chris LaLonde, Risk Assessor

Approved by 

Rebekah Brooks, PG, Senior Principal Hydrogeologist

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ATTACHMENT E.3-C TIME SERIES PLOTS

ATTACHMENT E.3-D LINEAR REGRESSION PLOTS

ATTACHMENT E.3-E LINEAR REGRESSION RESULTS

Abbreviations

CASRN	Chemical Abstracts Service Registry Number
CCR	Coal Combustion Residuals
CCR Parameters	Constituents listed in Appendices III and IV of Title 40, Code of Federal Regulations, Part 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations, Part 257
EAR	Environmental Assessment Report
EI	Environmental Investigation
GSL	Groundwater Screening Level
µg/L	Micrograms Per Liter
NA	Not Available
%	Percent
RCRA	Resource Conservation and Recovery Act
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TDS	Total Dissolved Solids
TVA	Tennessee Valley Authority
Unified Guidance	Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance
USEPA	United States Environmental Protection Agency
WBF Plant	Watts Bar Fossil Plant

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this appendix on behalf of the Tennessee Valley Authority (TVA) to summarize the statistical analyses performed on groundwater quality data to support evaluations conducted for the Environmental Assessment Report (EAR) at the Watts Bar Fossil Plant (WBF Plant) located in Spring City, Tennessee. These statistical analyses include an evaluation of groundwater quality data collected at the WBF Plant for the Tennessee Department of Environment and Conservation (TDEC) Order Environmental Investigation (EI) and in compliance with the TDEC groundwater monitoring program for the Ash Pond coal combustion residuals (CCR) management unit. The statistical analysis in this appendix focused on the parameters listed in Appendices III and IV of Title 40, Code of Federal Regulations, Part 257 (CCR Rule) and five additional inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04 (CCR Parameters) (see Table E.3-1). The wells included in this statistical analysis are listed in Table E.3-2.

The dataset compiled for statistical analysis includes available analytical data for groundwater samples collected from the wells listed in Table E.3-2 between October 2014 and October 2022, although the specific start date and frequency of sampling may vary between wells based on date of well installation and the applicable monitoring program. This time period was selected because it includes the data that met the data quality objectives of the EI.

The complete groundwater quality results for the dataset compiled for statistical analysis are reported in Appendix H.1.

APPENDIX E.3 - STATISTICAL ANALYSIS OF GROUNDWATER ANALYTICAL RESULTS

March 31, 2024

Table E.3-1 – CCR Parameters Evaluated in Statistical Analysis

Parameter	CASRN
CCR Rule Appendix III Parameters	
Boron	7440-42-8
Calcium	7440-70-2
Chloride	16887-00-6
Fluoride[1] (also Appendix IV)	16984-48-8
pH	NA
Sulfate	14808-79-8
TDS	NA
CCR Rule Appendix IV Parameters	
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Lead	7439-92-1
Lithium	7439-93-2
Mercury	7439-97-6
Molybdenum	7439-98-7
Radium-226+228	13982-63-3/ 15262-20-1
Selenium	7782-49-2
Thallium	7440-28-0
Additional TDEC Appendix I Parameters	
Copper	7440-50-8
Nickel	7440-02-0
Silver	7440-22-4
Vanadium	7440-62-2
Zinc	7440-66-6

Notes: CASRN - Chemical Abstracts Service Registry Number; CCR – Coal Combustion Residuals; NA - Not available; TDS - Total dissolved solids

[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV constituent. In this table and in the results figures and tables for this report, fluoride has been grouped with the Appendix III constituents only to avoid duplication.

APPENDIX E.3 - STATISTICAL ANALYSIS OF GROUNDWATER ANALYTICAL RESULTS

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Table E.3-2 - Groundwater Monitoring Wells and Parameters Included in Statistical Analysis

Well Location	Well	Program		Parameters Included in Statistical Analysis		
		EI Wells	TDEC Non-Registered Site Wells[1]	CCR Rule Appendix III	CCR Rule Appendix IV	TDEC Appendix I
Background	WBF-103	X	-	X	X	X
Upgradient	MW-1	-	X	X	X	X
	WBF-100	-	X	X	X	X
	WBF-102	X	-	X	X	X
Ash Pond	MW-2	-	X	X	X	X
	MW-3	-	X	X	X	X
	WBF-101	X	-	X	X	X
Slag Disposal Area	WBF-104	X	-	X	X	X
	WBF-105	X	-	X	X	X
	WBF-106	X	-	X	X	X

Notes:
For each well, the program to which the well belongs as well as the parameters evaluated in this statistical analysis are identified with an 'X' and highlighted gray. Programs or parameters that are not applicable to that well are indicated with a dash (-).
[1]TDEC Non-Registered Site Wells support the TDEC groundwater monitoring program for the Ash Pond coal combustion residuals (CCR) management unit.

2.0 METHODS

2.1 EXPLORATORY DATA ANALYSIS

The initial step of statistical analysis was the exploratory data analysis. The process of the exploratory data analysis utilizes simple summary statistics (e.g., mean, median, standard deviation, and percentiles) and graphical representations to identify important characteristics of an analytical dataset, such as the center of the data (i.e., mean, median), variation, distribution, patterns, presence of outliers, and randomness.

Summary statistics were calculated for each well-constituent pair. These summary statistics include information such as total number of available samples, frequency of detection, and maximum detected values and detected concentrations for each well-constituent pair. Exploratory data plots for each well-constituent pair (i.e., box plots and time series plots) were also constructed to support a visual review of the data and identify potential outliers.

Outliers are data points that are abnormally high or low as compared to other measurements and may represent anomalous data or data errors. Outliers may also represent natural variation of concentrations in environmental systems. Therefore, where potential outliers were visually identified in box plots or time-series plots, secondary statistical screening was completed using Tukey's procedure to identify extreme outliers (Tukey 1977) followed by statistical testing for outliers (Dixon or Rosner's test, α=0.05). Following confirmation of the outliers as statistically significant, a desktop evaluation was conducted to verify that the data points were not errors (e.g., laboratory or transcriptional error). Field forms, data validation reports, and other variables in the dataset that could influence analytical results were also evaluated. If a verifiable error was discovered, the outlier was removed and, if possible, replaced with a corrected value.

In the absence of a verifiable error, additional lines of evidence were reviewed to determine final outlier disposition (e.g., frequency of detection, spatial and temporal variability). If an outlier was identified as suitable for removal from further statistical analysis, a clear and defensible rationale based on multiple lines of evidence was provided. In addition, values that were identified as outliers and removed from further evaluation in the present statistical analysis were retained in the historical database and will be reevaluated for inclusion or exclusion in future statistical analyses of this dataset.

2.2 COMPARISON OF GROUNDWATER QUALITY DATA TO GROUNDWATER SCREENING LEVELS

The United States Environmental Protection Agency (USEPA) document "*Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance*" (USEPA 2009; hereafter referred to as the Unified Guidance) describes statistical methods for comparing groundwater concentrations to fixed standards such as the TDEC-approved groundwater screening levels (GSLs) identified in Appendix A.2. In the Unified Guidance, a confidence interval approach is recommended for comparing groundwater monitoring data to a fixed numerical limit. If the underlying population is stable (i.e., no trend is present), then the Unified Guidance indicates that comparison to a fixed standard can be made based on a

confidence interval around the mean. However, the Unified Guidance indicates that "*where the data exhibit a trend over time the interval will incorporate not only the natural variability in the underlying population, but also additional variation induced by the trend itself. The net result is a confidence interval that can be much wider than expected for a given confidence level and sample size (n).*" Therefore, in the presence of a statistically significant trend, the Unified Guidance recommends constructing a confidence band around a trend line, where the comparison is made to the fixed standard based on the confidence band as of the most recent evaluated sampling event, rather than a static confidence interval around the mean.

For the groundwater data reviewed herein, these approaches were applied to identify well-constituent pairs where the available data indicate a statistically significant concentration above or equal to the GSL for constituents other than pH, or statistically significant values outside the GSL range for pH. For this dataset, the null hypothesis was that the groundwater concentrations were less than the GSL for constituents other than pH and that levels were within the GSL range for pH. In accordance with the methods described in the Unified Guidance, constituent concentrations were determined to represent a statistically significant concentration above or equal to a GSL for constituents other than pH, only when there were sufficient data to support statistical confidence band or interval evaluation and the applicable lower confidence band or interval was greater than or equal to the GSL as of the most recent sampling event included in the statistical analysis. For pH, which has both an upper and lower GSL, a statistical difference was identified if there were sufficient data to support statistical analysis, and either the applicable lower confidence band or interval was greater than or equal to the upper GSL or the applicable upper confidence band or interval was less than or equal to the lower GSL as of the most recent sampling event included in the statistical analysis. Whether comparison should be made using a confidence band or confidence interval was determined for each well-constituent pair based on the results of a linear regression trend analysis for each well-constituent pair. If no significant linear trend was detected ($p \geq 0.05$ for the regression slope), comparison to the GSLs was completed based on a static confidence interval around the mean. If a statistically significant linear trend was present ($p < 0.05$ for the regression slope), comparison to the GSLs was completed based on a confidence band around the linear regression trend line at the most recent evaluated sampling event. In both cases, the confidence band or intervals were constructed with 98 percent (%) confidence, which correspond to a lower confidence limit with 99% confidence.

Additional details regarding the methods used to compare groundwater quality data to groundwater screening levels are provided below. As described below, the approach adopted for this comparison was dependent on the number of samples available and the proportion of detected concentrations for each well-constituent pair.

2.2.1 Linear Regression Trend Analysis and Confidence Interval/ Confidence Band Evaluation

For well-constituent pairs with five or more samples and at least four detected values, groundwater quality data were compared to GSLs using a linear regression trend analysis and confidence interval/ confidence band evaluation summarized in **Figure E.3-1** (below) and described in more detail in this section.

APPENDIX E.3 - STATISTICAL ANALYSIS OF GROUNDWATER ANALYTICAL RESULTS

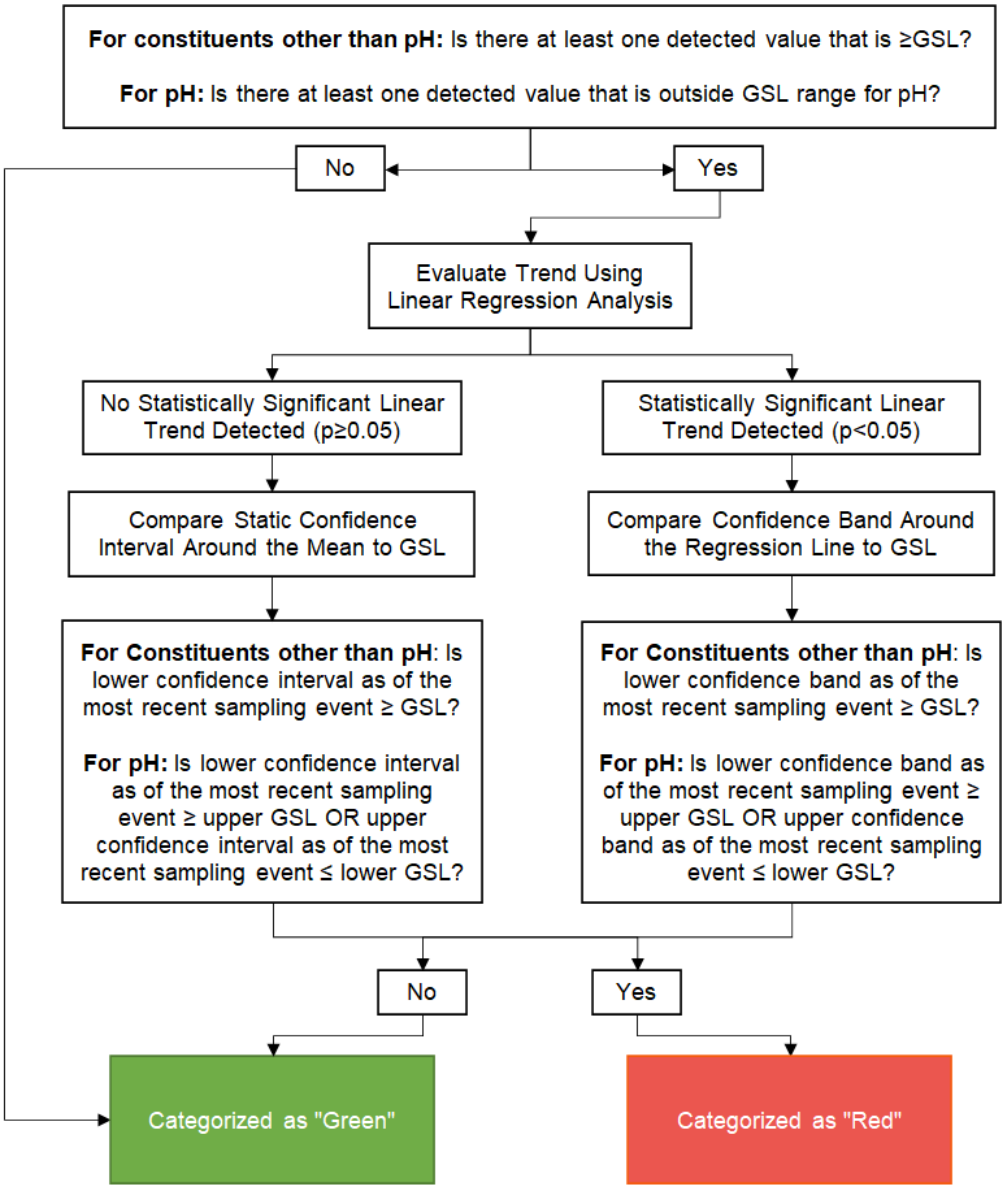
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First, data were screened to identify if there were reported individual values greater than or equal to the GSL for constituents other than pH or outside the GSL range for pH. In the absence of such a value, well-constituent pairs were classified as 'Green'. If such a value was observed, then linear regression analysis was completed to identify well-constituent pairs with a statistically significant linear trend ($p<0.05$) over the analyzed time period. As noted above, if no statistically significant linear trend was detected ($p\geq0.05$), a static confidence interval around the mean was used for comparison to the GSLs. If a statistically significant linear trend was present ($p<0.05$), a confidence band around the linear regression trend line at the most recent evaluated sampling event was used for comparison to the GSLs. In both cases, 98% confidence intervals were constructed, which correspond to a lower confidence limit with 99% confidence. Non-detect values were conservatively represented at the reported detection limit.

The resulting confidence intervals and confidence bands were then compared to the GSL for the analyzed well-constituent pairs as of the most recent sampling event included in the statistical analysis. For constituents other than pH, well-constituent pairs were classified as 'Red', indicating a statistically significant concentration above or equal to the GSL at a 99% confidence level only if the applicable lower confidence band or interval was greater than or equal to the GSL as of the most recent sampling event included in the statistical analysis (see examples in **Figure E.3-2** below). For pH, well-constituent pairs were classified as 'Red', indicating a statistically significant difference from the GSL range at a 99% confidence level, if the applicable lower confidence band or interval was greater than or equal to the upper GSL or if the applicable upper confidence interval was less than or equal to the lower GSL as of the most recent sampling event included in the statistical analysis (see examples in **Figure E.3-3** below). The remaining well-constituent pairs with five or more samples and at least four detected values that were not classified as 'Red' using the linear regression trend analysis and confidence interval/ confidence band evaluation described above were classified as 'Green'. The 'Green' category indicates that as of the most recent sampling event included in the analysis, constituent levels were not statistically significantly greater than or equal to the GSL (for constituents other than pH) and not statistically greater than or equal to the upper GSL or less than or equal to the lower GSL for pH at a 99% confidence level.

APPENDIX E.3 - STATISTICAL ANALYSIS OF GROUNDWATER ANALYTICAL RESULTS

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Note: GSL = TDEC-approved Groundwater Screening Level (see Appendix A.2)

Figure E.3-1 – Flow chart summarizing linear regression trend analysis and confidence interval/ confidence band evaluation

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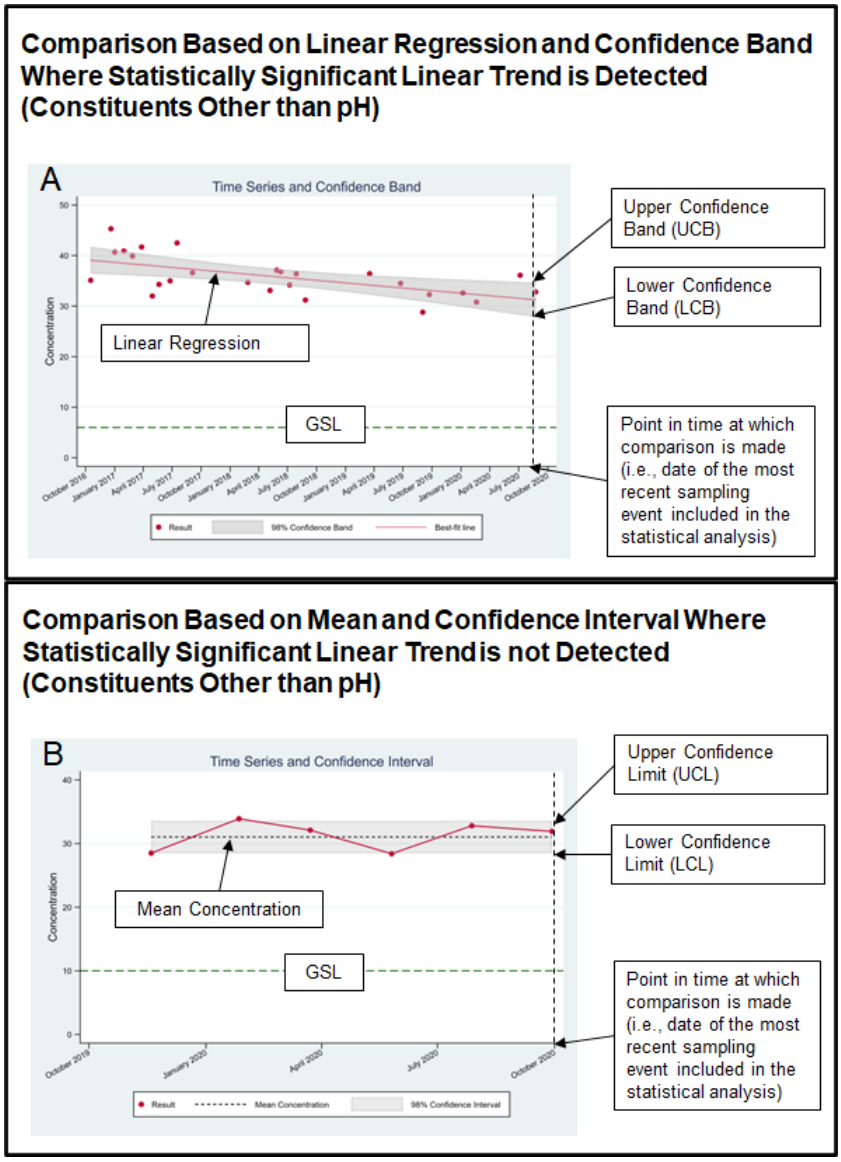


Figure E.3-2 – Examples of well-constituent pairs classified as 'Red' for constituents other than pH (A) in the presence of a statistically significant linear trend ($p<0.05$) and (B) in the absence of a statistically significant linear trend ($p\geq0.05$)

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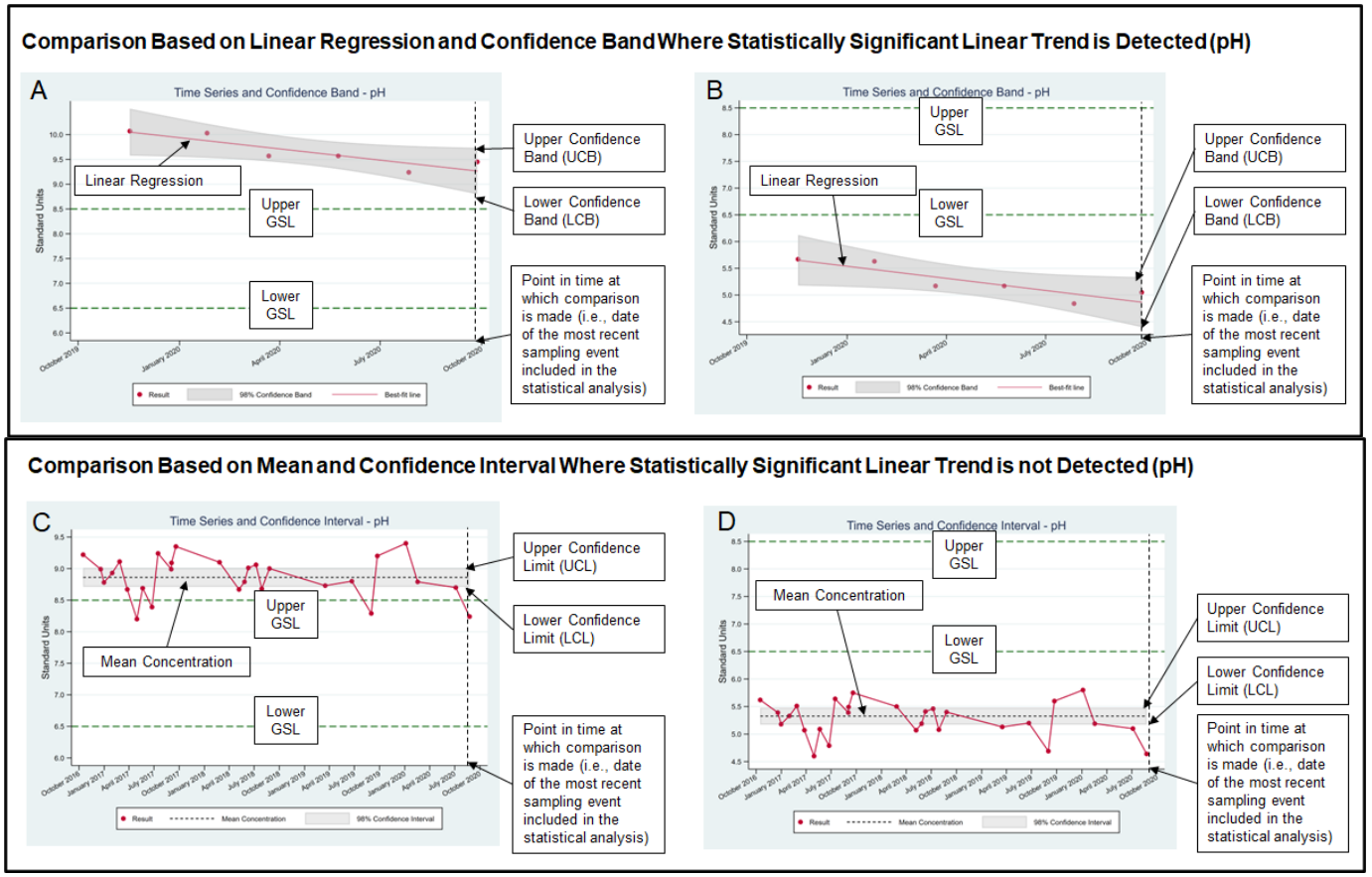


Figure E.3-3 - Examples of well-constituent pairs classified as 'Red' for pH (A, B) in the presence of a statistically significant linear trend (p<0.05) and (C, D) in the absence of a statistically significant linear trend (p≥0.05)

2.2.2 Evaluation for Well-Constituent Pairs Using Point-by-Point Method

Well-constituent pairs with less than five samples in the dataset or less than four detected results were not well suited to a linear regression trend analysis and confidence band or interval evaluation. Therefore, an alternate evaluation was completed for these well-constituent pairs based on a point-by-point comparison of the reported concentration for each sample to the applicable GSL. In this approach, well-constituent pairs were classified as 'Green*,' if there were no detected values that were greater than or equal to the GSL for constituents other than pH, or there were no detected values outside the GSL range for pH. However, if there was a limited dataset (i.e., less than five samples in the dataset or less than four detected results), and at least one value was greater than or equal to the GSL for constituents other than pH or there were detected values outside the GSL range for pH, this triggered further data review and an alternate evaluation of that well-constituent pair. For these well-constituent pairs, the available data were reviewed and alternate statistical approaches were considered (e.g., completing a statistical evaluation resulting in a 'Red' or 'Green' classification as described in Section 2.2.1 using the limited dataset). If such an alternate evaluation was required, then this was clearly identified and additional rationale provided in the applicable sub-sections of Section 3.0.

3.0 RESULTS AND DISCUSSION

3.1 EXPLORATORY DATA ANALYSIS

Summary statistics for each evaluated well-constituent pair are provided in Attachment E.3-A**,** with results grouped by well and sorted by constituent type. Exploratory data analysis plots for each well-constituent pair (i.e., box plots and time-series plots) are provided in Attachments E.3-B and E.3-C. These plots were reviewed to identify potential outliers and provide a qualitative evaluation of data distribution. The plots also provide a preliminary comparison of the results from individual sampling events to the applicable GSLs. There were no outliers removed from further statistical analysis based on this evaluation.

3.2 COMPARISON OF GROUNDWATER QUALITY DATA TO APPROVED GROUNDWATER SCREENING LEVELS

A summary of the results comparing groundwater quality data to GSLs is provided in Table E.3-3. The confidence bands or confidence intervals generated to support this comparison are provided in Attachment E.3-D, and the statistical results of the regression analyses are reported in Attachment E.3-E. Further discussion is provided below.

For most well-constituent pairs that were evaluated by linear regression, no statistically significant trend over time was observed based on the linear regression analyses. Comparison to the GSLs for these well-constituent pairs was completed based on a static confidence interval around the mean as shown in Attachment E.3-D. However, there were two well-constituent pairs where a statistically significant decreasing trend was detected and three well-constituent pairs where a statistically significant increasing trend was detected, as indicated in Attachment E.3-E. Comparison to the GSLs for these well-constituent pairs was completed based on a confidence band around the trend line as shown in in Attachment E.3-D.

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Table E.3-3 – Summary of Statistically Significant Concentrations/Values

Parameter	Background	Upgradient			Ash Pond			Slag Disposal Area		
	WBF-103	MW-1	WBF-100	WBF-102	MW-2	MW-3	WBF-101	WBF-104	WBF-105	WBF-106
CCR Rule Appendix III Parameters										
Boron	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Chloride	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Fluoride[1] (also Appendix IV)	Green	Green	Green	Green	Green	Green	Green	Green*	Green	Green
pH (field)	Red	Red	Red	Green	Red	Red	Green	Red	Green	Red
Sulfate	Green	Green	Green	Green	Green	Green	Green	Red	Red	Red
Total Dissolved Solids	Green	Green	Red	Green	Green	Green	Green	Red	Red	Red
CCR Rule Appendix IV Parameters										
Antimony	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Arsenic	Green*	Green	Green	Green	Green*	Green	Green	Green	Green	Green
Barium	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Beryllium	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green	Green*	Green*
Cadmium	Green*	Green*	Green*	Green*	Green*	Green*	Green	Red	Green*	Green
Chromium	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Cobalt	Green	Red	Green*	Green[2]	Green*	Green	Green	Red	Green*	Red
Lead	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Lithium	Green*	Green	Green	Green*	Green	Green	Green*	Green	Green*	Green
Mercury	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Molybdenum	Green*	Green*	Green*	Green	Green*	Green*	Green*	Green*	Green*	Green*
Radium-226+228	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Selenium	Green*	Green*	Green*	Green	Green*	Green*	Green*	Green*	Green*	Green*
Thallium	Green*	Green*	Green*	Green	Green*	Green*	Green*	Green*	Green*	Green*
Additional TDEC Appendix I Parameters										
Copper	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Nickel	Green	Green	Green	Green*	Green	Green	Green	Green	Green*	Green
Silver	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Vanadium	Green*	Green	Green*	Green*	Green	Green	Green*	Green*	Green*	Green*
Zinc	Green*	Green	Green*	Green*	Green*	Green*	Green	Green	Green*	Green

Notes:

Green - No statistically significant concentration greater than or equal to the GSL for constituents other than pH and no statistically significant difference outside the GSL range for pH.
Green* - Limited dataset (sample size <5 or <4 detected values), but none of the available results are greater than or equal to the GSL or outside the GSL range for pH.
Red - Statistically significant concentration greater than or equal to the GSL for constituents other than pH or a statistically significant difference outside the GSL range for pH.
Bold colors are used to represent CCR Rule Appendix IV Parameter and TDEC Appendix I Parameter results; subdued colors represent CCR Rule Appendix III Parameter results.
[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV constituent. In this table, fluoride has been grouped only with the Appendix III constituents to avoid duplication of results.
[2]For Cobalt at WBF-102, a detected concentration of 11.1 µg/L, which was greater than the GSL (6 µg/L), was observed for a single sampling event in August, 2019. Since that sampling event, cobalt at WBF-102 has been analyzed for an additional eight sampling events that took place between October 2019 and April 2022. The cobalt concentration at WBF-102 has been less than the GSL for cobalt for all eight subsequent sampling events and has been non-detect with a reported detection limit of ≤0.261 for the last seven sampling events. Because there were only two detected values (both from 2019), this well-constituent pair was not initially categorized for analysis by linear regression and confidence band/confidence interval. However, due to the single exceedance of the GSL, a confidence interval was generated for this well-constituent pair based on a replacement of the non-detect values with the full detection limit. The results of this confidence interval analysis are shown in Appendix E.3-D.

In total, 11 well-constituent pairs were identified with CCR Parameters at statistically significant concentrations greater than or equal to the GSL for constituents other than pH. There were also seven wells where a statistically significant difference from the GSL range for pH was observed. The well-constituent pairs with statistically significant concentrations greater than or equal to the GSL or outside the GSL range for pH (i.e., categorized as 'Red' in Table E.3-3) are summarized in Table E.3-4.

Table E.3-4 – Summary of Statistically Significant Concentrations Greater than the GSL

Well Location	Well	Appendix III			Appendix IV	
		pH (field)	Sulfate	Total Dissolved Solids	Cadmium	Cobalt
Background	WBF-103	X	-	-	-	-
Upgradient	MW-1	X	-	-	-	X
	WBF-100	X	-	X	-	-
Ash Pond	MW-2	X	-	-	-	-
	MW-3	X	-	-	-	-
Slag Disposal Area	WBF-104	X	X	X	X	X
	WBF-105	-	X	X	-	-
	WBF-106	X	X	X	-	X

Notes
Well-constituent pairs with CCR Parameters at statistically significant concentrations greater than or equal to the GSL for constituents other than pH or outside the GSL range for pH are identified with an 'X' and highlighted gray.
Dash (-) indicates the absence of a statistically significant concentration greater than or equal to the GSL or outside the GSL range for pH for that well-constituent pair.

4.0 REFERENCES

Tukey, J.W. (1977). *Exploratory Data Analysis*. Reading, Massachusetts: Addison-Wesley. 1977.

United States Environmental Protection Agency. (2009). *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance*. EPA 530/R-09-007, 884 pp.

ATTACHMENT E.3-A
SUMMARY STATISTICS

Summary Statistics - Groundwater Investigation Watts Bar Fossil Plant - Spring City, Tennessee									
Parameter	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
				Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Well: WBF-103									
CCR Rule Appendix III Parameters									
Boron	5/10	(38.6 - 82.7)	50.0%	41.8	79.5	52.09	13.47	59.45	81.58
Calcium	10/10	--	0.0%	12,800	44,200	24,820	11,232	21,100	42,400
Chloride	10/10	--	0.0%	4,410	6,680	5,223	697.6	5,280	6,208
Fluoride[1] (also Appendix IV)	4/10	(26 - 66.9)	60.0%	27.6	56.2	32.59	9.172	40.25	62.09
pH	9/9	--	0.0%	5.15	5.83	5.509	0.233	5.48	5.814
Sulfate	10/10	--	0.0%	32,900	102,000	65,210	22,298	64,500	95,070
TDS	10/10	--	0.0%	97,000	230,000	168,300	43,955	172,500	226,850
CCR Rule Appendix IV Parameters									
Antimony	0/10	(0.378 - 0.506)	100.0%	--	--	--	--	0.378	0.506
Arsenic	2/10	(0.282 - 0.781)	80.0%	0.324	0.373	0.297	0.03	0.313	0.597
Barium	10/10	--	0.0%	65.8	155	87.47	28.08	76.25	139.3
Beryllium	0/10	(0.182 - 0.274)	100.0%	--	--	--	--	0.182	0.274
Cadmium	0/10	(0.125 - 0.217)	100.0%	--	--	--	--	0.217	0.217
Chromium	1/10	(1.53 - 2.04)	90.0%	1.55	1.55	1.532	0.00629	1.53	1.82
Cobalt	9/10	(0.903 - 0.903)	10.0%	0.317	4.44	1.257	1.192	0.904	3.495
Lead	1/10	(0.128 - 0.167)	90.0%	6.21	6.21	0.736	1.825	0.128	3.491
Lithium	0/10	(0.831 - 4.97)	100.0%	--	--	--	--	3.39	4.259
Mercury	0/10	(0.101 - 0.13)	100.0%	--	--	--	--	0.13	0.13
Molybdenum	0/10	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
Radium-226+228	0/10	(0 - 0.845)	100.0%	--	--	--	--	0.568	0.835
Selenium	1/10	(0.739 - 1.51)	90.0%	0.93	0.93	0.835	0.0955	1.51	1.51
Thallium	1/10	(0.148 - 0.649)	90.0%	0.172	0.172	0.151	0.0084	0.148	0.569
TDEC Appendix I Parameters									
Copper	1/10	(0.627 - 1.22)	90.0%	2.92	2.92	0.856	0.688	0.627	2.155
Nickel	7/10	(1.38 - 3.4)	30.0%	1.14	3.16	1.707	0.679	1.56	3.292
Silver	0/10	(0.177 - 0.223)	100.0%	--	--	--	--	0.177	0.223
Vanadium	1/10	(0.776 - 1.22)	90.0%	0.999	0.999	0.801	0.0701	0.991	1.121
Zinc	3/10	(2.88 - 8.94)	70.0%	4.66	9.38	4.244	2.145	3.94	9.182
Well: MW-1									
CCR Rule Appendix III Parameters									
Boron	17/17	--	0.0%	679	1320	863.5	141.4	834	1055
Calcium	17/17	--	0.0%	56,500	79,400	69,465	6,537	69,800	79,160
Chloride	17/17	--	0.0%	6,600	8,520	7,360	558.4	7,350	8,184
Fluoride[1] (also Appendix IV)	7/21	(25 - 100)	66.7%	23	42.2	32.51	7.032	100	100
pH	11/11	--	0.0%	5.54	6.34	5.869	0.204	5.87	6.17
Sulfate	17/17	--	0.0%	76,900	102,000	85,412	6,956	84,700	96,640
TDS	17/17	--	0.0%	234,000	432,000	292,941	42,130	287,000	340,800
CCR Rule Appendix IV Parameters									
Antimony	0/21	(0.071 - 2)	100.0%	--	--	--	--	2	2
Arsenic	6/21	(0.313 - 2)	71.4%	0.1	0.487	0.229	0.108	1	2
Barium	21/21	--	0.0%	37.7	53	43.31	4.031	43.1	48.8
Beryllium	2/21	(0.066 - 2)	90.5%	0.054	0.076	0.0613	0.0104	1	2
Cadmium	3/21	(0.084 - 1)	85.7%	0.061	0.071	0.0657	0.00411	1	1
Chromium	2/21	(0.26 - 5)	90.5%	0.29	2.12	0.367	0.402	2	2.12
Cobalt	21/21	--	0.0%	6.27	15.5	10.2	2.199	9.8	14.1
Lead	1/21	(0.037 - 2)	95.2%	0.045	0.045	0.0397	0.00377	1	2
Lithium	17/17	--	0.0%	6.85	12.7	10.16	1.851	10.1	12.54
Mercury	0/21	(0.07 - 0.2)	100.0%	--	--	--	--	0.2	0.2
Molybdenum	0/17	(0.075 - 5)	100.0%	--	--	--	--	0.61	5
Radium-226+228	3/17	(0.0202 - 0.883)	82.4%	0.394	1.876	0.218	0.455	0.426	1.082
Selenium	0/21	(0.067 - 10)	100.0%	--	--	--	--	2	5
Thallium	0/21	(0.041 - 2)	100.0%	--	--	--	--	1	2
TDEC Appendix I Parameters									
Copper	1/21	(0.33 - 10)	95.2%	69.1	69.1	3.605	14.65	2	10
Nickel	20/21	(10 - 10)	4.8%	5.4	11.6	7.255	1.534	6.9	10.5
Silver	0/21	(0.077 - 5)	100.0%	--	--	--	--	1	2
Vanadium	5/21	(0.16 - 4)	76.2%	2.1	5.71	0.935	1.498	1.44	4
Zinc	8/21	(3.22 - 50)	61.9%	0.0758	10.8	4.205	3.179	8.3	25

Summary Statistics - Groundwater Investigation Watts Bar Fossil Plant - Spring City, Tennessee									
Parameter	**Frequency of Detection**	**Range of Reporting Limits**	**% Non Detect**	**Statistics using Detected Data Only**		**Statistics using Detects & Non-Detects**			
				Minimum Detect	**Maximum Detect**	**Mean**	**Standard Deviation**	**50th Percentile**	**95th Percentile**
Well: WBF-100									
CCR Rule Appendix III Parameters									
Boron	14/14	--	0.0%	1,560	2,650	1,799	278.5	1,680	2,247
Calcium	14/14	--	0.0%	141,000	178,000	155,571	10,839	151,500	174,100
Chloride	14/14	--	0.0%	6,390	9,900	7,873	1,245	7,550	9,900
Fluoride[1] (also Appendix IV)	8/13	(100 - 100)	38.5%	25	54.3	35.93	9.205	45.9	100
pH	9/9	--	0.0%	6.01	6.39	6.304	0.12	6.36	6.39
Sulfate	14/14	--	0.0%	169,000	266,000	217,786	28,146	219,000	263,400
TDS	14/14	--	0.0%	488,000	725,000	578,786	58,442	568,500	665,200
CCR Rule Appendix IV Parameters									
Antimony	1/13	(0.071 - 2)	92.3%	0.088	0.088	0.0744	0.0068	0.378	2
Arsenic	5/13	(0.083 - 1)	61.5%	0.13	0.475	0.204	0.136	0.389	1
Barium	13/13	--	0.0%	40.2	108	62.67	19.95	63.4	101.2
Beryllium	0/13	(0.032 - 1)	100.0%	--	--	--	--	0.182	1
Cadmium	1/13	(0.016 - 1)	92.3%	0.029	0.029	0.0225	0.0065	0.217	1
Chromium	0/13	(0.47 - 2.09)	100.0%	--	--	--	--	1.53	2.036
Cobalt	2/13	(0.081 - 0.5)	84.6%	0.109	0.12	0.0922	0.0161	0.134	0.5
Lead	3/13	(0.043 - 1)	76.9%	0.061	0.541	0.149	0.173	0.541	1
Lithium	8/14	(5 - 5)	42.9%	1.6	3.65	2.425	0.912	3.63	5
Mercury	0/13	(0.07 - 0.2)	100.0%	--	--	--	--	0.101	0.2
Molybdenum	0/14	(0.081 - 5)	100.0%	--	--	--	--	0.61	5
Radium-226+228	1/14	(0.116 - 0.814)	92.9%	0.519	0.519	0.156	0.121	0.349	0.783
Selenium	2/13	(0.14 - 5)	84.6%	0.089	0.13	0.11	0.0205	1.51	5
Thallium	0/13	(0.026 - 1)	100.0%	--	--	--	--	0.386	1
TDEC Appendix I Parameters									
Copper	3/13	(0.43 - 2)	76.9%	0.468	0.677	0.498	0.0971	0.65	2
Nickel	8/13	(1 - 1.1)	38.5%	0.53	1.03	0.711	0.155	0.926	1.058
Silver	0/13	(0.077 - 1)	100.0%	--	--	--	--	0.177	1
Vanadium	2/13	(0.16 - 1.5)	84.6%	0.32	1.22	0.285	0.302	0.991	1.458
Zinc	3/13	(2 - 8.3)	76.9%	4.4	24.1	4.355	5.835	5	14.62
Well: WBF-102									
CCR Rule Appendix III Parameters									
Boron	7/9	(71.2 - 105)	22.2%	42	90.8	66.13	16.02	71.2	99.32
Calcium	9/9	--	0.0%	89,300	309,000	158,833	73,750	131,000	273,400
Chloride	9/9	--	0.0%	4,150	37,800	15,188	11,404	12,200	33,000
Fluoride[1] (also Appendix IV)	5/9	(41.5 - 126)	44.4%	43.9	98.9	59.69	19.34	62.9	115.2
pH	8/8	--	0.0%	6.52	6.98	6.771	0.175	6.79	6.966
Sulfate	9/9	--	0.0%	90,200	664,000	281,800	213,084	179,000	616,400
TDS	9/9	--	0.0%	386,000	1,280,000	704,222	347,094	562,000	1,224,000
CCR Rule Appendix IV Parameters									
Antimony	0/9	(0.378 - 0.506)	100.0%	--	--	--	--	0.378	0.455
Arsenic	5/9	(0.313 - 0.866)	44.4%	0.369	0.495	0.398	0.0713	0.464	0.718
Barium	9/9	--	0.0%	23.7	61.5	43.57	13.92	42.9	61.14
Beryllium	0/9	(0.182 - 0.486)	100.0%	--	--	--	--	0.182	0.401
Cadmium	2/9	(0.217 - 0.217)	77.8%	0.127	0.178	0.153	0.0255	0.217	0.217
Chromium	3/9	(1.53 - 2.74)	66.7%	1.91	2.39	1.738	0.299	1.53	2.6
Cobalt	2/9	(0.134 - 0.261)	77.8%	1.15	11.1	1.465	3.421	0.134	7.12
Lead	1/9	(0.128 - 0.128)	88.9%	0.199	0.199	0.136	0.0223	0.128	0.171
Lithium	1/9	(0.831 - 5.63)	88.9%	4.23	4.23	1.256	1.124	3.39	5.07
Mercury	3/9	(0.101 - 0.13)	66.7%	0.543	1.23	0.327	0.369	0.13	0.964
Molybdenum	5/9	(0.61 - 1.62)	44.4%	0.648	4.32	1.296	1.274	0.656	3.736
Radium-226+228	0/9	(0.15 - 1.394)	100.0%	--	--	--	--	0.6	1.216
Selenium	5/9	(1.51 - 1.51)	44.4%	1.89	5.48	2.281	1.194	1.89	4.28
Thallium	4/9	(0.148 - 0.148)	55.6%	0.23	0.589	0.229	0.135	0.148	0.459
TDEC Appendix I Parameters									
Copper	2/9	(0.627 - 2.06)	77.8%	0.67	1.02	0.701	0.143	0.804	1.92
Nickel	2/9	(0.336 - 1.31)	77.8%	0.397	2.21	0.558	0.585	0.517	1.85
Silver	0/9	(0.177 - 0.223)	100.0%	--	--	--	--	0.177	0.205
Vanadium	2/9	(0.776 - 0.991)	77.8%	1.57	1.68	0.965	0.354	0.991	1.636
Zinc	2/9	(3.22 - 7.24)	77.8%	3.07	4.14	3.223	0.374	3.22	6.844

Summary Statistics - Groundwater Investigation Watts Bar Fossil Plant - Spring City, Tennessee									
Parameter	**Frequency of Detection**	**Range of Reporting Limits**	**% Non Detect**	**Statistics using Detected Data Only**		**Statistics using Detects & Non-Detects**			
				Minimum Detect	**Maximum Detect**	**Mean**	**Standard Deviation**	**50th Percentile**	**95th Percentile**
Well: MW-2									
CCR Rule Appendix III Parameters									
Boron	17/17	--	0.0%	86.6	1740	355.5	525.8	125	1636
Calcium	17/17	--	0.0%	25,800	70,400	38,382	13,061	34,600	69,840
Chloride	17/17	--	0.0%	1,300	9,370	3,057	2,437	1,900	7,674
Fluoride[1] (also Appendix IV)	7/21	(60 - 100)	66.7%	53	84	62.76	8.789	100	100
pH	11/11	--	0.0%	5.89	6.33	6.205	0.147	6.28	6.33
Sulfate	17/17	--	0.0%	19,900	73,000	35,588	13,088	33,800	57,960
TDS	17/17	--	0.0%	86,000	299,000	163,294	58,909	148,000	297,400
CCR Rule Appendix IV Parameters									
Antimony	0/21	(0.071 - 2)	100.0%	--	--	--	--	2	2
Arsenic	1/21	(0.083 - 2)	95.2%	0.332	0.332	0.114	0.0823	1	2
Barium	21/21	--	0.0%	31.3	83.1	49.37	16.09	43.6	78.2
Beryllium	0/21	(0.032 - 2)	100.0%	--	--	--	--	1	2
Cadmium	2/21	(0.018 - 1)	90.5%	0.04	0.065	0.0318	0.0187	1	1
Chromium	1/21	(0.2 - 5)	95.2%	2.97	2.97	0.339	0.604	2	2.97
Cobalt	2/21	(0.081 - 2)	90.5%	0.079	0.65	0.127	0.158	0.5	2
Lead	0/21	(0.028 - 2)	100.0%	--	--	--	--	1	2
Lithium	5/17	(2.56 - 50)	70.6%	0.42	0.59	0.534	0.0618	3.39	14
Mercury	0/21	(0.07 - 0.2)	100.0%	--	--	--	--	0.2	0.2
Molybdenum	0/17	(0.081 - 5)	100.0%	--	--	--	--	0.61	5
Radium-226+228	3/17	(0.015 - 0.713)	82.4%	0.33	0.605	0.12	0.195	0.33	0.678
Selenium	0/21	(0.067 - 10)	100.0%	--	--	--	--	2	5
Thallium	0/21	(0.026 - 2)	100.0%	--	--	--	--	1	2
TDEC Appendix I Parameters									
Copper	2/21	(0.33 - 10)	90.5%	0.59	0.816	0.429	0.172	2	2
Nickel	4/21	(0.18 - 10)	81.0%	0.21	2.15	0.329	0.421	1	2.15
Silver	1/21	(0.077 - 5)	95.2%	0.087	0.087	0.082	0.005	1	2
Vanadium	10/21	(0.27 - 4)	52.4%	0.16	5.66	1.3	1.734	1.42	5.61
Zinc	1/21	(1.9 - 50)	95.2%	2.3	2.3	1.98	0.16	8.3	25
Well: MW-3									
CCR Rule Appendix III Parameters									
Boron	16/16	--	0.0%	147	2,030	749.6	494.4	600	1,490
Calcium	16/16	--	0.0%	29,800	79,200	55,088	12,052	54,100	72,300
Chloride	16/16	--	0.0%	1,890	7,040	3,716	1,560	3,175	6,253
Fluoride[1] (also Appendix IV)	8/21	(100 - 100)	61.9%	51	80.9	57.59	9.078	100	100
pH	10/10	--	0.0%	5.96	6.29	6.129	0.0985	6.125	6.259
Sulfate	16/16	--	0.0%	21,800	118,000	47,319	27,571	37,150	102,175
TDS	16/16	--	0.0%	129,000	343,000	210,500	57,467	203,000	316,750
CCR Rule Appendix IV Parameters									
Antimony	0/21	(0.071 - 2)	100.0%	--	--	--	--	2	2
Arsenic	5/21	(0.14 - 2)	76.2%	0.099	0.38	0.149	0.0884	1	2
Barium	21/21	--	0.0%	34.7	132	91.05	25.2	94.3	120
Beryllium	0/21	(0.032 - 2)	100.0%	--	--	--	--	1	2
Cadmium	1/21	(0.016 - 1)	95.2%	0.12	0.12	0.0368	0.0416	1	1
Chromium	2/21	(0.64 - 5)	90.5%	1.4	2.74	0.889	0.518	2	2.74
Cobalt	4/21	(0.081 - 2)	81.0%	0.264	0.87	0.249	0.256	0.687	2
Lead	1/21	(0.028 - 2)	95.2%	0.138	0.138	0.0437	0.0385	1	2
Lithium	5/16	(2.56 - 50)	68.8%	0.55	0.8	0.64	0.108	3.39	16.25
Mercury	0/21	(0.07 - 0.2)	100.0%	--	--	--	--	0.2	0.2
Molybdenum	2/16	(0.08 - 5)	87.5%	0.089	0.13	0.0936	0.0186	0.61	5
Radium-226+228	3/16	(0.0834 - 0.794)	81.3%	0.16	0.68	0.171	0.183	0.403	0.787
Selenium	3/21	(0.14 - 10)	85.7%	0.075	0.2	0.115	0.05	2	5
Thallium	0/21	(0.026 - 2)	100.0%	--	--	--	--	1	2
TDEC Appendix I Parameters									
Copper	2/21	(0.42 - 10)	90.5%	0.405	1.7	0.567	0.428	2	2
Nickel	6/21	(0.17 - 10)	71.4%	0.44	1.3	0.559	0.367	1.02	2
Silver	0/21	(0.077 - 5)	100.0%	--	--	--	--	1	2
Vanadium	13/21	(0.991 - 4)	38.1%	0.35	5.7	1.52	1.589	1.57	4.29
Zinc	2/21	(1.9 - 50)	90.5%	2.4	3.8	2.279	0.653	5	25

Summary Statistics - Groundwater Investigation Watts Bar Fossil Plant - Spring City, Tennessee									
Parameter	**Frequency of Detection**	**Range of Reporting Limits**	**% Non Detect**	**Statistics using Detected Data Only**		**Statistics using Detects & Non-Detects**			
				Minimum Detect	**Maximum Detect**	**Mean**	**Standard Deviation**	**50th Percentile**	**95th Percentile**
Well: WBF-101									
CCR Rule Appendix III Parameters									
Boron	7/10	(38.6 - 76.4)	30.0%	42.5	2,030	503.4	674	83.4	1,783
Calcium	10/10	--	0.0%	105,000	302,000	164,400	66,029	145,000	279,050
Chloride	10/10	--	0.0%	4,600	9,960	6,656	1,480	6,575	8,781
Fluoride[1] (also Appendix IV)	6/10	(60.2 - 110)	40.0%	39.6	128	62.12	23.29	62	119.9
pH	9/9	--	0.0%	5.76	6.79	6.416	0.355	6.48	6.742
Sulfate	10/10	--	0.0%	158,000	884,000	406,800	249,260	349,000	844,850
TDS	10/10	--	0.0%	425,000	1,340,000	740,900	332,465	640,500	1,317,500
CCR Rule Appendix IV Parameters									
Antimony	0/10	(0.378 - 1.07)	100.0%	--	--	--	--	0.378	0.816
Arsenic	8/10	(1.19 - 2.18)	20.0%	0.644	1.94	1.121	0.456	1.25	2.072
Barium	10/10	--	0.0%	29.9	466	204.2	157.5	169.5	443.5
Beryllium	2/10	(0.182 - 0.317)	80.0%	0.213	0.338	0.202	0.0466	0.198	0.329
Cadmium	4/10	(0.125 - 0.414)	60.0%	0.668	3.76	0.821	1.179	0.316	3.121
Chromium	0/10	(1.53 - 1.53)	100.0%	--	--	--	--	1.53	1.53
Cobalt	10/10	--	0.0%	0.462	297	72.7	111.4	4.045	275
Lead	1/10	(0.128 - 0.167)	90.0%	0.238	0.238	0.139	0.033	0.128	0.206
Lithium	3/10	(0.831 - 3.39)	70.0%	2.24	4.23	2.031	1.179	3.39	4.037
Mercury	1/10	(0.101 - 0.13)	90.0%	0.16	0.16	0.107	0.0177	0.13	0.147
Molybdenum	0/10	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
Radium-226+228	1/10	(0 - 1.159)	90.0%	0.948	0.948	0.105	0.298	0.705	1.064
Selenium	0/10	(0.739 - 1.51)	100.0%	--	--	--	--	1.51	1.51
Thallium	1/10	(0.148 - 0.692)	90.0%	0.19	0.19	0.155	0.0157	0.169	0.593
TDEC Appendix I Parameters									
Copper	0/10	(0.627 - 4.36)	100.0%	--	--	--	--	0.627	2.911
Nickel	4/10	(0.336 - 1.72)	60.0%	10.5	47.3	11.82	17.04	1.126	44.15
Silver	0/10	(0.177 - 0.223)	100.0%	--	--	--	--	0.177	0.223
Vanadium	0/10	(0.776 - 0.991)	100.0%	--	--	--	--	0.991	0.991
Zinc	6/10	(2.88 - 3.88)	40.0%	8.02	145	38.52	51.83	8.815	137.4
Well: WBF-104									
CCR Rule Appendix III Parameters									
Boron	10/10	--	0.0%	1,910	5,320	4,095	1,020	4,095	5,244
Calcium	10/10	--	0.0%	208,000	604,000	487,000	113,641	509,500	593,650
Chloride	10/10	--	0.0%	2,950	11,100	6,410	2,116	6,220	9,480
Fluoride[1] (also Appendix IV)	2/10	(32.8 - 149)	80.0%	36.8	77.7	39.57	13.61	65	116.9
pH	10/10	--	0.0%	5.32	5.78	5.464	0.137	5.48	5.672
Sulfate	10/10	--	0.0%	726,000	1,970,000	1,550,600	359,610	1,640,000	1,920,500
TDS	10/10	--	0.0%	1,050,000	2,810,000	2,093,000	573,257	2,225,000	2,769,500
CCR Rule Appendix IV Parameters									
Antimony	0/10	(0.378 - 0.506)	100.0%	--	--	--	--	0.378	0.506
Arsenic	5/10	(0.282 - 0.872)	50.0%	0.318	0.701	0.451	0.14	0.538	0.795
Barium	10/10	--	0.0%	19.7	43.4	27.13	8.436	22.85	41.11
Beryllium	5/10	(0.182 - 0.274)	50.0%	0.182	0.309	0.214	0.0395	0.227	0.293
Cadmium	10/10	--	0.0%	6.08	10.9	8.47	1.576	8.37	10.72
Chromium	0/10	(1.53 - 1.7)	100.0%	--	--	--	--	1.53	1.624
Cobalt	10/10	--	0.0%	167	598	404.8	149.7	408	597.1
Lead	2/10	(0.128 - 0.218)	80.0%	0.178	0.232	0.145	0.0335	0.167	0.226
Lithium	4/10	(3.39 - 7.07)	60.0%	3.54	4.06	3.584	0.248	3.565	6.58
Mercury	0/10	(0.101 - 0.13)	100.0%	--	--	--	--	0.13	0.13
Molybdenum	0/10	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
Radium-226+228	3/10	(0.0847 - 1.002)	70.0%	0.758	1.366	0.403	0.463	0.739	1.202
Selenium	0/10	(0.739 - 1.51)	100.0%	--	--	--	--	1.51	1.51
Thallium	1/10	(0.148 - 0.472)	90.0%	0.158	0.158	0.15	0.00373	0.153	0.472
TDEC Appendix I Parameters									
Copper	1/10	(0.627 - 2.1)	90.0%	1.06	1.06	0.689	0.152	0.753	1.668
Nickel	10/10	--	0.0%	32.2	105	70.71	23.25	67.2	102.3
Silver	0/10	(0.177 - 0.223)	100.0%	--	--	--	--	0.177	0.223
Vanadium	1/10	(0.776 - 1.18)	90.0%	1.02	1.02	0.803	0.0767	0.991	1.108
Zinc	10/10	--	0.0%	48	241	131.2	56.41	119	215.8

Summary Statistics - Groundwater Investigation Watts Bar Fossil Plant - Spring City, Tennessee									
Parameter	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
				Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Well: WBF-105									
CCR Rule Appendix III Parameters									
Boron	5/10	(38.6 - 114)	50.0%	47.8	64.5	48.2	8.119	51	91.73
Calcium	10/10	--	0.0%	127,000	140,000	133,300	4,322	133,000	139,550
Chloride	10/10	--	0.0%	4,240	7,860	5,710	898.6	5,570	7,032
Fluoride[1] (also Appendix IV)	5/10	(74.1 - 139)	50.0%	53	79.3	68.09	10.1	79.15	135.9
pH	10/10	--	0.0%	6.51	6.73	6.618	0.091	6.635	6.721
Sulfate	10/10	--	0.0%	326,000	354,000	341,600	9,192	342,500	352,200
TDS	10/10	--	0.0%	640,000	716,000	680,300	26,411	678,500	713,300
CCR Rule Appendix IV Parameters									
Antimony	1/10	(0.378 - 0.563)	90.0%	0.584	0.584	0.399	0.0618	0.378	0.575
Arsenic	7/10	(1.27 - 1.7)	30.0%	1.22	1.54	1.317	0.0972	1.32	1.628
Barium	10/10	--	0.0%	92	112	100.1	6.377	98.3	111.1
Beryllium	0/10	(0.182 - 0.347)	100.0%	--	--	--	--	0.182	0.314
Cadmium	0/10	(0.125 - 0.217)	100.0%	--	--	--	--	0.217	0.217
Chromium	0/10	(1.53 - 10.9)	100.0%	--	--	--	--	1.53	6.913
Cobalt	2/10	(0.134 - 0.262)	80.0%	0.113	0.151	0.119	0.0142	0.143	0.262
Lead	0/10	(0.128 - 0.167)	100.0%	--	--	--	--	0.128	0.167
Lithium	1/10	(0.831 - 6.41)	90.0%	1.16	1.16	0.996	0.165	3.39	5.983
Mercury	0/10	(0.101 - 0.13)	100.0%	--	--	--	--	0.13	0.13
Molybdenum	2/10	(0.61 - 0.61)	80.0%	0.615	1.4	0.69	0.237	0.61	1.047
Radium-226+228	3/10	(0.438 - 0.939)	70.0%	1.236	1.512	0.713	0.424	0.764	1.423
Selenium	0/10	(0.739 - 1.51)	100.0%	--	--	--	--	1.51	1.51
Thallium	1/10	(0.148 - 0.472)	90.0%	0.294	0.294	0.169	0.0511	0.148	0.472
TDEC Appendix I Parameters									
Copper	1/10	(0.627 - 1.14)	90.0%	0.93	0.93	0.67	0.106	0.682	1.14
Nickel	0/10	(0.336 - 0.865)	100.0%	--	--	--	--	0.336	0.708
Silver	0/10	(0.177 - 0.223)	100.0%	--	--	--	--	0.177	0.223
Vanadium	2/10	(0.776 - 0.991)	80.0%	1.01	1.4	0.862	0.192	0.991	1.225
Zinc	2/10	(2.88 - 4.51)	80.0%	3.05	4.39	3.123	0.455	3.22	4.456
Well: WBF-106									
CCR Rule Appendix III Parameters									
Boron	7/10	(57.7 - 252)	30.0%	66.4	260	168.2	78.81	206	256.4
Calcium	10/10	--	0.0%	132,000	163,000	152,300	11,870	159,000	162,550
Chloride	10/10	--	0.0%	3,300	7,790	4,936	1,438	4,690	7,484
Fluoride[1] (also Appendix IV)	6/10	(77.8 - 133)	40.0%	26.7	89.9	53.69	20.57	71	132.6
pH	10/10	--	0.0%	5.46	6.32	5.738	0.311	5.6	6.235
Sulfate	10/10	--	0.0%	427,000	550,000	485,500	41,674	482,500	539,650
TDS	10/10	--	0.0%	636,000	891,000	794,300	84,782	792,000	888,300
CCR Rule Appendix IV Parameters									
Antimony	0/10	(0.378 - 0.506)	100.0%	--	--	--	--	0.378	0.506
Arsenic	5/10	(0.282 - 1.66)	50.0%	0.382	1.7	0.57	0.4	0.732	1.682
Barium	10/10	--	0.0%	17.6	51.4	31.58	10.32	31.7	47.22
Beryllium	2/10	(0.182 - 0.642)	80.0%	0.186	0.198	0.185	0.00554	0.184	0.476
Cadmium	8/10	(0.125 - 0.217)	20.0%	0.218	0.98	0.519	0.307	0.495	0.97
Chromium	0/10	(1.53 - 1.76)	100.0%	--	--	--	--	1.53	1.657
Cobalt	10/10	--	0.0%	2.19	80.7	52.54	28.75	64.15	79.67
Lead	2/10	(0.128 - 0.223)	80.0%	0.137	0.251	0.142	0.0365	0.138	0.238
Lithium	4/10	(3.39 - 3.81)	60.0%	2.1	3.93	2.524	0.683	3.39	3.885
Mercury	0/10	(0.101 - 0.13)	100.0%	--	--	--	--	0.13	0.13
Molybdenum	0/10	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
Radium-226+228	2/10	(0.0967 - 1.334)	80.0%	0.659	1.785	0.338	0.517	0.626	1.582
Selenium	0/10	(0.739 - 1.51)	100.0%	--	--	--	--	1.51	1.51
Thallium	0/10	(0.148 - 0.57)	100.0%	--	--	--	--	0.151	0.526
TDEC Appendix I Parameters									
Copper	0/10	(0.627 - 3.89)	100.0%	--	--	--	--	0.627	2.909
Nickel	9/10	(1.79 - 1.79)	10.0%	0.359	16.5	10.12	5.751	12.75	16.19
Silver	0/10	(0.177 - 0.223)	100.0%	--	--	--	--	0.177	0.223
Vanadium	1/10	(0.776 - 0.991)	90.0%	1.01	1.01	0.799	0.0702	0.991	1.001
Zinc	9/10	(5.44 - 5.44)	10.0%	6.09	42.1	25.53	12.53	30.2	39.13

Notes

CCR Rule - Title 40, Code of Federal Regulations, Part 257

TDEC - Tennessee Department of Environment and Conservation

"--" - Not Applicable

Except for Radium-226 + 228, and pH, all units micrograms per liter (µg/L).

Units for Radium 226+228 are picocuries per liter (pCi/L).

Units for pH are standard units (SU).

Mean and Standard Deviation are Kaplan Meier (KM) Mean and Standard Deviation for data with reported non-detect values.

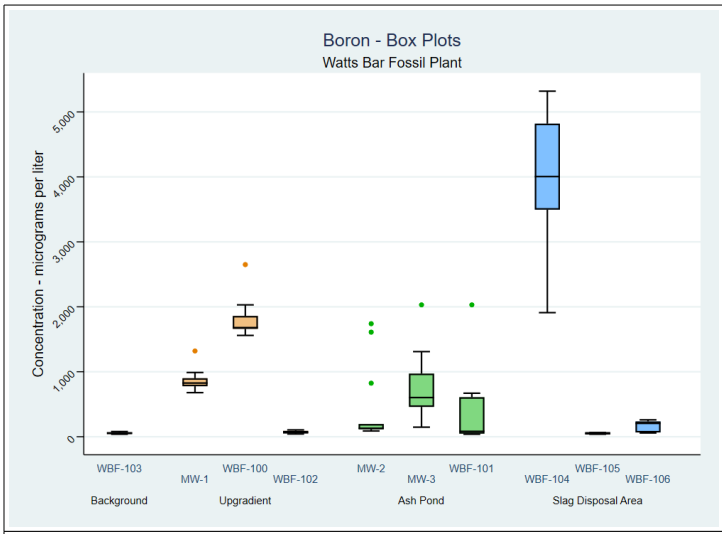
All non-detects reported at the laboratory reporting limit

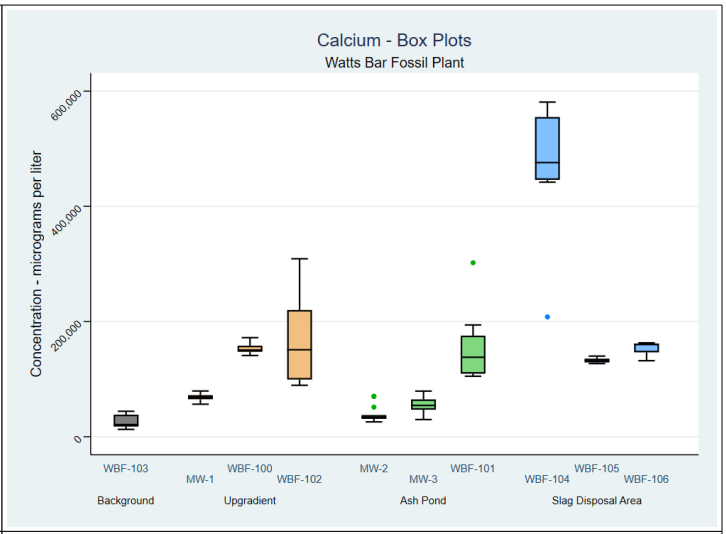
[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV constituent. In this table, fluoride has been grouped with the Appendix III constituents only to avoid duplication of results.

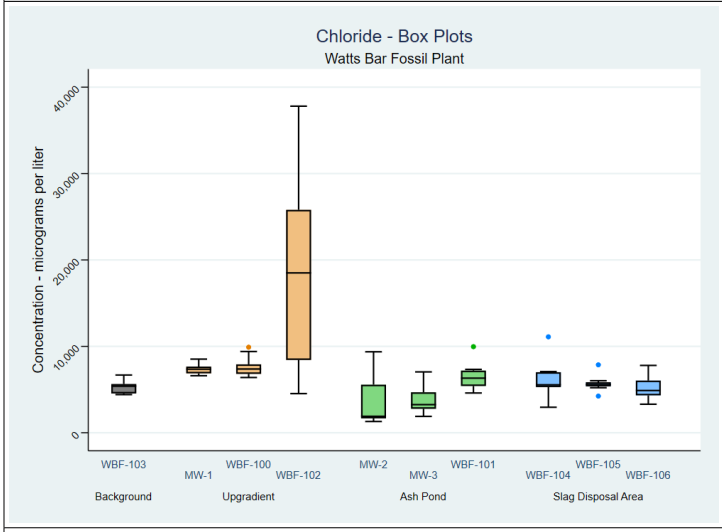
ATTACHMENT E.3-B
BOX PLOTS

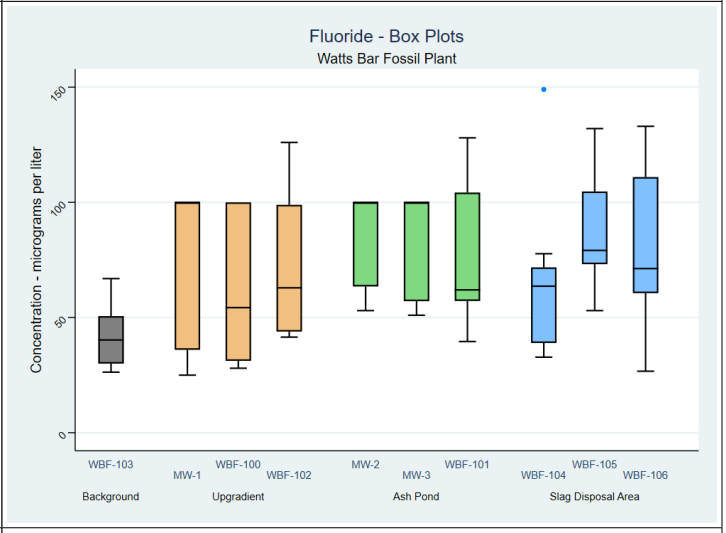
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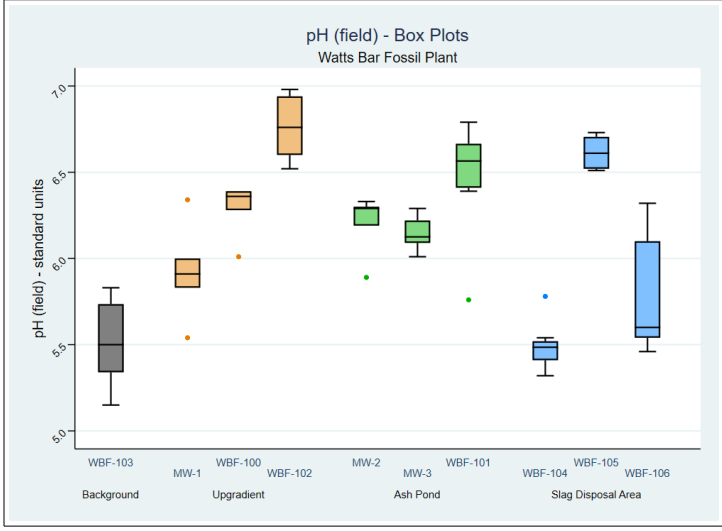
Box Plots
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

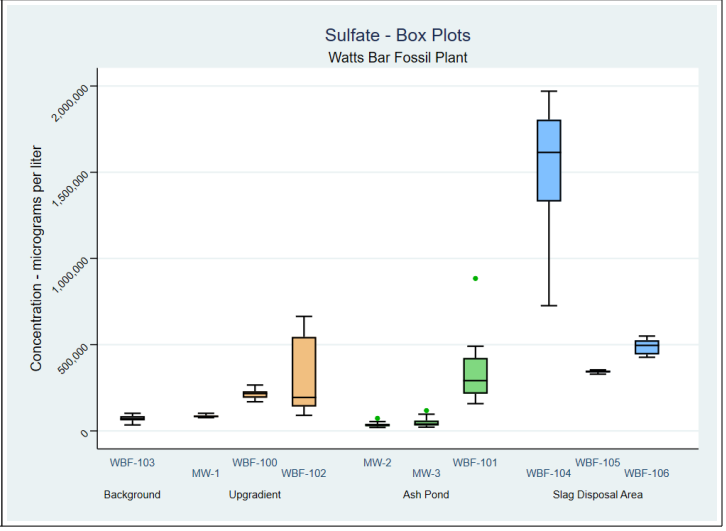


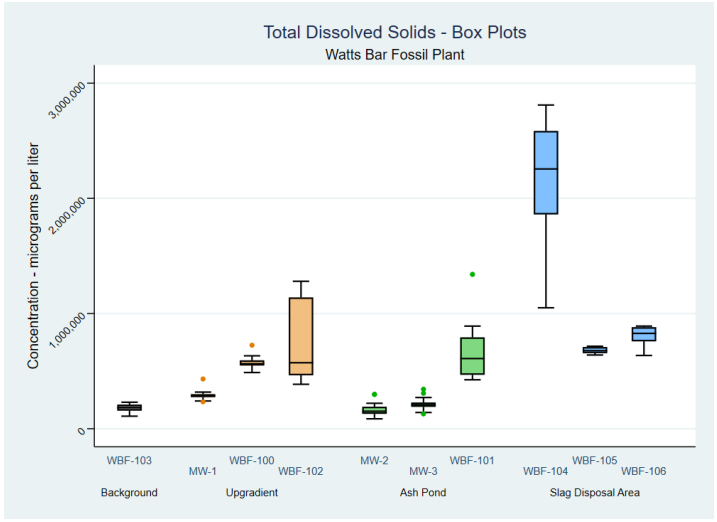








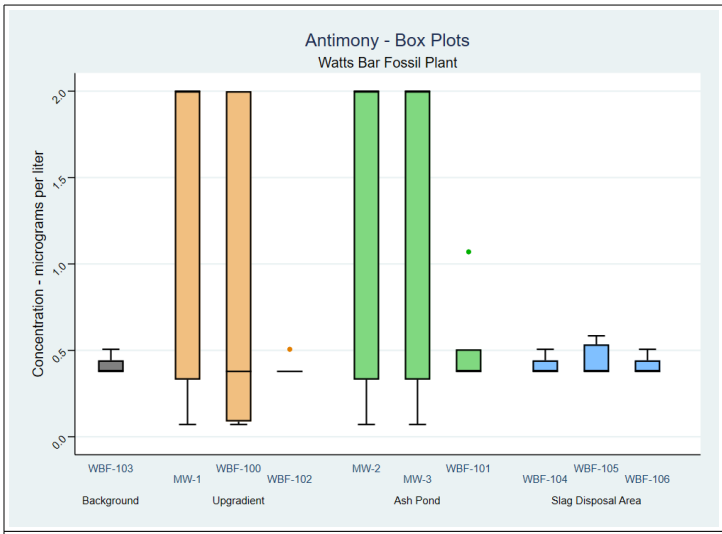


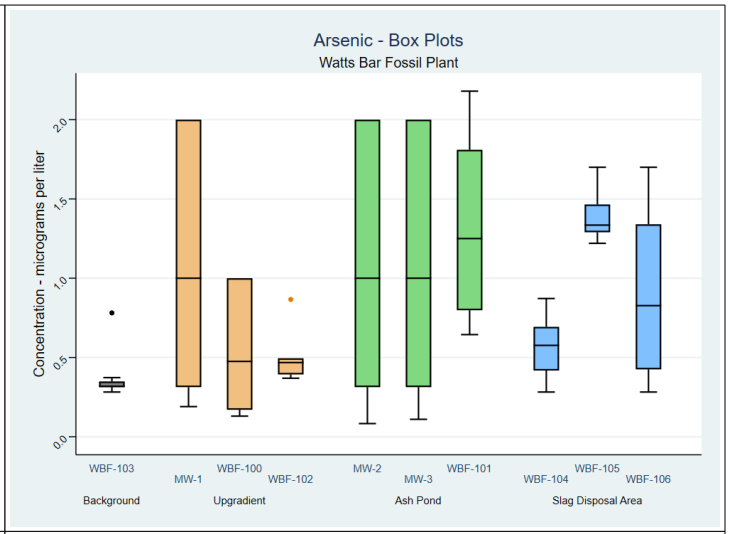


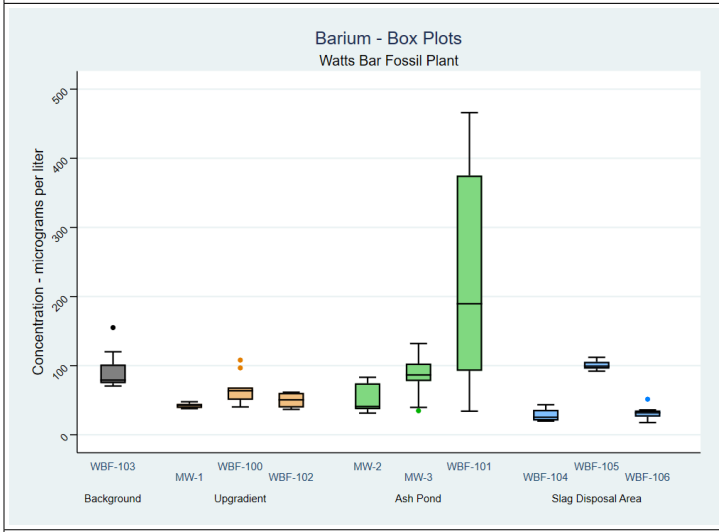
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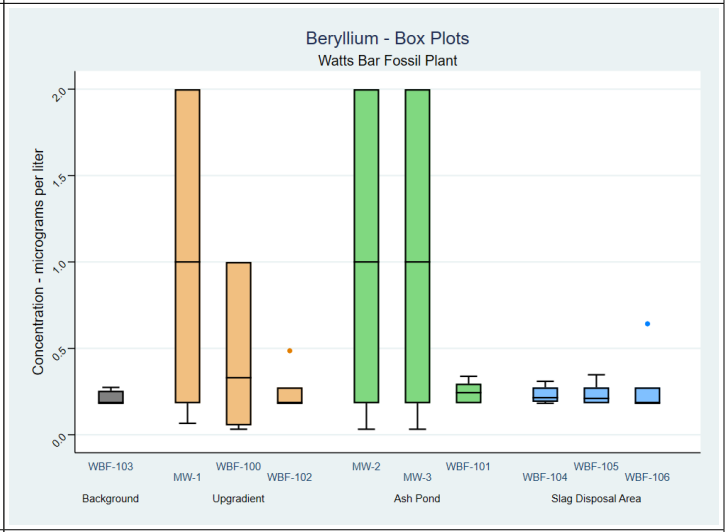
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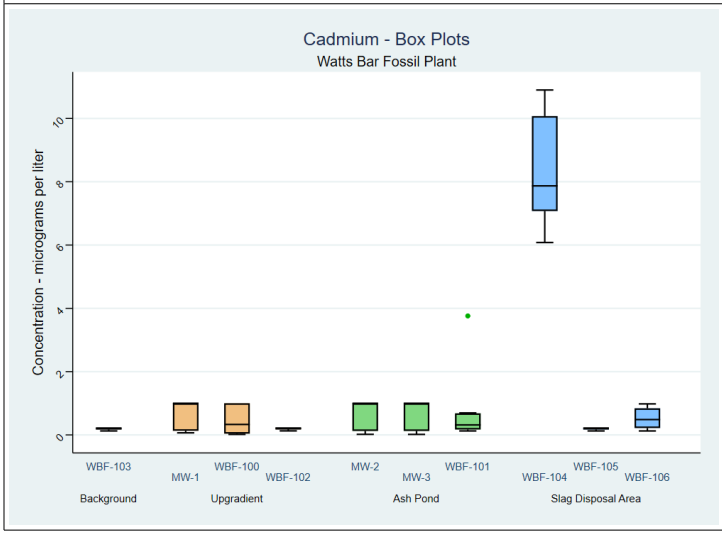
Box Plots
CCR Rule Appendix IV Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

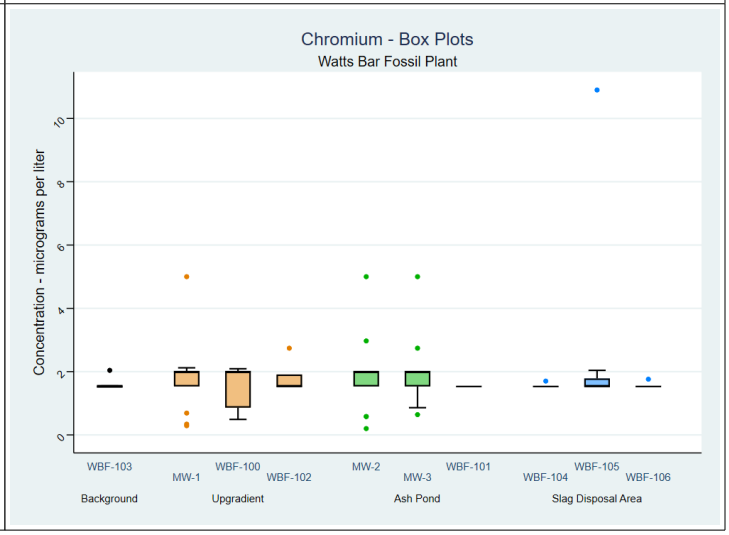




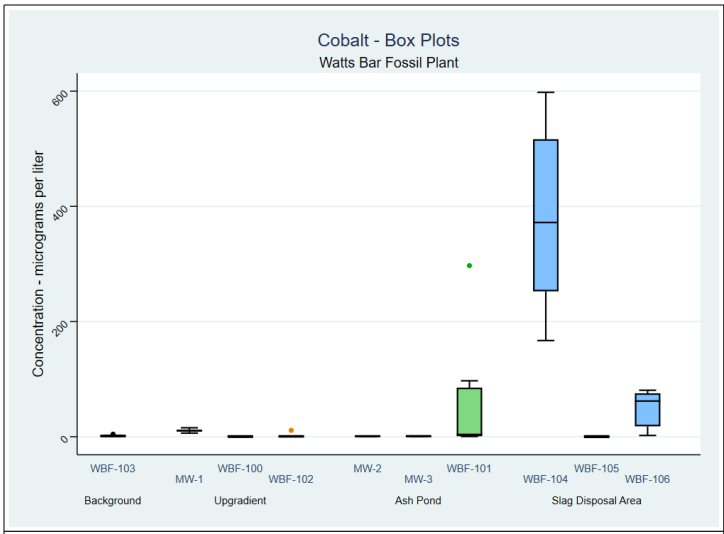


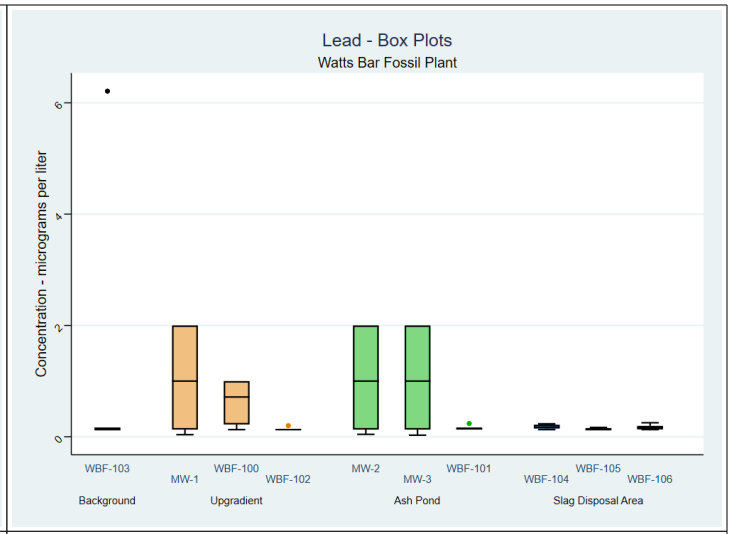


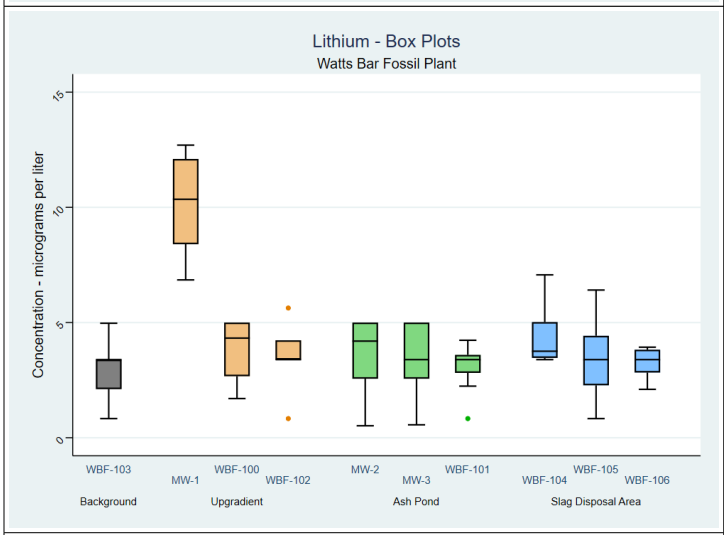


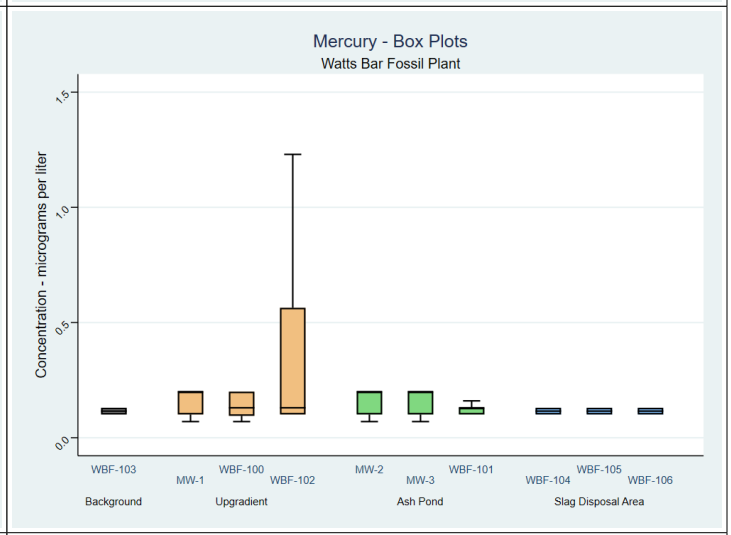


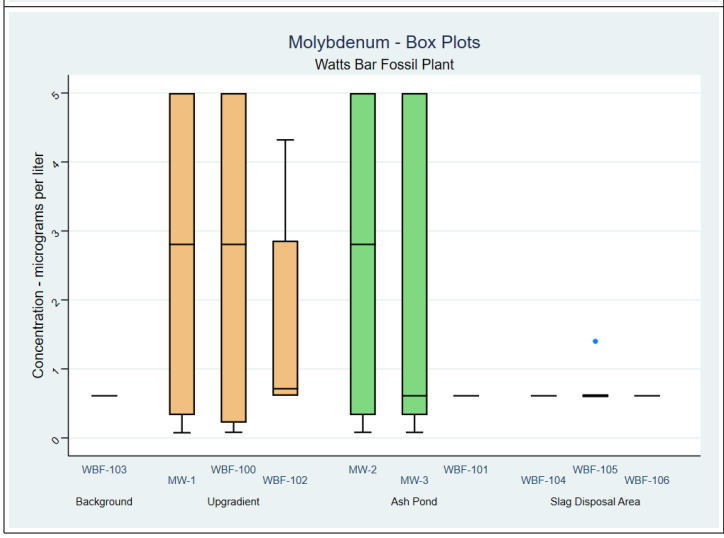
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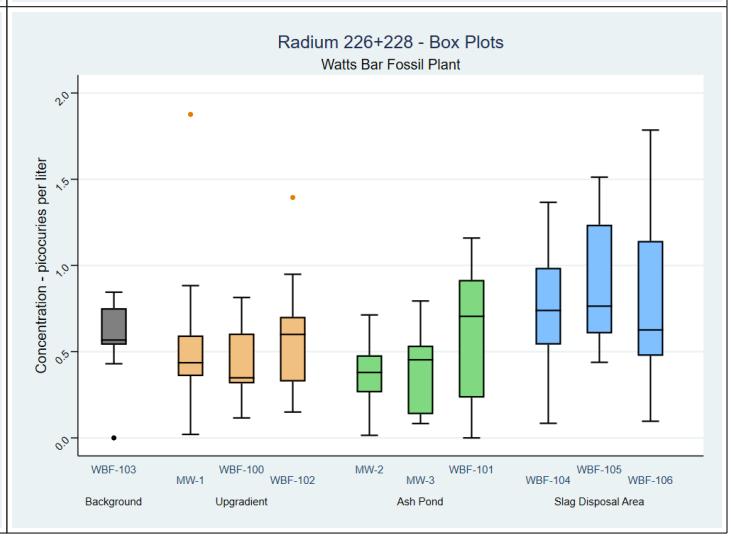

Cobalt - Box Plots
Watts Bar Fossil Plant
Concentration - micrograms per liter
0
200
400
600
WBF-103
MW-1
WBF-100
WBF-102
MW-2
MW-3
WBF-101
WBF-104
WBF-105
WBF-106
Background
Upgradient
Ash Pond
Slag Disposal Area


Lead - Box Plots
Watts Bar Fossil Plant
Concentration - micrograms per liter
0
2
4
6
WBF-103
MW-1
WBF-100
WBF-102
MW-2
MW-3
WBF-101
WBF-104
WBF-105
WBF-106
Background
Upgradient
Ash Pond
Slag Disposal Area

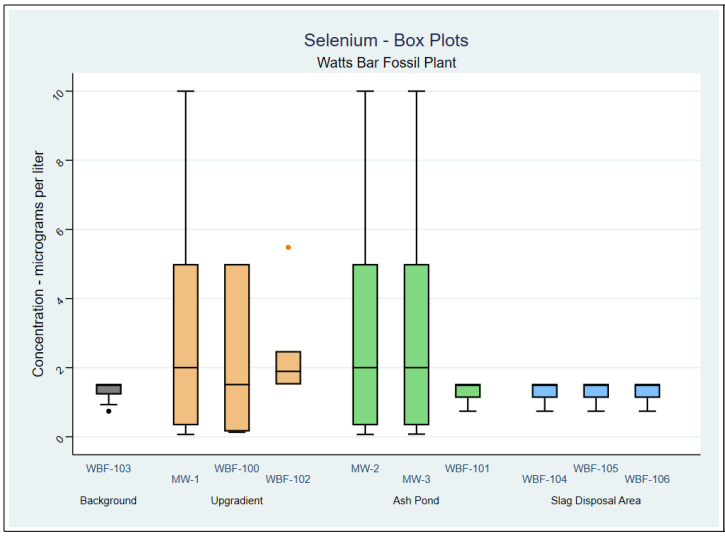

Lithium - Box Plots
Watts Bar Fossil Plant
Concentration - micrograms per liter
0
5
10
15
WBF-103
MW-1
WBF-100
WBF-102
MW-2
MW-3
WBF-101
WBF-104
WBF-105
WBF-106
Background
Upgradient
Ash Pond
Slag Disposal Area

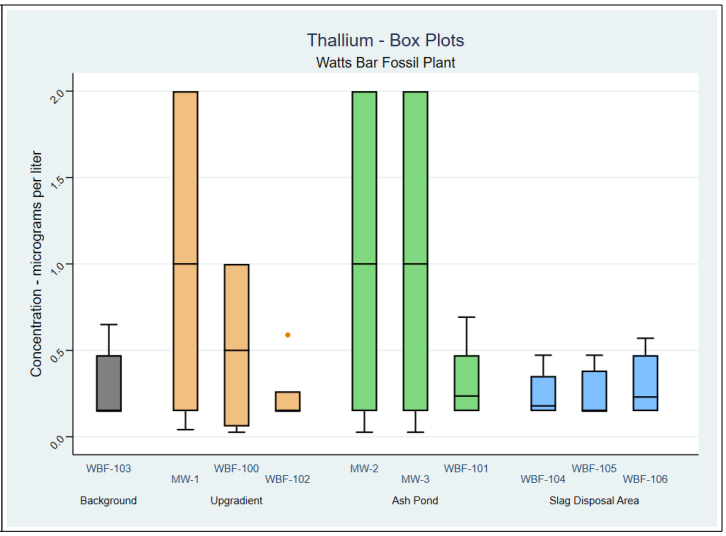

Mercury - Box Plots
Watts Bar Fossil Plant
Concentration - micrograms per liter
0.0
0.5
1.0
1.5
WBF-103
MW-1
WBF-100
WBF-102
MW-2
MW-3
WBF-101
WBF-104
WBF-105
WBF-106
Background
Upgradient
Ash Pond
Slag Disposal Area


Molybdenum - Box Plots
Watts Bar Fossil Plant
Concentration - micrograms per liter
0
1
2
3
4
5
WBF-103
MW-1
WBF-100
WBF-102
MW-2
MW-3
WBF-101
WBF-104
WBF-105
WBF-106
Background
Upgradient
Ash Pond
Slag Disposal Area


Radium 226+228 - Box Plots
Watts Bar Fossil Plant
Concentration - picocuries per liter
0.0
0.5
1.0
1.5
2.0
WBF-103
MW-1
WBF-100
WBF-102
MW-2
MW-3
WBF-101
WBF-104
WBF-105
WBF-106
Background
Upgradient
Ash Pond
Slag Disposal Area

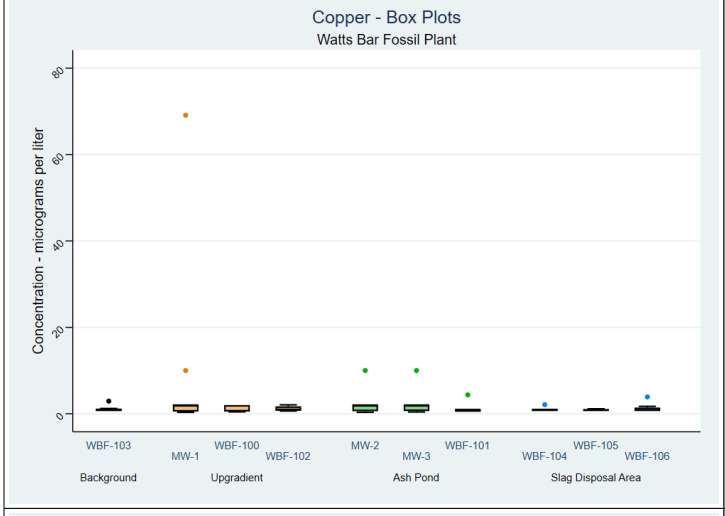
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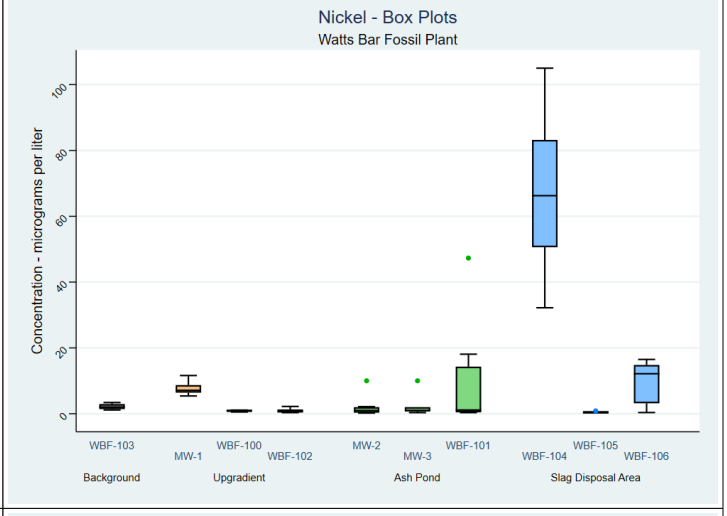

Selenium - Box Plots
Watts Bar Fossil Plant
Concentration - micrograms per liter
0
2
4
6
8
10
WBF-103
MW-1
WBF-100
WBF-102
MW-2
MW-3
WBF-101
WBF-104
WBF-105
WBF-106
Background
Upgradient
Ash Pond
Slag Disposal Area

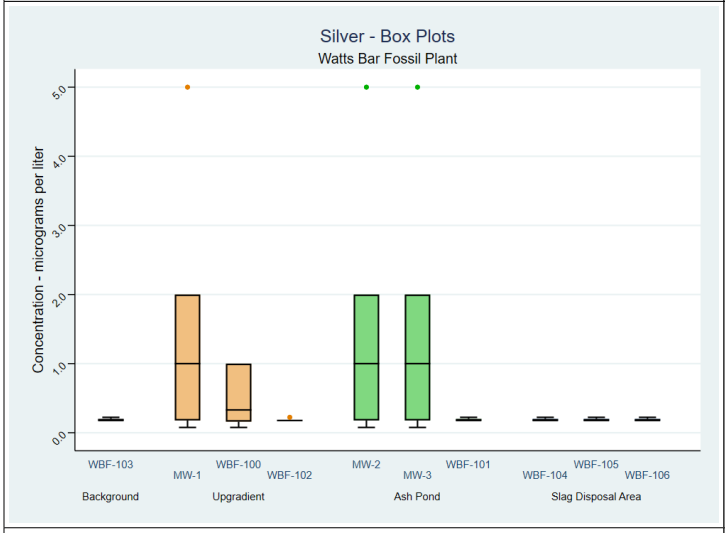

Thallium - Box Plots
Watts Bar Fossil Plant
Concentration - micrograms per liter
0.0
0.5
1.0
1.5
2.0
WBF-103
MW-1
WBF-100
WBF-102
MW-2
MW-3
WBF-101
WBF-104
WBF-105
WBF-106
Background
Upgradient
Ash Pond
Slag Disposal Area

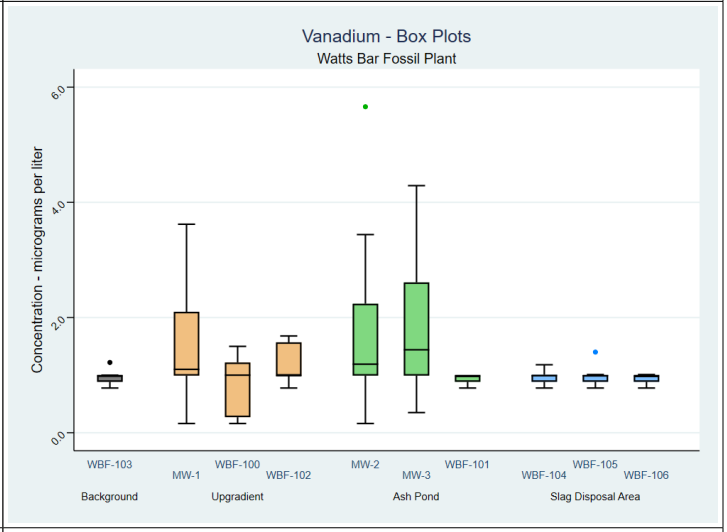
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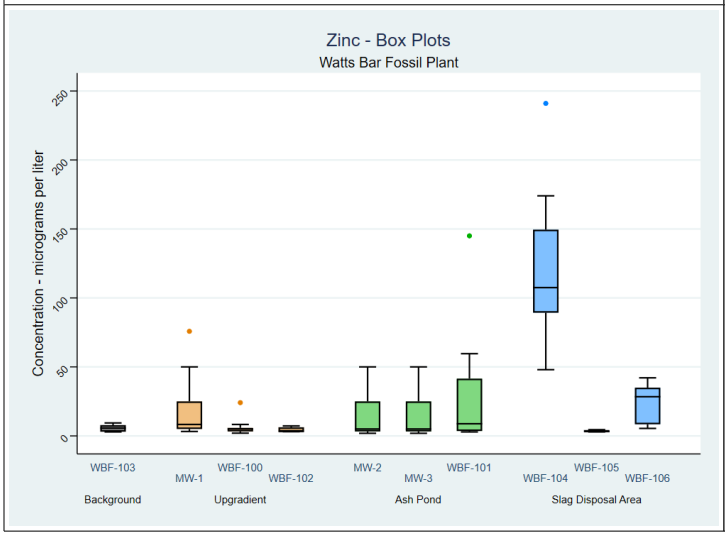
Box Plots
TDEC Appendix I Parameters
Watts Bar Fossil Plant - Spring City, Tennessee









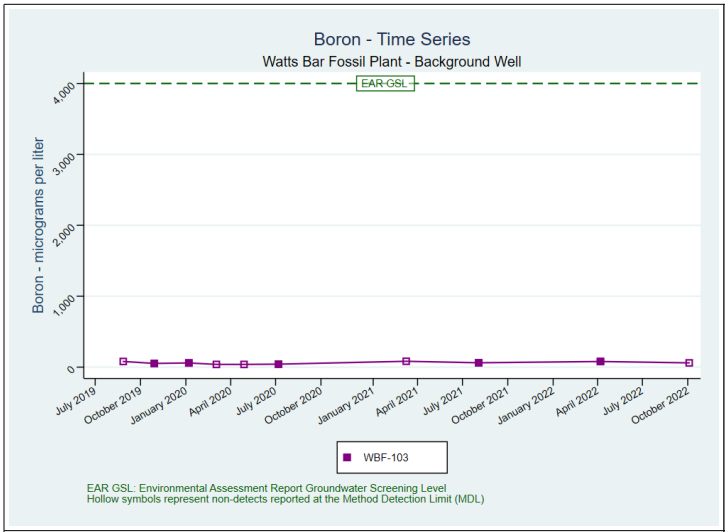


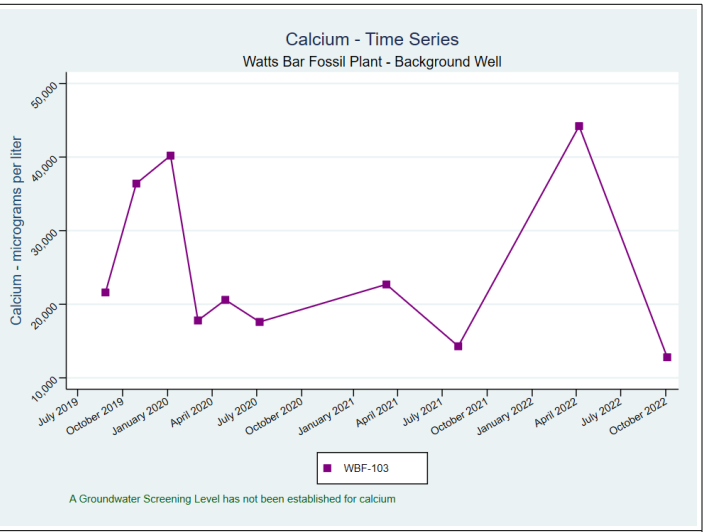
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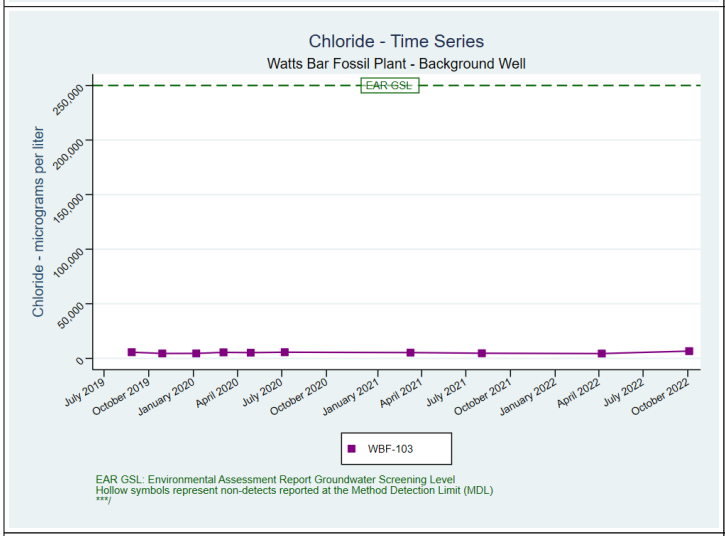
ATTACHMENT E.3-C
TIME SERIES PLOTS

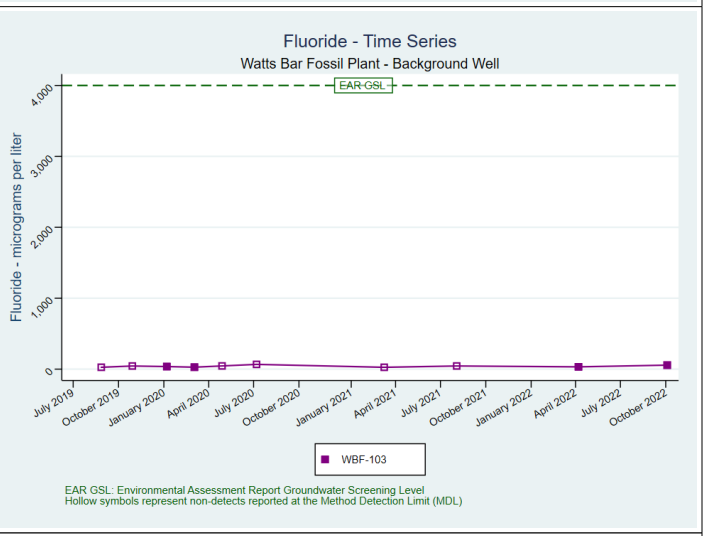
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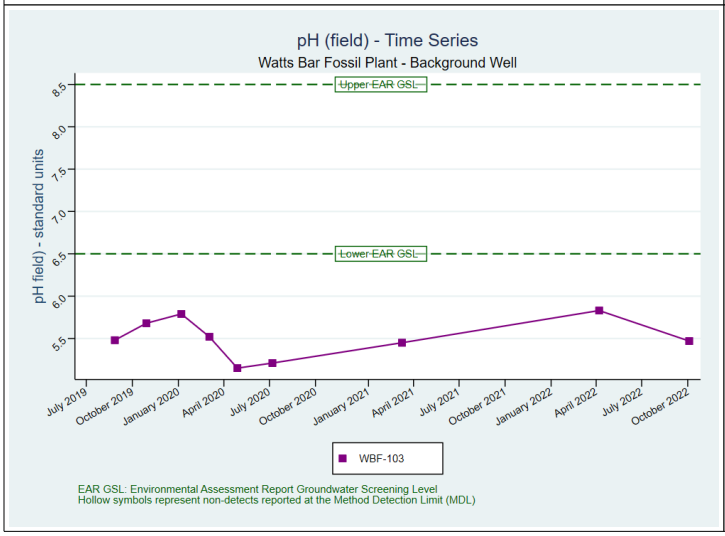
Time Series Plots
Background Well
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

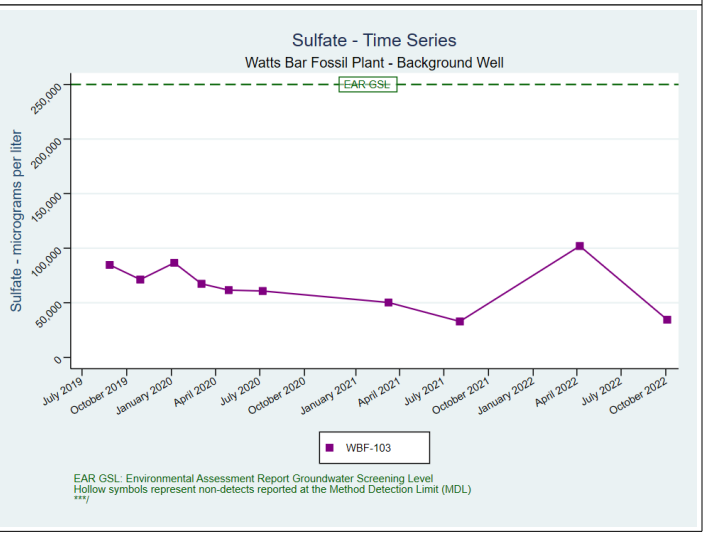


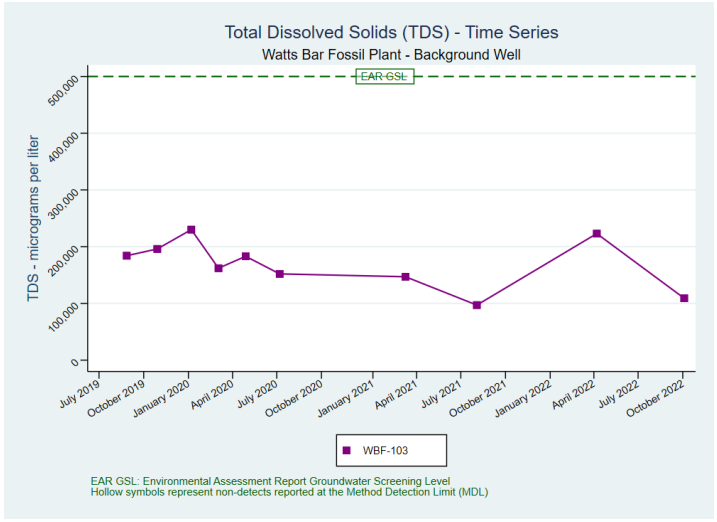








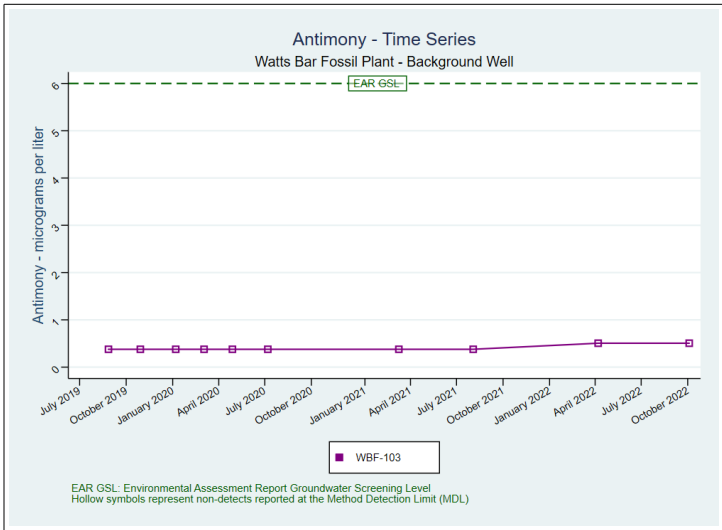


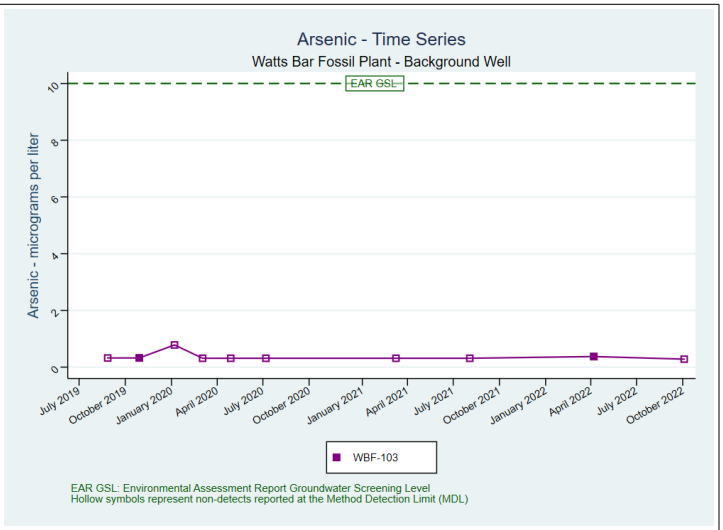


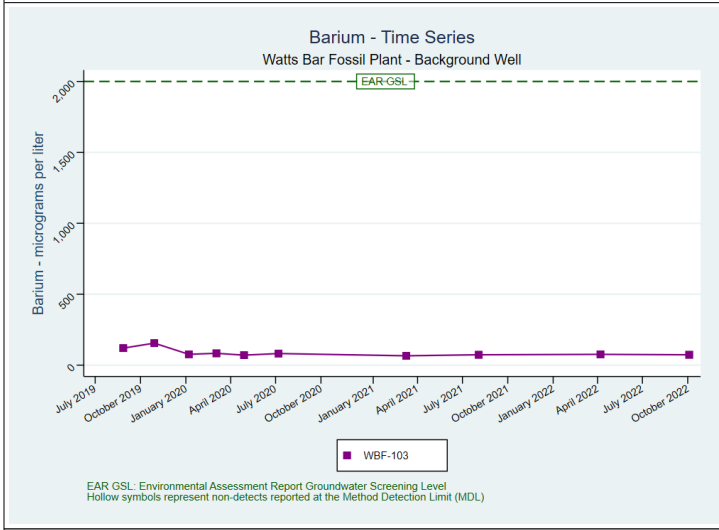
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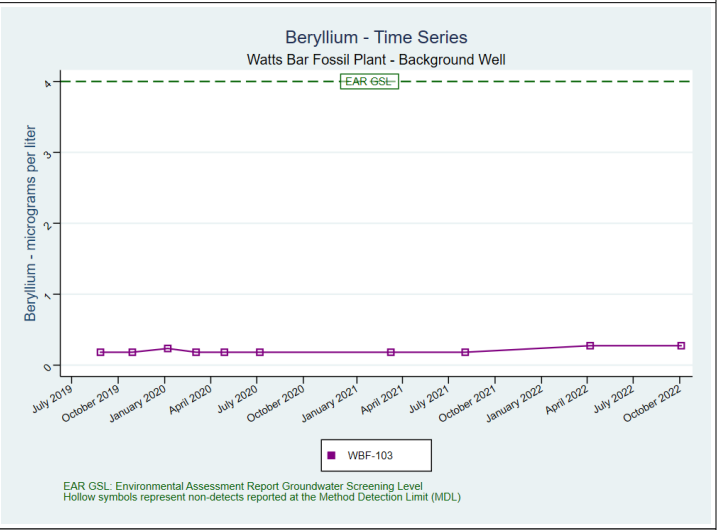
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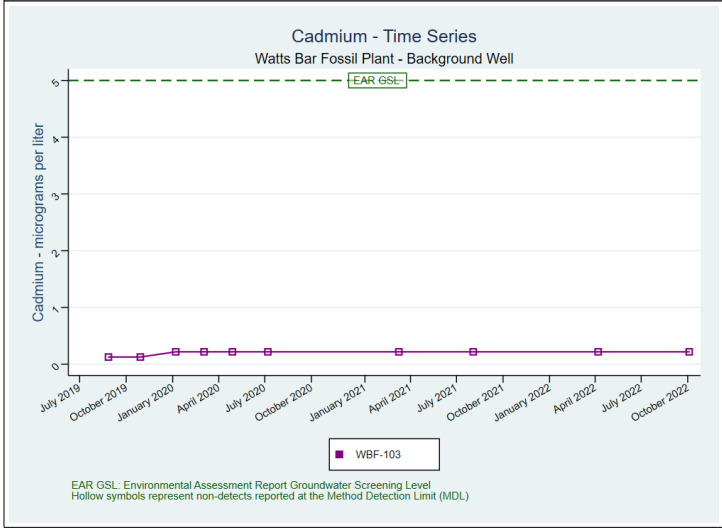
Time Series Plots
Background Well
CCR Rule Appendix IV Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

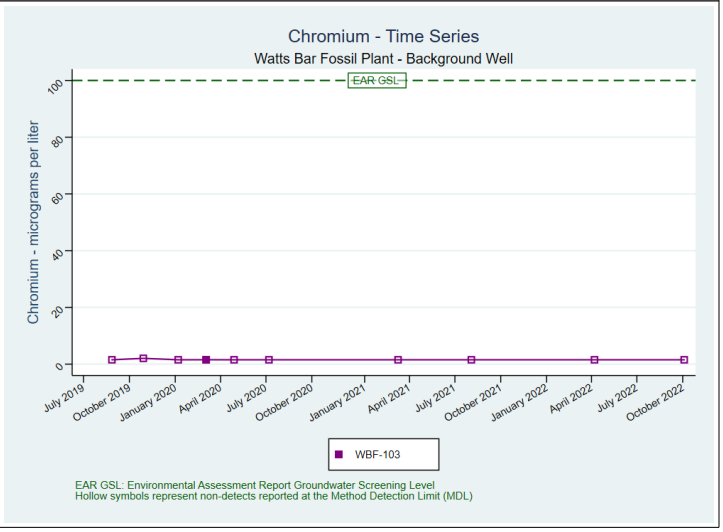




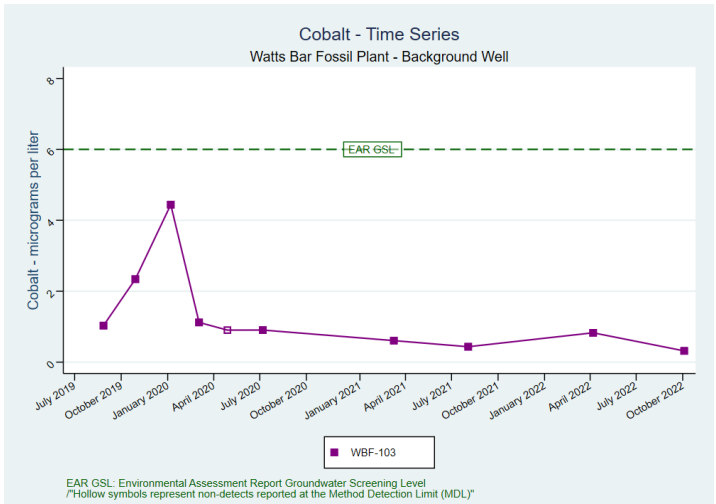


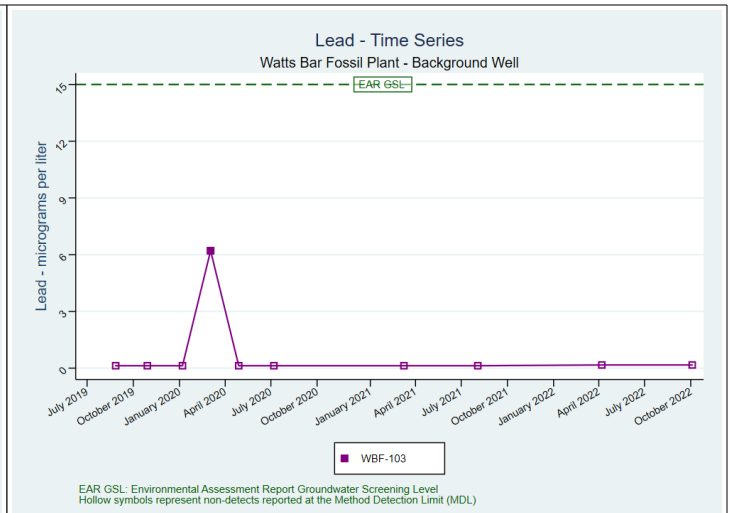


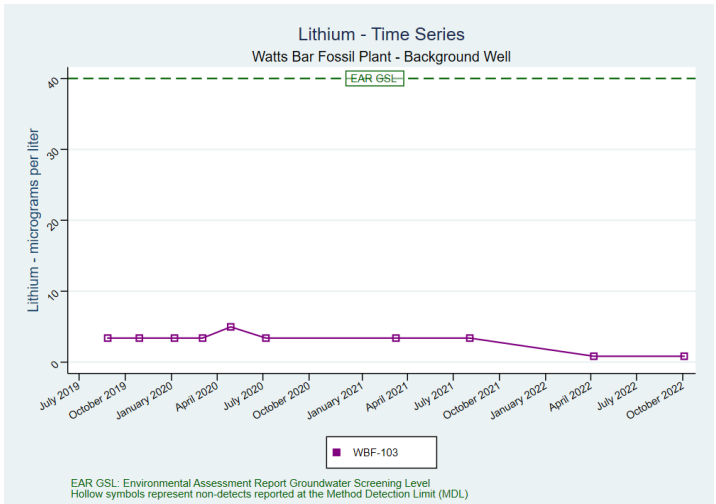


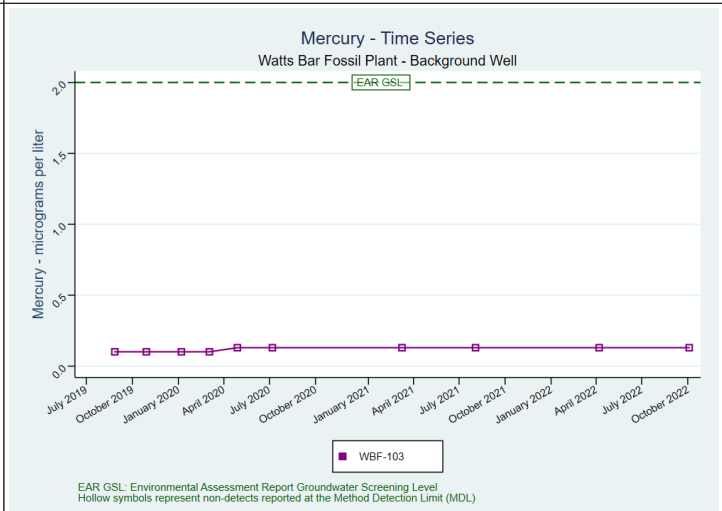


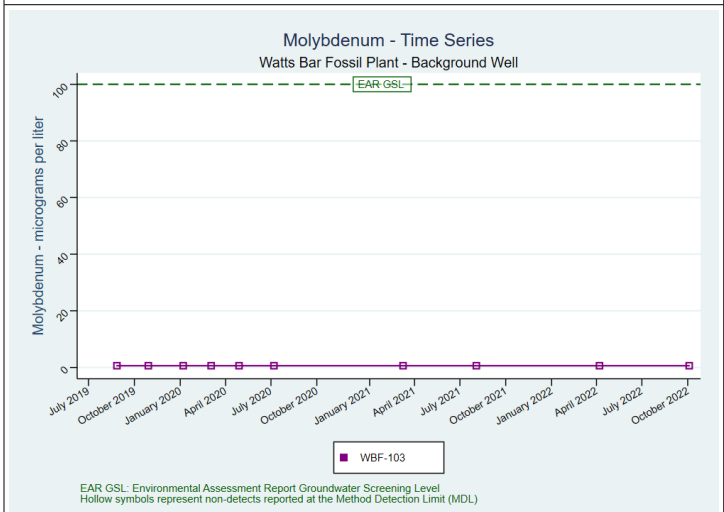
DRAFT


Cobalt - Time Series
Watts Bar Fossil Plant - Background Well
Cobalt - micrograms per liter
EAR GSL
WBF-103
EAR GSL: Environmental Assessment Report Groundwater Screening Level
/"Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)"


Lead - Time Series
Watts Bar Fossil Plant - Background Well
Lead - micrograms per liter
EAR GSL
WBF-103
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

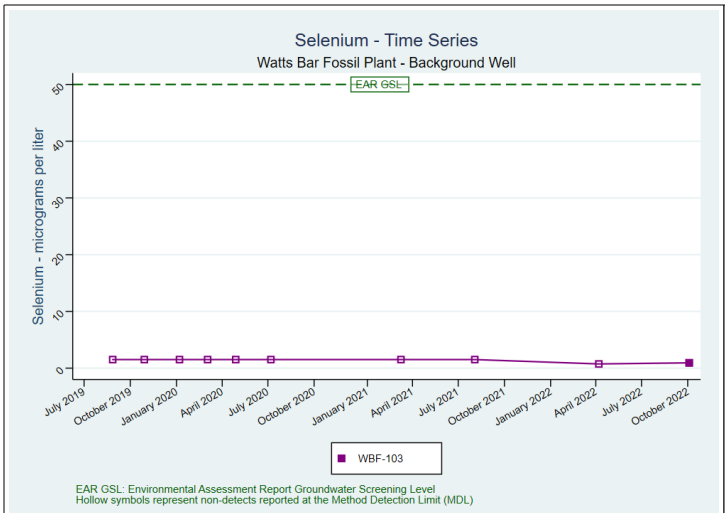

Lithium - Time Series
Watts Bar Fossil Plant - Background Well
Lithium - micrograms per liter
EAR GSL
WBF-103
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

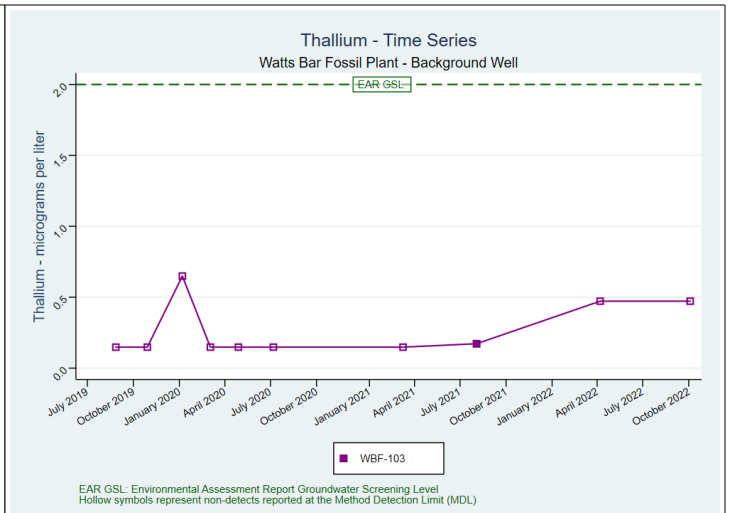

Mercury - Time Series
Watts Bar Fossil Plant - Background Well
Mercury - micrograms per liter
EAR GSL
WBF-103
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)


Molybdenum - Time Series
Watts Bar Fossil Plant - Background Well
Molybdenum - micrograms per liter
EAR GSL
WBF-103
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)


Radium 226+228 - Time Series
Watts Bar Fossil Plant - Background Well
Radium 226+228 - picocuries per liter
EAR GSL
WBF-103
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

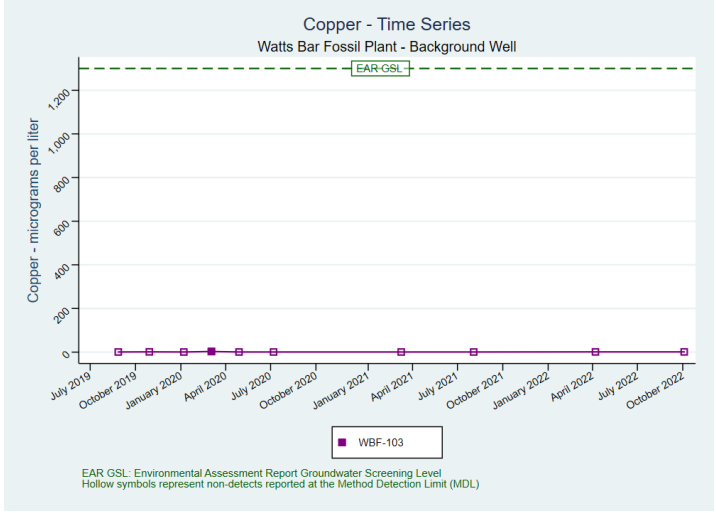
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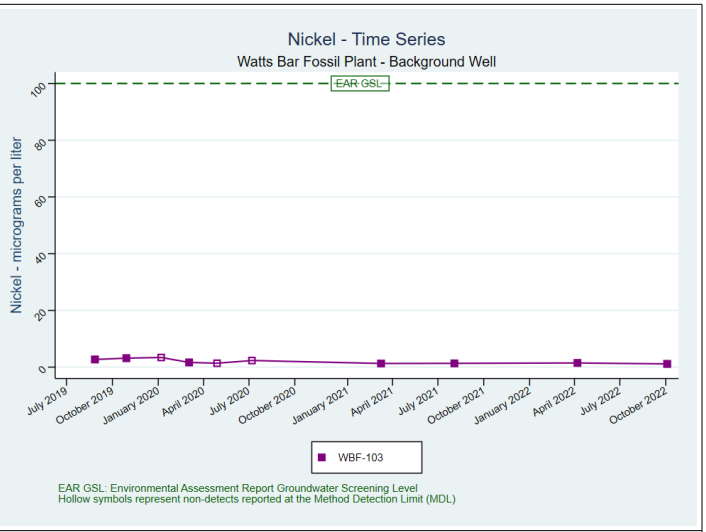

Selenium - Time Series
Watts Bar Fossil Plant - Background Well
EAR GSL
Selenium - micrograms per liter
0
10
20
30
40
50
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-103
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

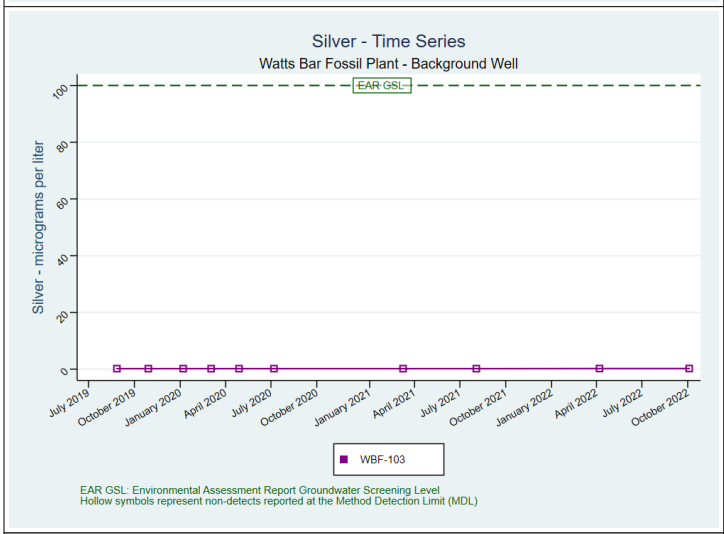

Thallium - Time Series
Watts Bar Fossil Plant - Background Well
EAR GSL
Thallium - micrograms per liter
0.0
0.5
1.0
1.5
2.0
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-103
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

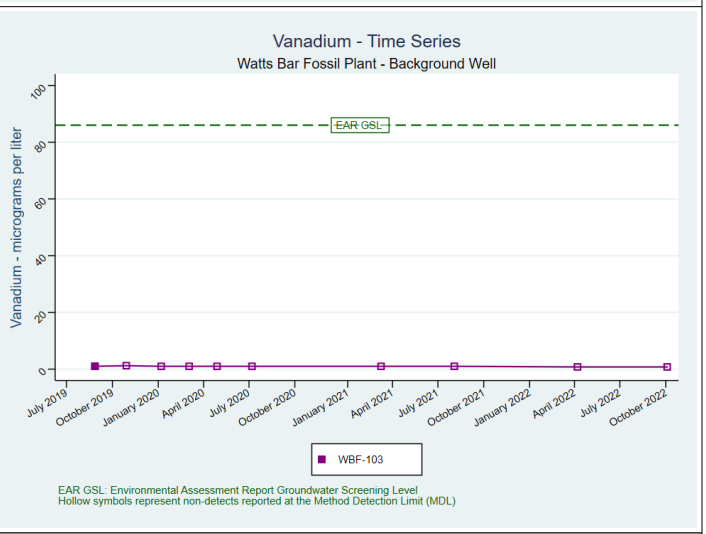
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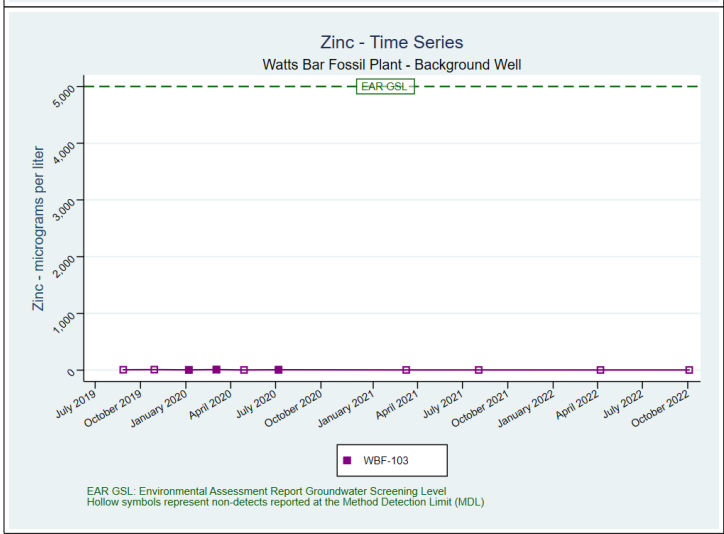
Time Series Plots
Background Well
TDEC Appendix I Parameters
Watts Bar Fossil Plant - Spring City, Tennessee







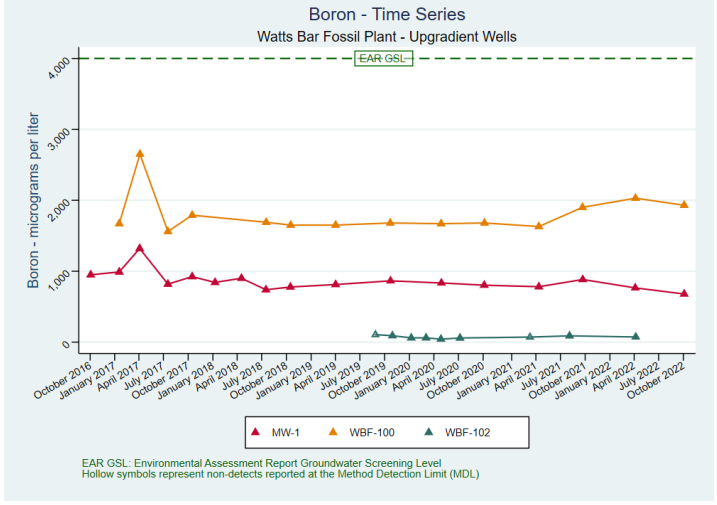


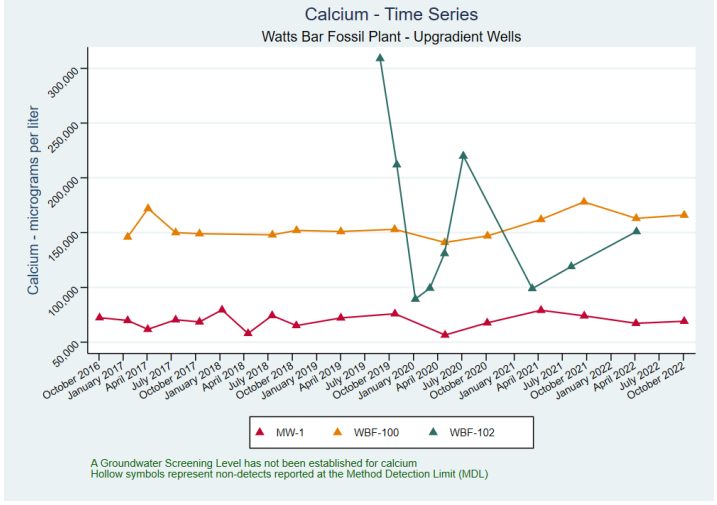


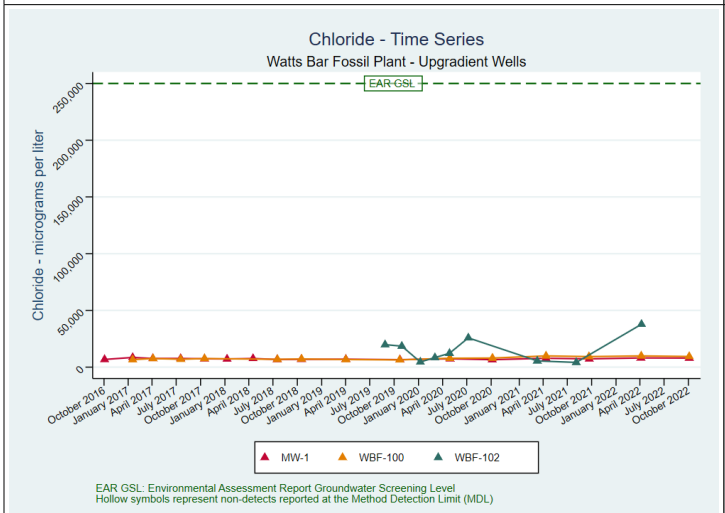
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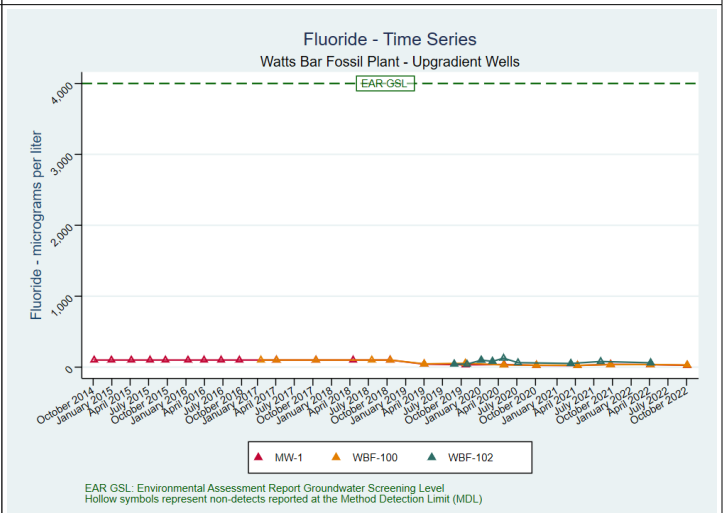
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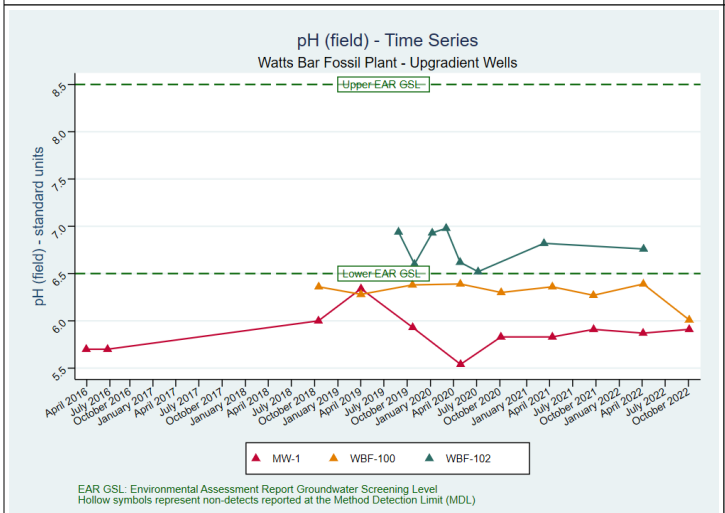
Time Series Plots
Upgradient Wells
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

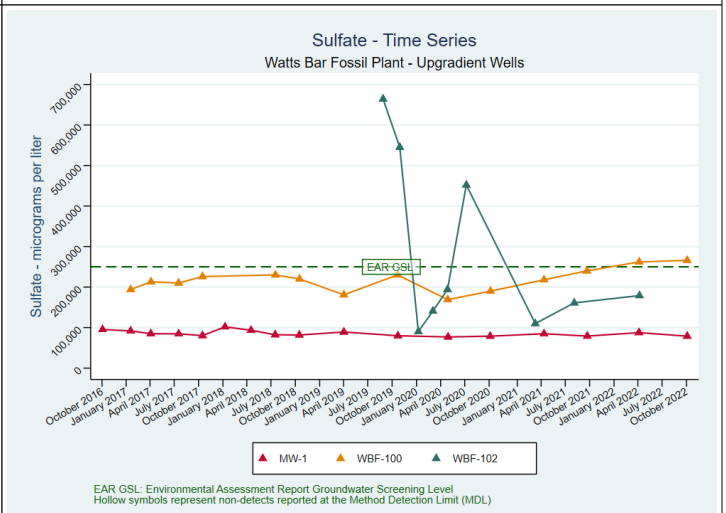


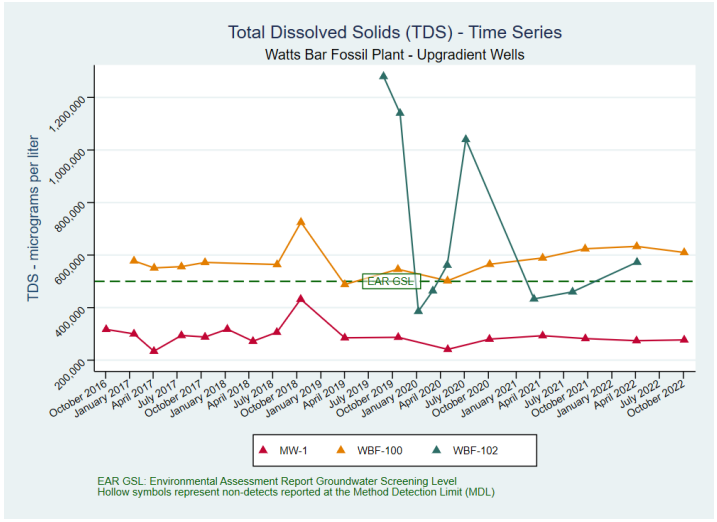








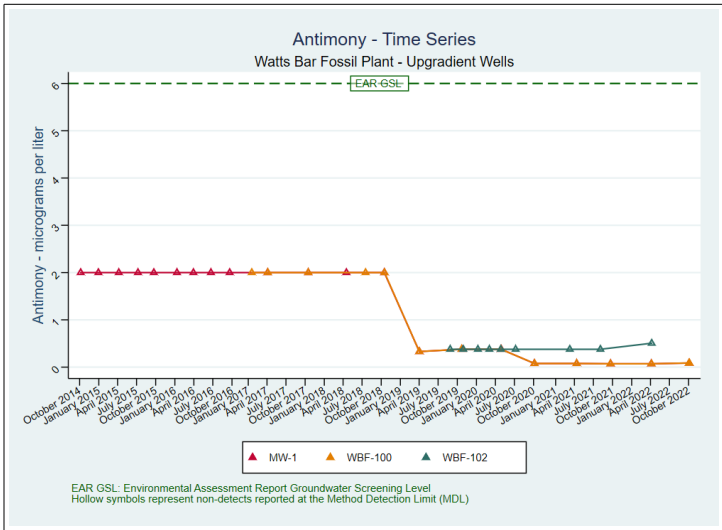


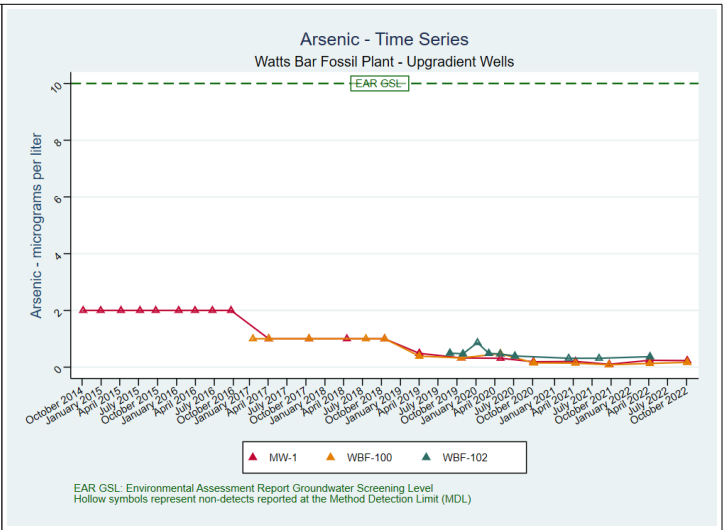


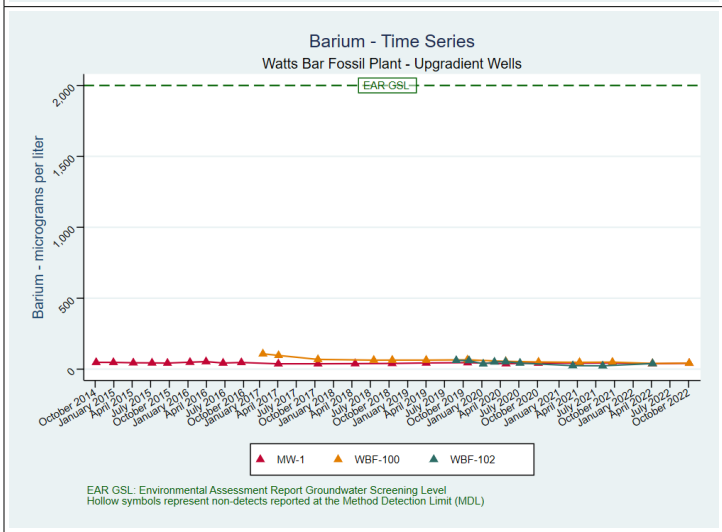
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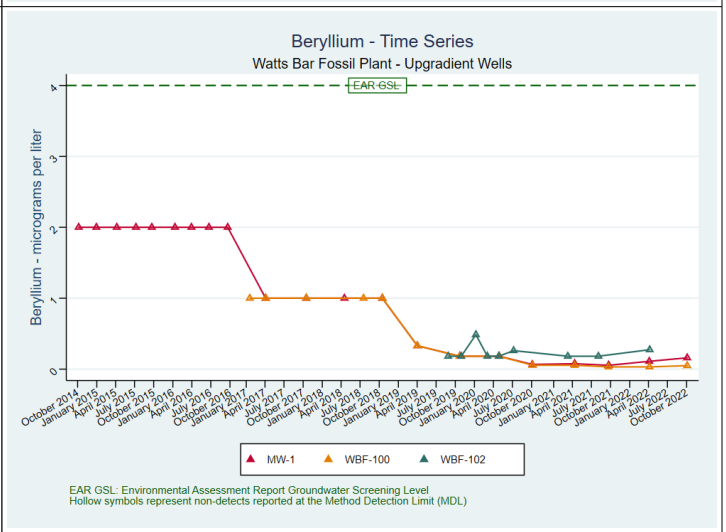
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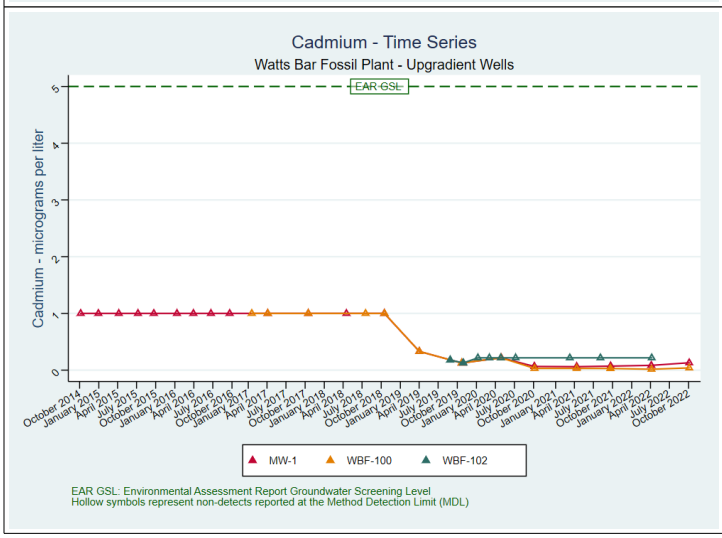
Time Series Plots
Upgradient Wells
CCR Rule Appendix IV Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

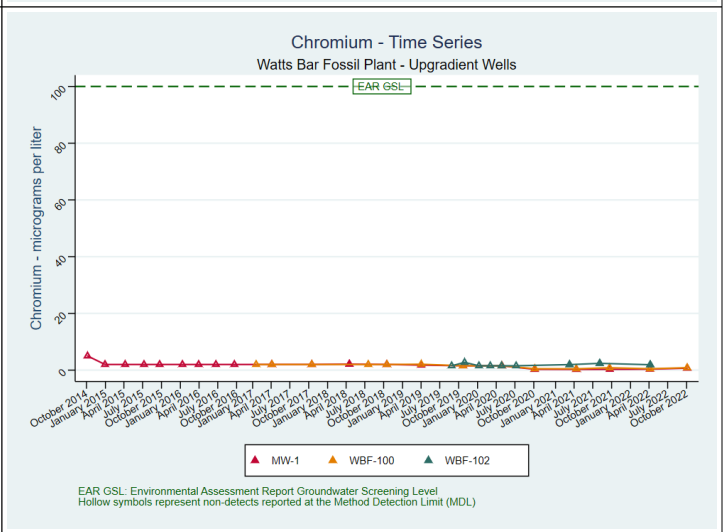








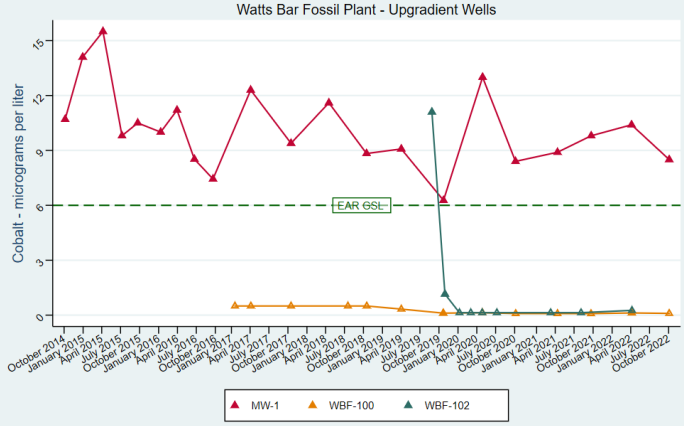




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Cobalt - Time Series

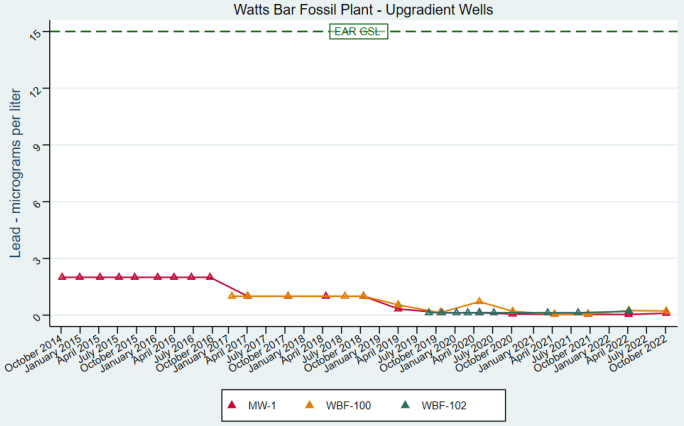
Watts Bar Fossil Plant - Upgradient Wells



EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

Lead - Time Series

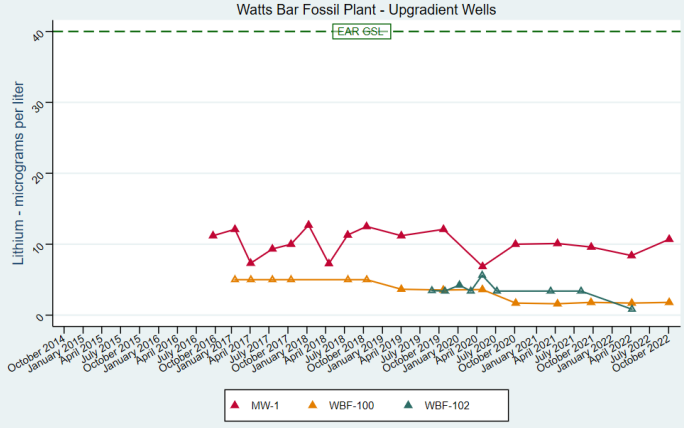
Watts Bar Fossil Plant - Upgradient Wells



EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

Lithium - Time Series

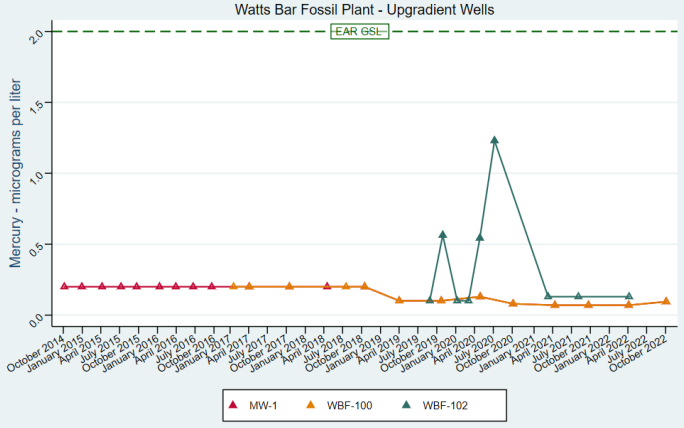
Watts Bar Fossil Plant - Upgradient Wells



EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

Mercury - Time Series

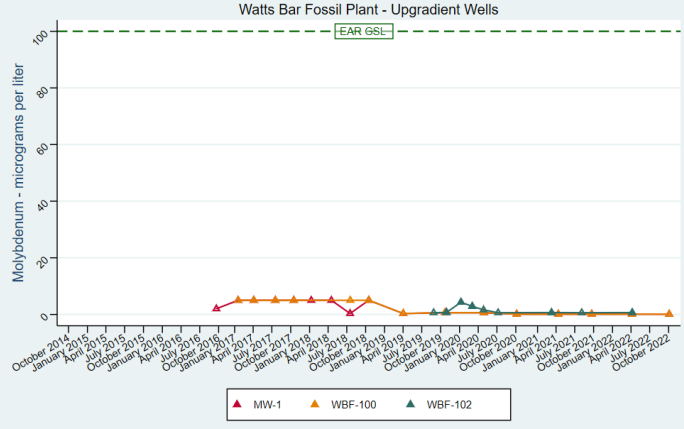
Watts Bar Fossil Plant - Upgradient Wells



EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

Molybdenum - Time Series

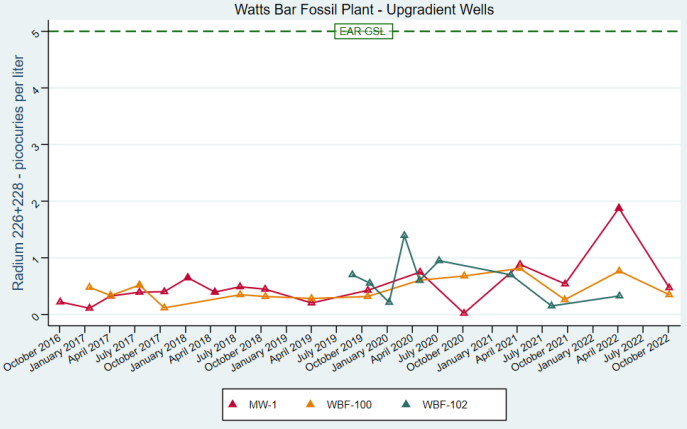
Watts Bar Fossil Plant - Upgradient Wells



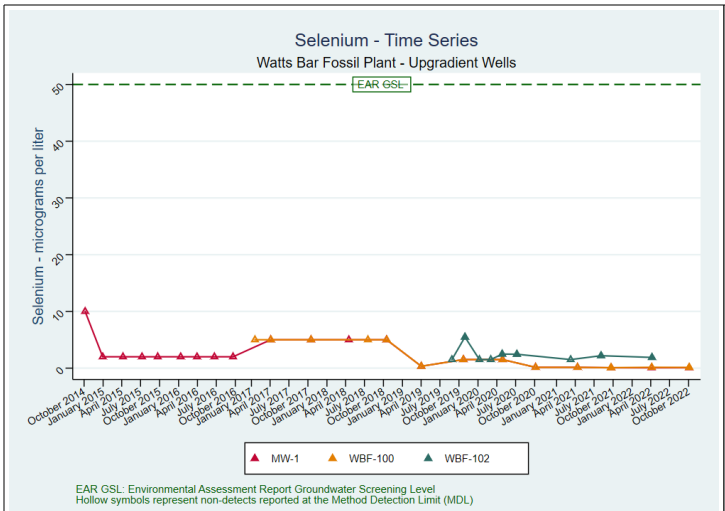
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

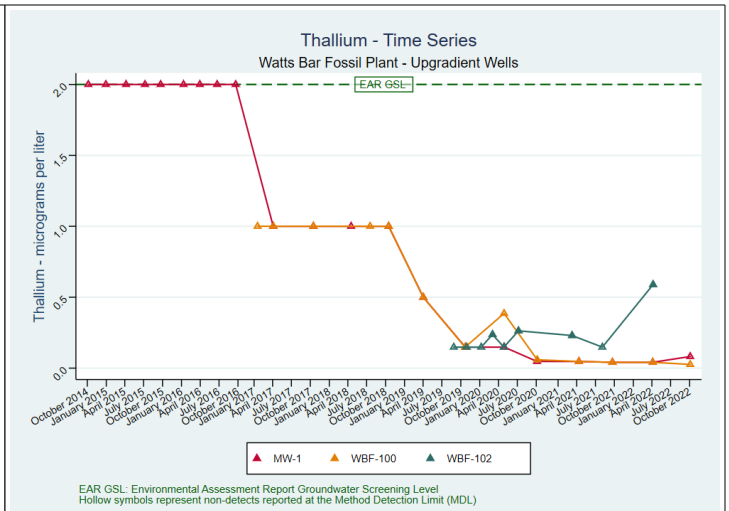
Radium 226+228 - Time Series

Watts Bar Fossil Plant - Upgradient Wells



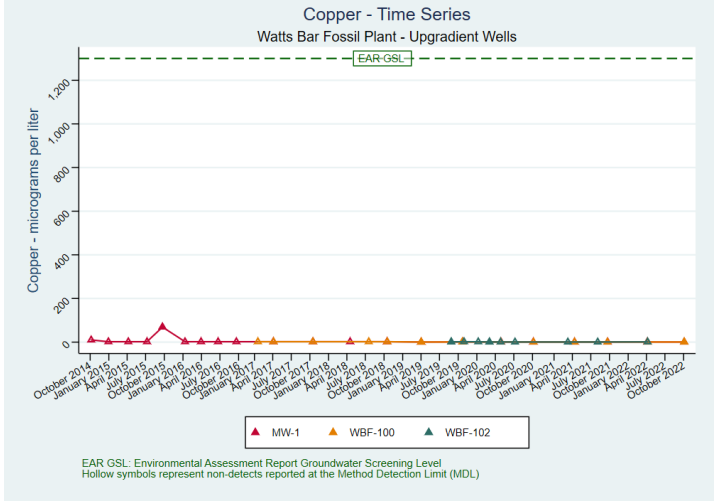
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

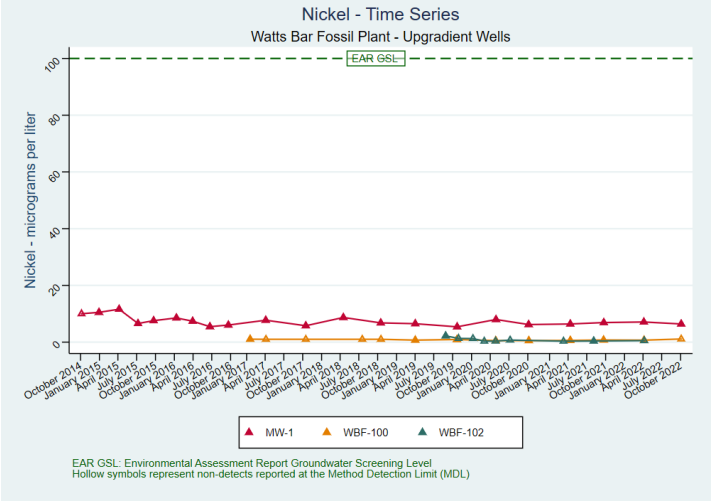

Selenium - Time Series
Watts Bar Fossil Plant - Upgradient Wells
EAR GSL
Selenium - micrograms per liter
0
10
20
30
40
50
October 2014
January 2015
April 2015
July 2015
October 2015
January 2016
April 2016
July 2016
October 2016
January 2017
April 2017
July 2017
October 2017
January 2018
April 2018
July 2018
October 2018
January 2019
April 2019
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
MW-1
WBF-100
WBF-102
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

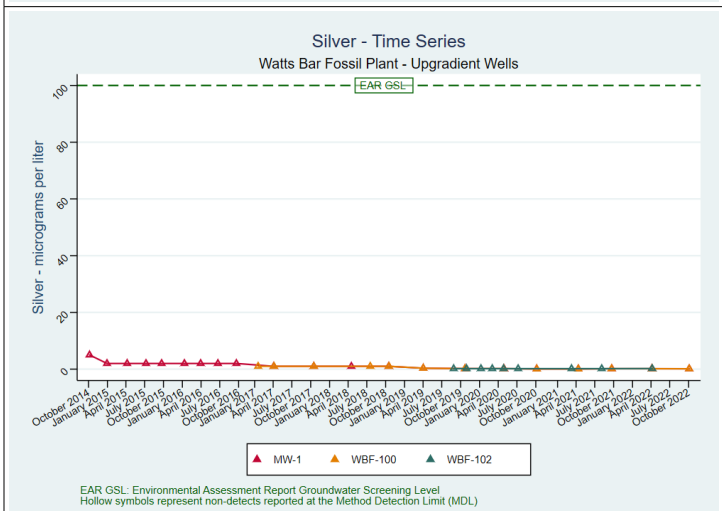

Thallium - Time Series
Watts Bar Fossil Plant - Upgradient Wells
EAR GSL
Thallium - micrograms per liter
0.0
0.5
1.0
1.5
2.0
October 2014
January 2015
April 2015
July 2015
October 2015
January 2016
April 2016
July 2016
October 2016
January 2017
April 2017
July 2017
October 2017
January 2018
April 2018
July 2018
October 2018
January 2019
April 2019
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
MW-1
WBF-100
WBF-102
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

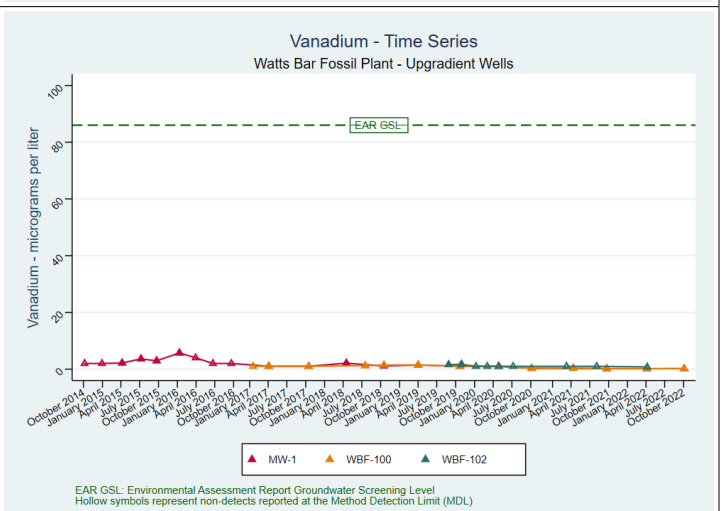
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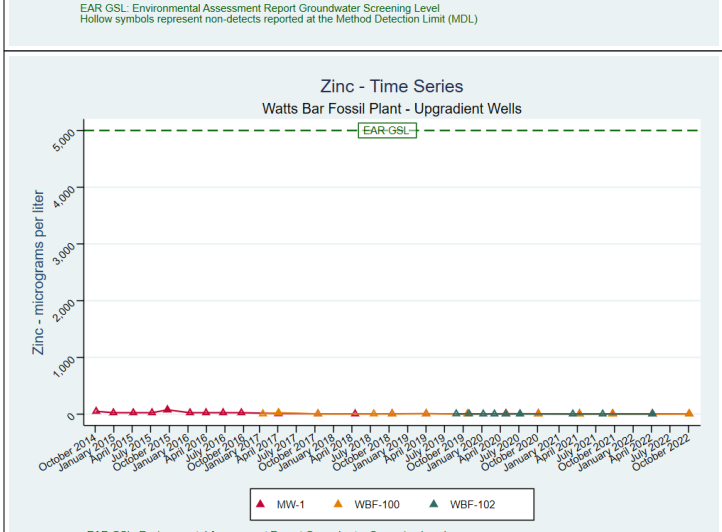
Time Series Plots
Upgradient Wells
TDEC Appendix I Parameters
Watts Bar Fossil Plant - Spring City, Tennessee







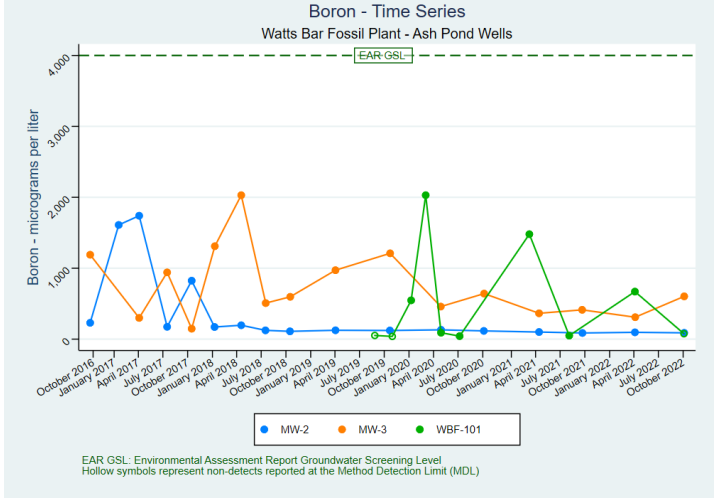


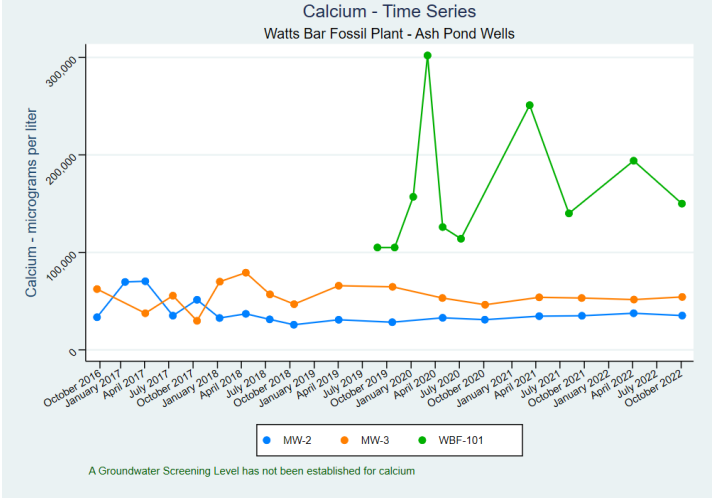


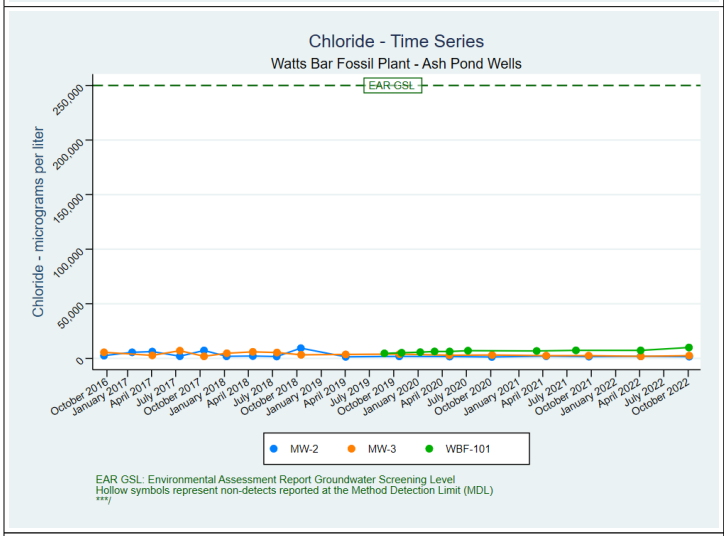
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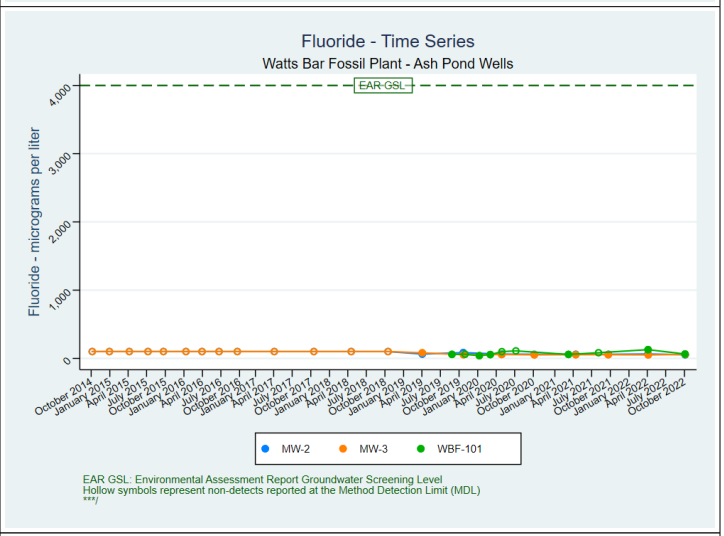
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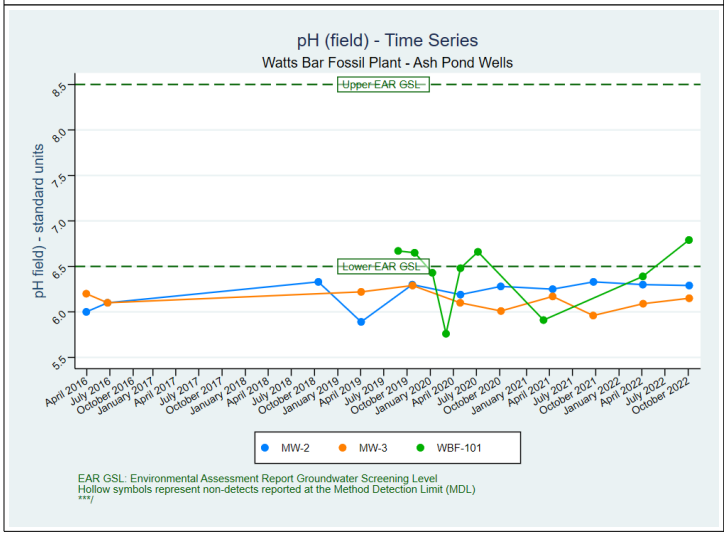
Time Series Plots
Ash Pond Wells
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

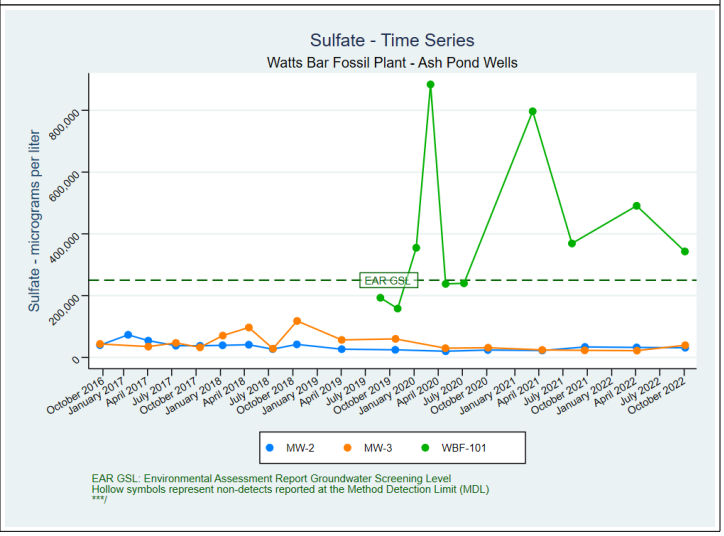


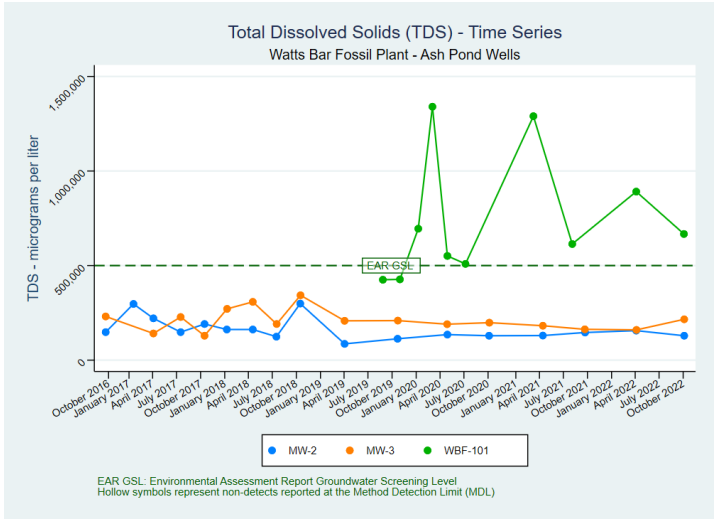








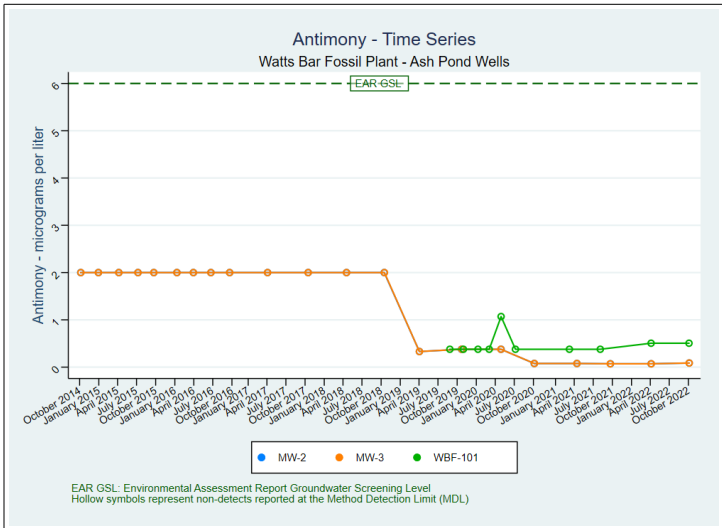


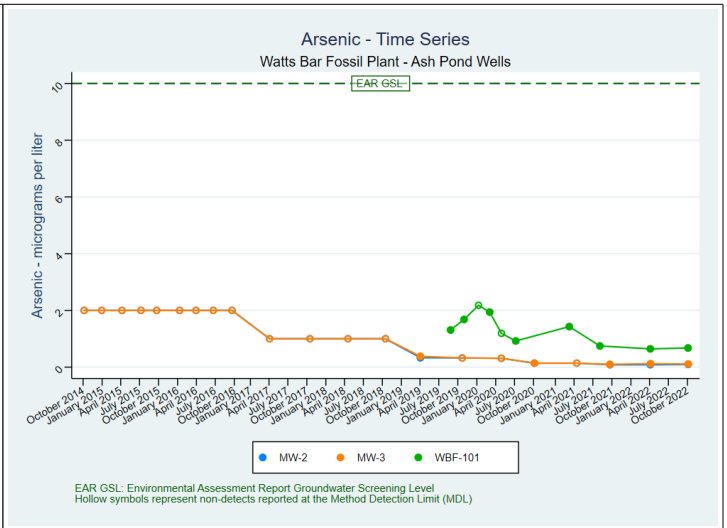


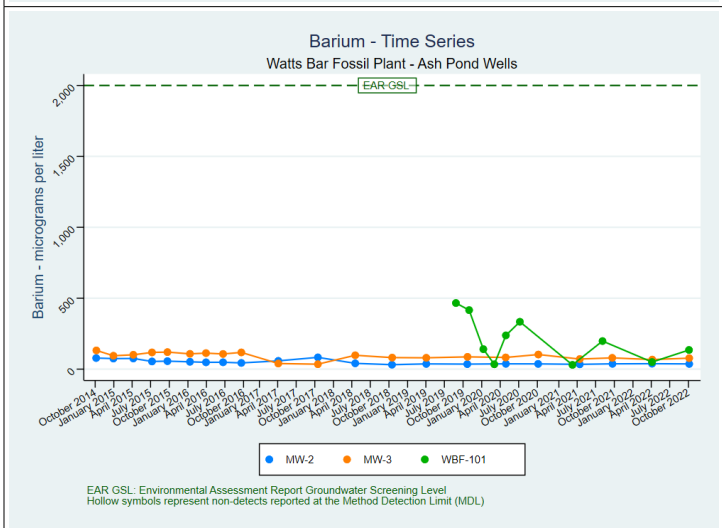
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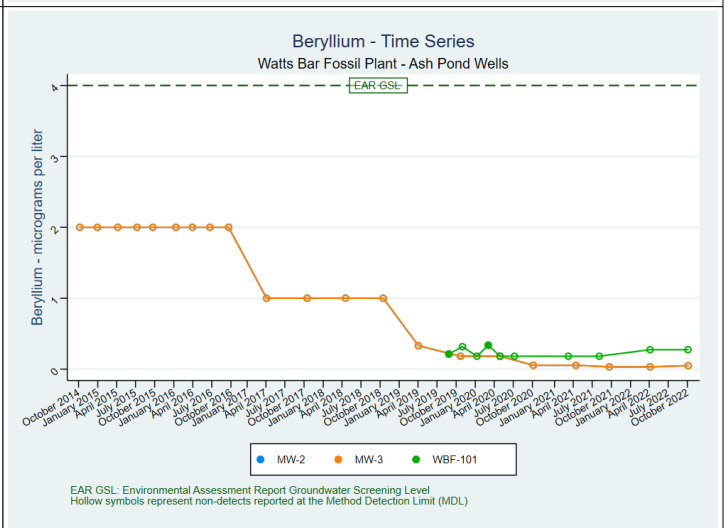
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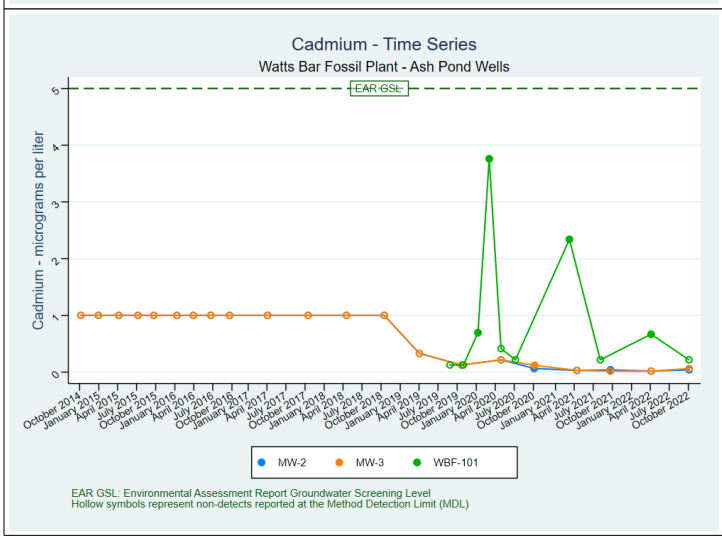
Time Series Plots
Ash Pond Wells
CCR Rule Appendix IV Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

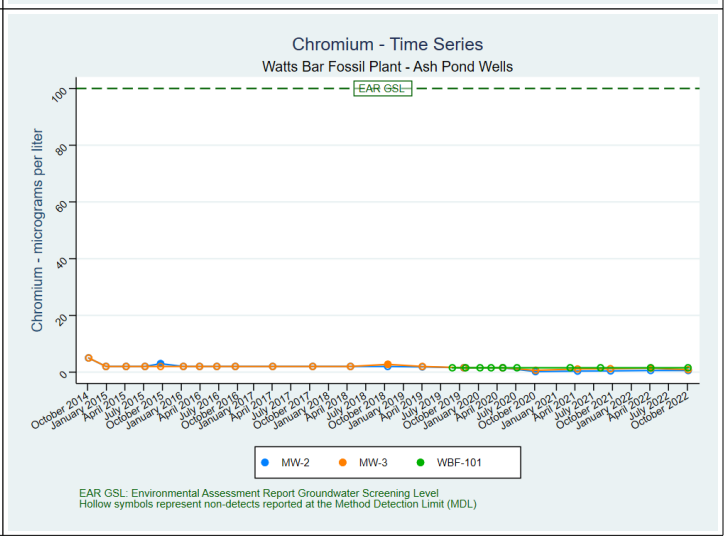




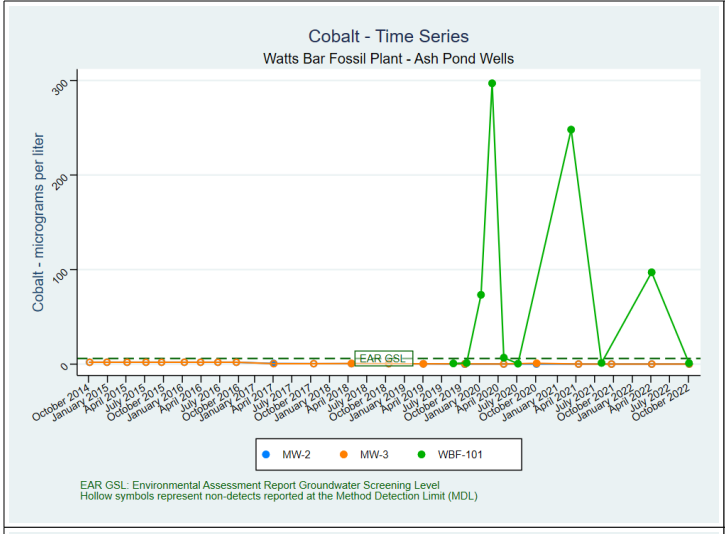


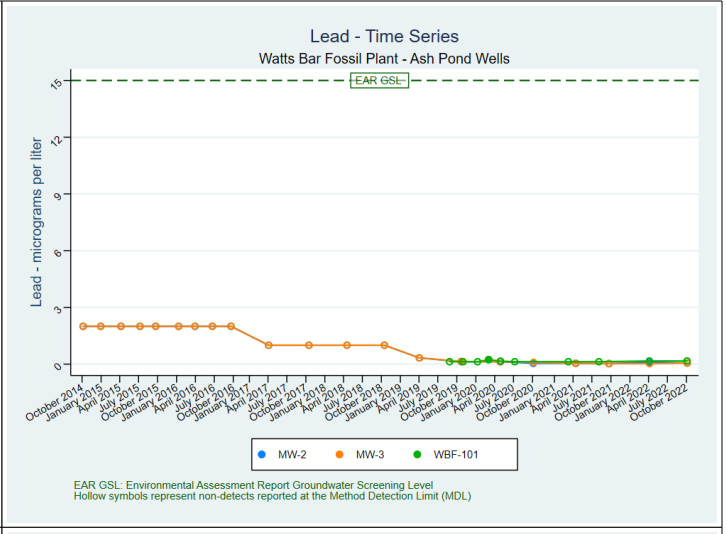


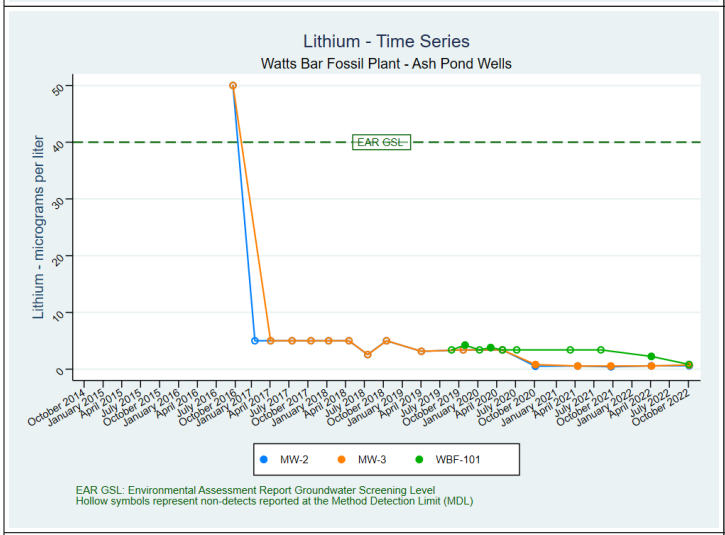


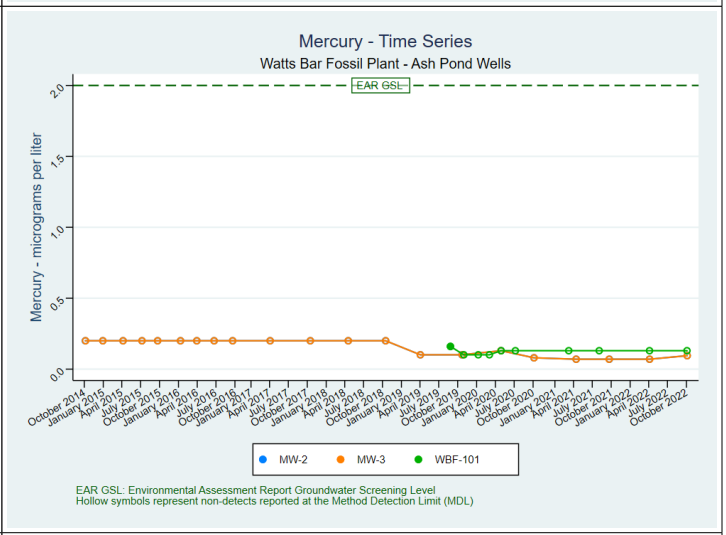


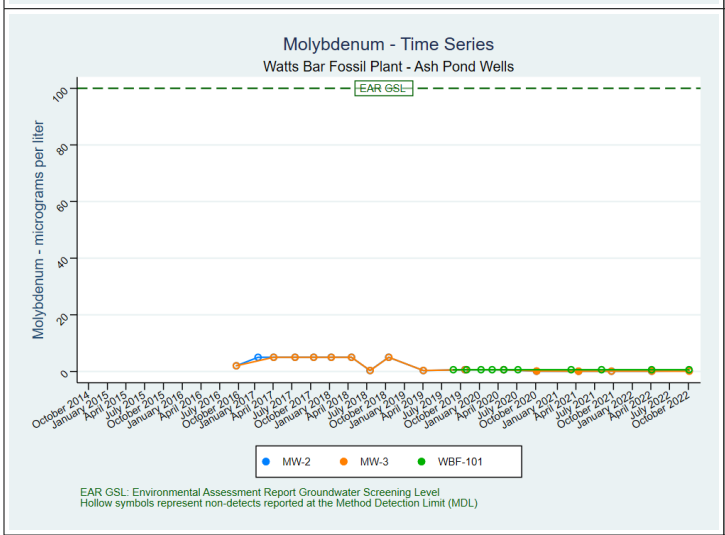
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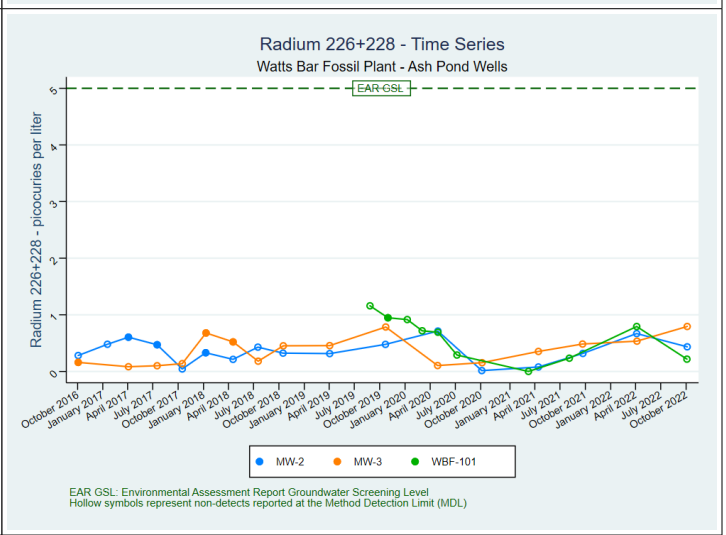

Cobalt - Time Series
Watts Bar Fossil Plant - Ash Pond Wells
Cobalt - micrograms per liter
EAR GSL
MW-2
MW-3
WBF-101
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

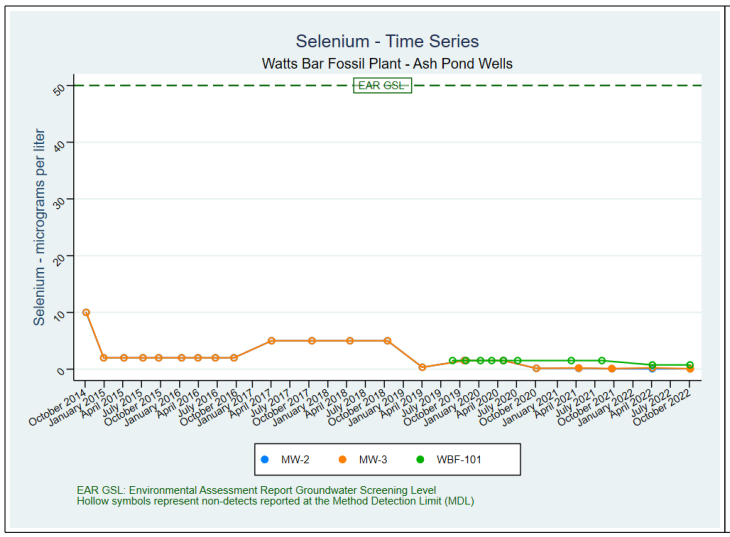

Lead - Time Series
Watts Bar Fossil Plant - Ash Pond Wells
Lead - micrograms per liter
EAR GSL
MW-2
MW-3
WBF-101
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

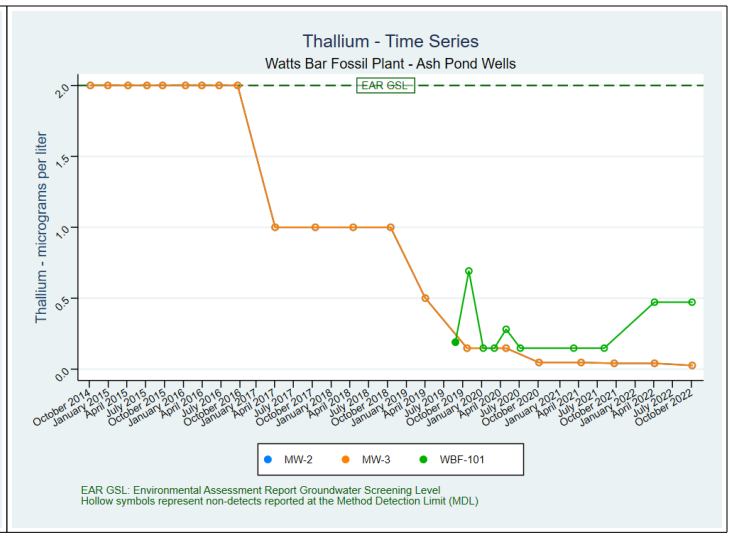

Lithium - Time Series
Watts Bar Fossil Plant - Ash Pond Wells
Lithium - micrograms per liter
EAR GSL
MW-2
MW-3
WBF-101
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)


Mercury - Time Series
Watts Bar Fossil Plant - Ash Pond Wells
Mercury - micrograms per liter
EAR GSL
MW-2
MW-3
WBF-101
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)


Molybdenum - Time Series
Watts Bar Fossil Plant - Ash Pond Wells
Molybdenum - micrograms per liter
EAR GSL
MW-2
MW-3
WBF-101
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

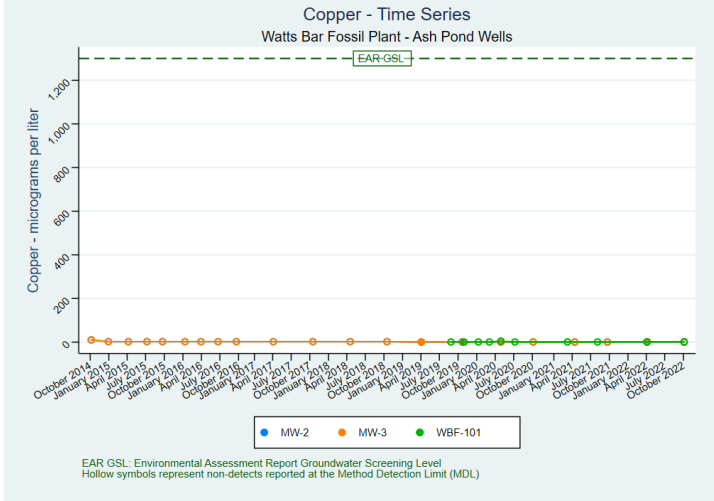

Radium 226+228 - Time Series
Watts Bar Fossil Plant - Ash Pond Wells
Radium 226+228 - picocuries per liter
EAR GSL
MW-2
MW-3
WBF-101
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

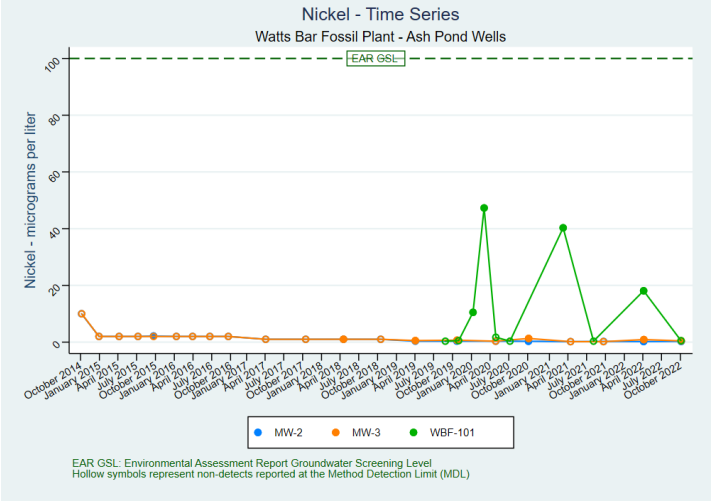

Selenium - Time Series
Watts Bar Fossil Plant - Ash Pond Wells
EAR GSL
Selenium - micrograms per liter
0
10
20
30
40
50
October 2014
January 2015
April 2015
July 2015
October 2015
January 2016
April 2016
July 2016
October 2016
January 2017
April 2017
July 2017
October 2017
January 2018
April 2018
July 2018
October 2018
January 2019
April 2019
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
MW-2
MW-3
WBF-101
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

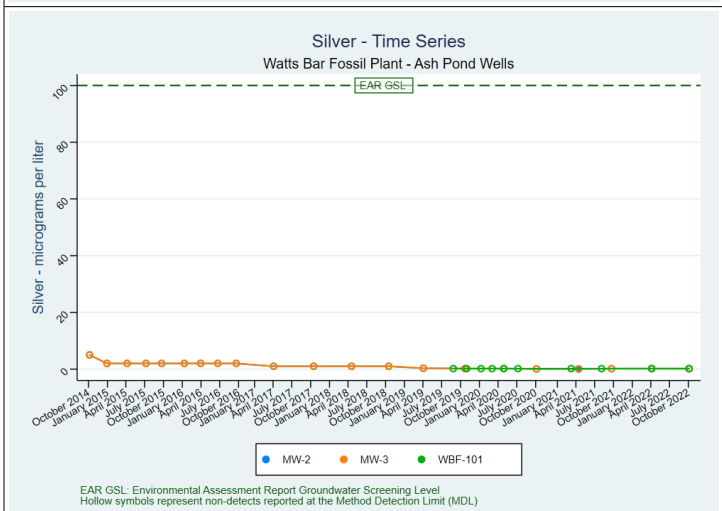

Thallium - Time Series
Watts Bar Fossil Plant - Ash Pond Wells
EAR GSL
Thallium - micrograms per liter
0.0
0.5
1.0
1.5
2.0
October 2014
January 2015
April 2015
July 2015
October 2015
January 2016
April 2016
July 2016
October 2016
January 2017
April 2017
July 2017
October 2017
January 2018
April 2018
July 2018
October 2018
January 2019
April 2019
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
MW-2
MW-3
WBF-101
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

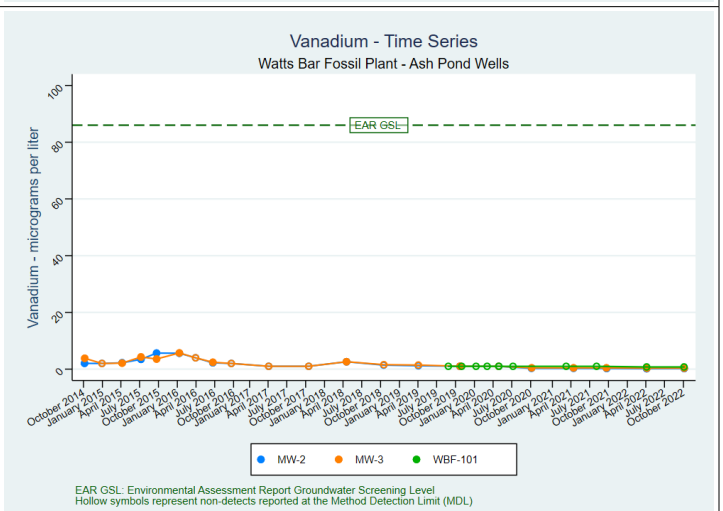
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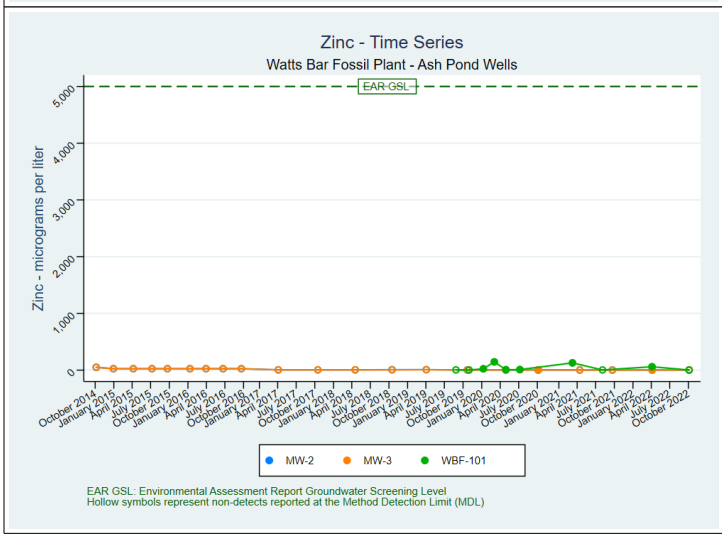
Time Series Plots
Ash Pond Wells
TDEC Appendix I Parameters
Watts Bar Fossil Plant - Spring City, Tennessee







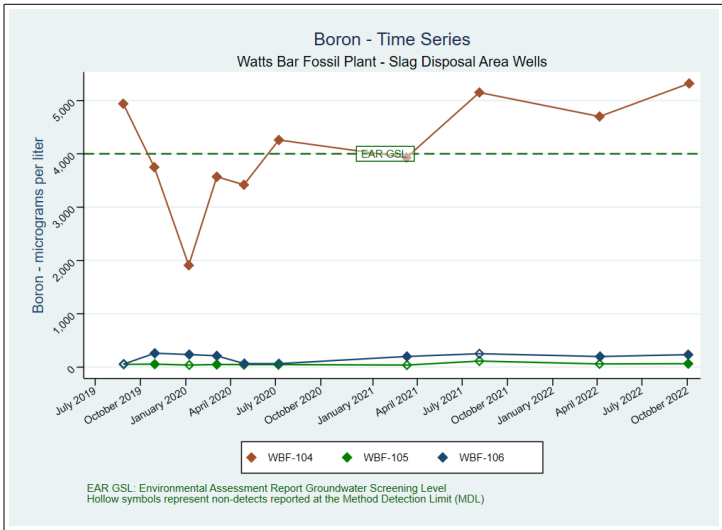


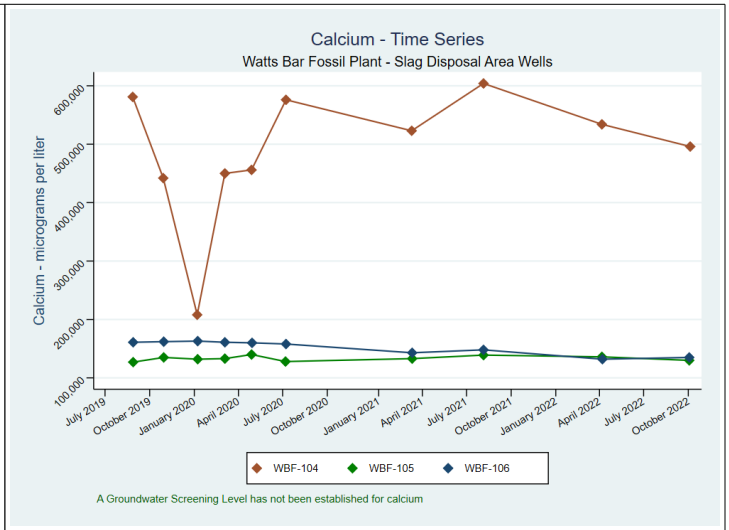


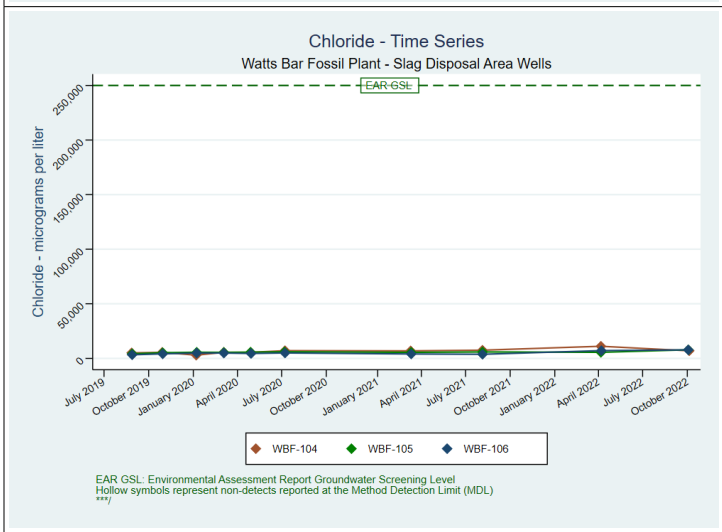
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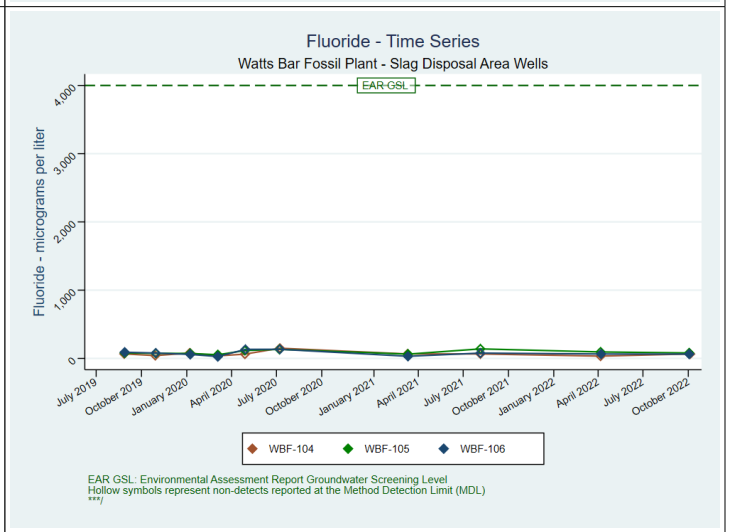
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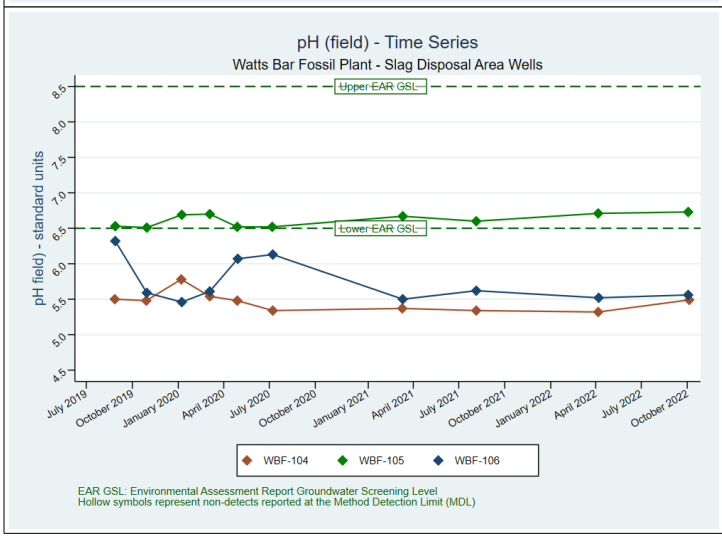
Time Series Plots
Slag Disposal Area Wells
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

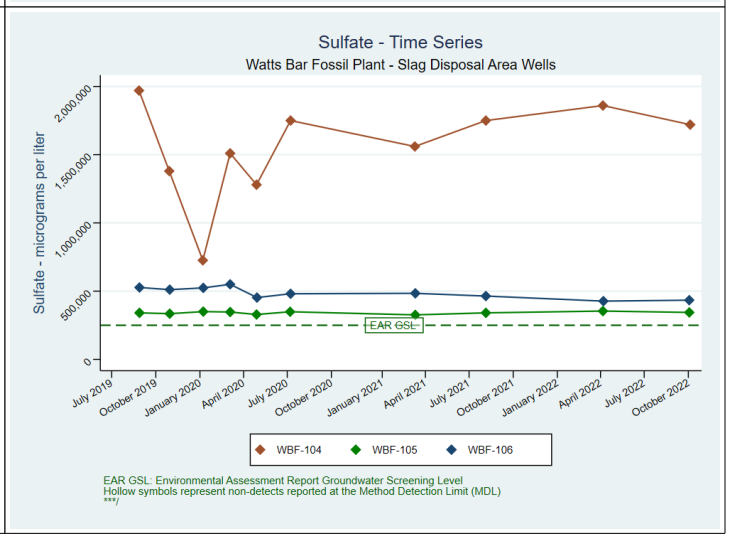


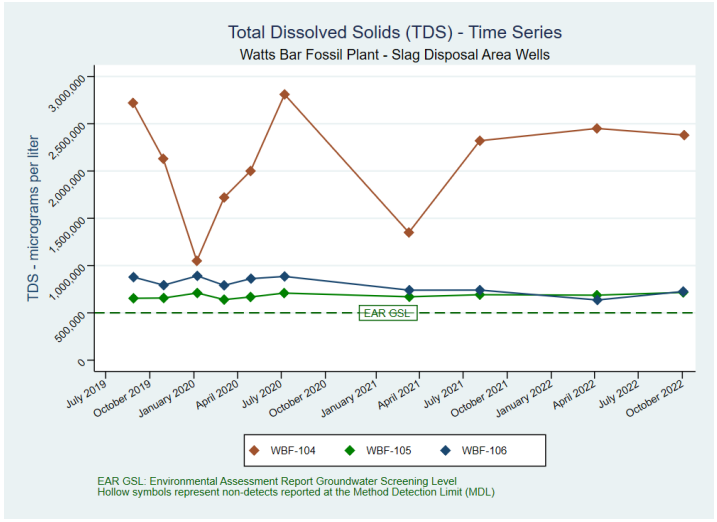








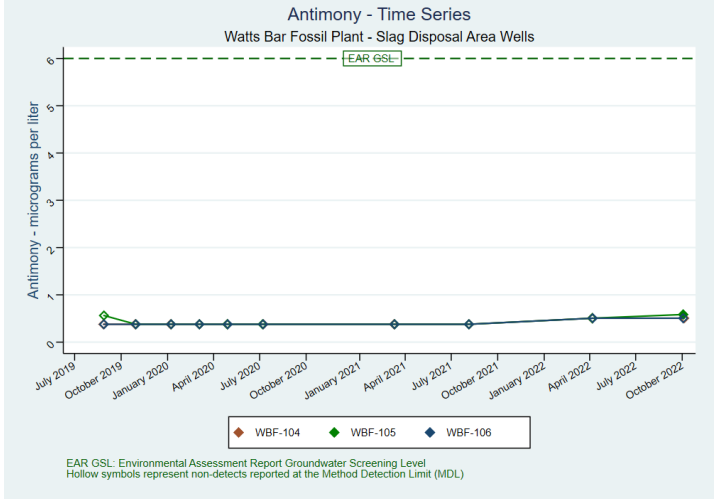


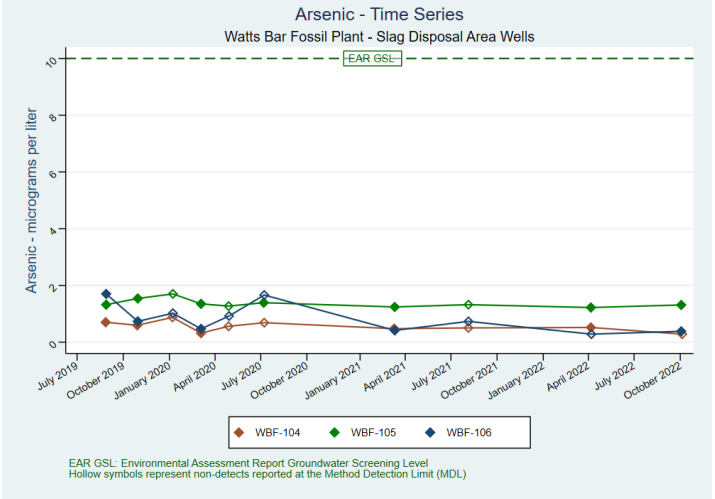


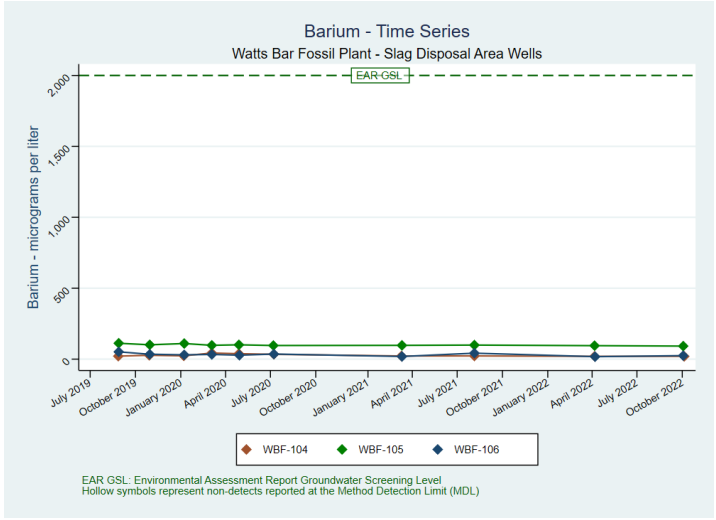
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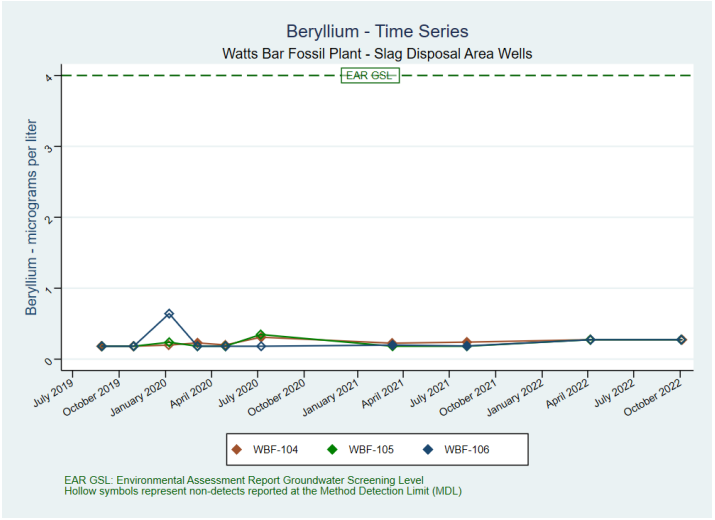
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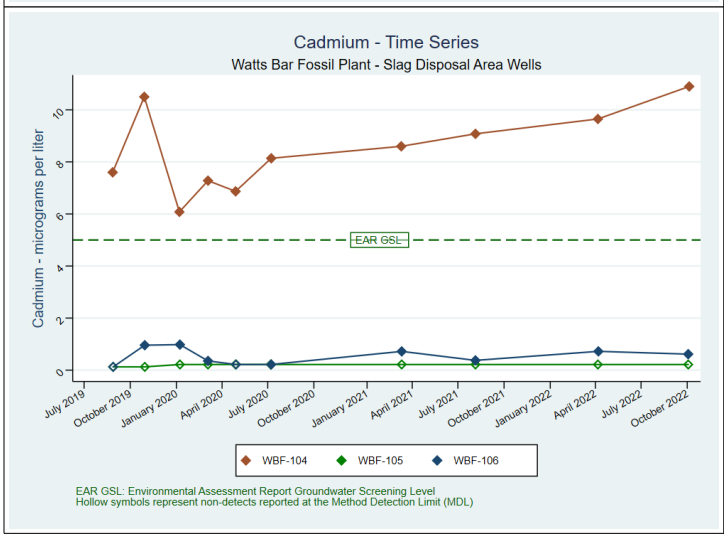
Time Series Plots
Slag Disposal Area Wells
CCR Rule Appendix IV Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

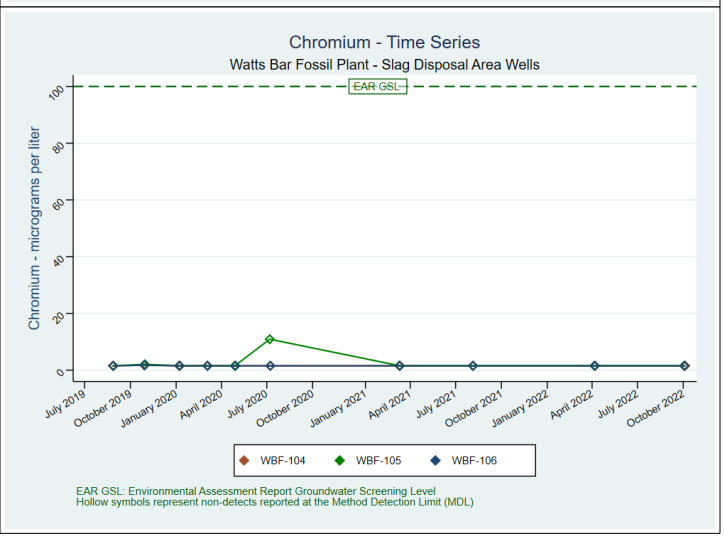




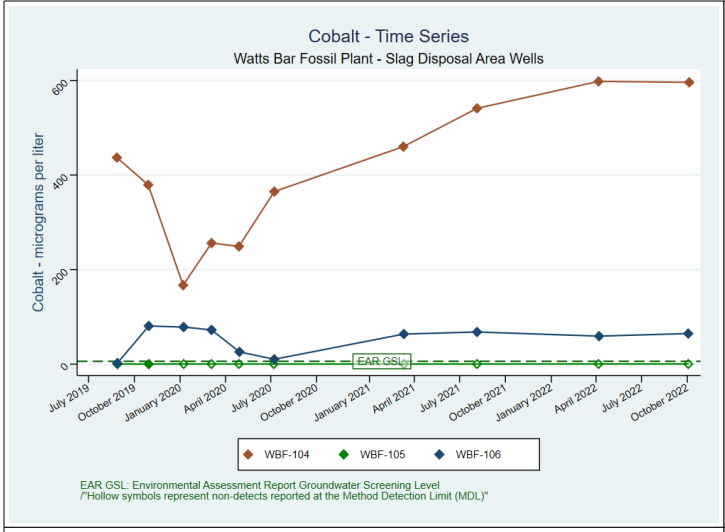


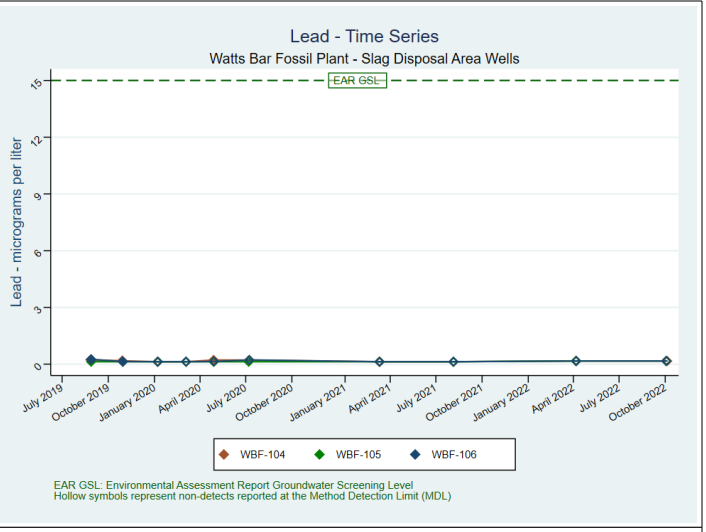


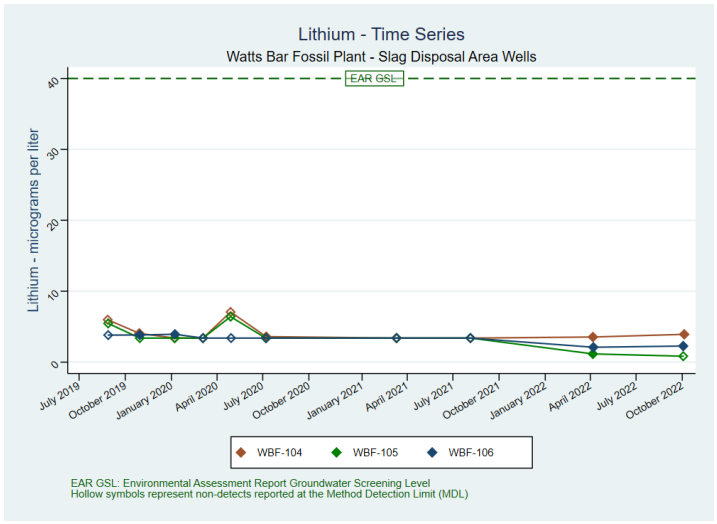


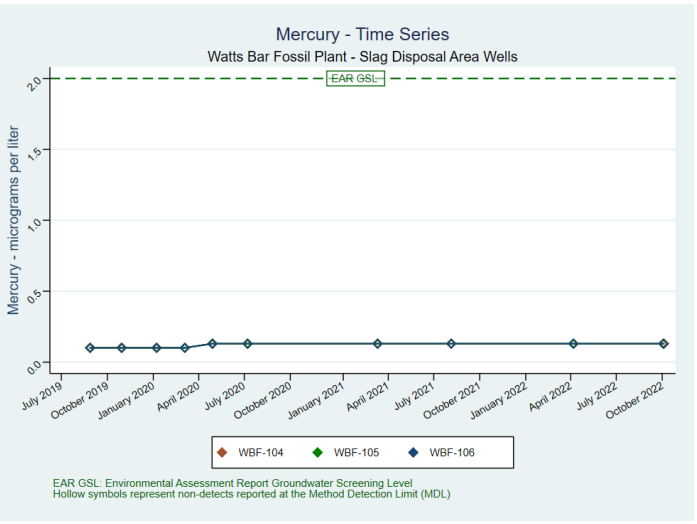


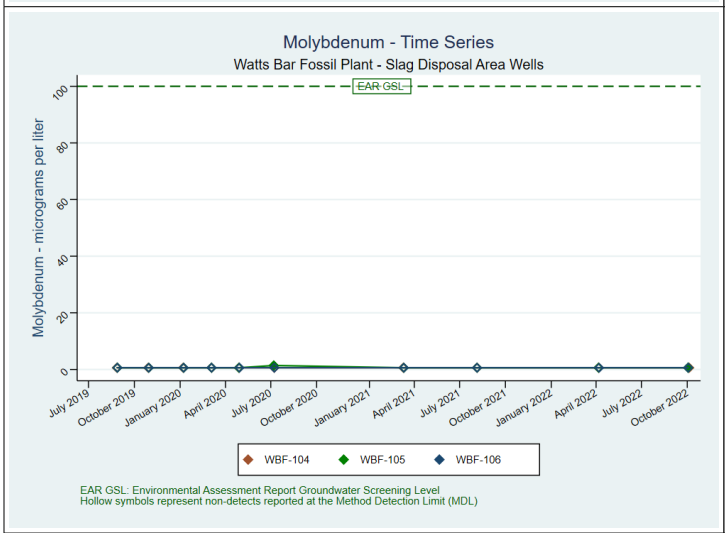
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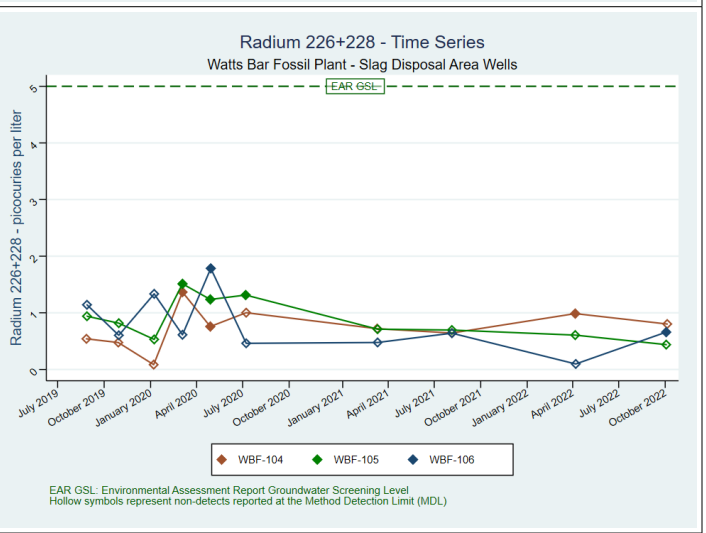

Cobalt - Time Series
Watts Bar Fossil Plant - Slag Disposal Area Wells
Cobalt - micrograms per liter
0
200
400
600
EAR GSL
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-104
WBF-105
WBF-106
EAR GSL: Environmental Assessment Report Groundwater Screening Level
/"Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)"

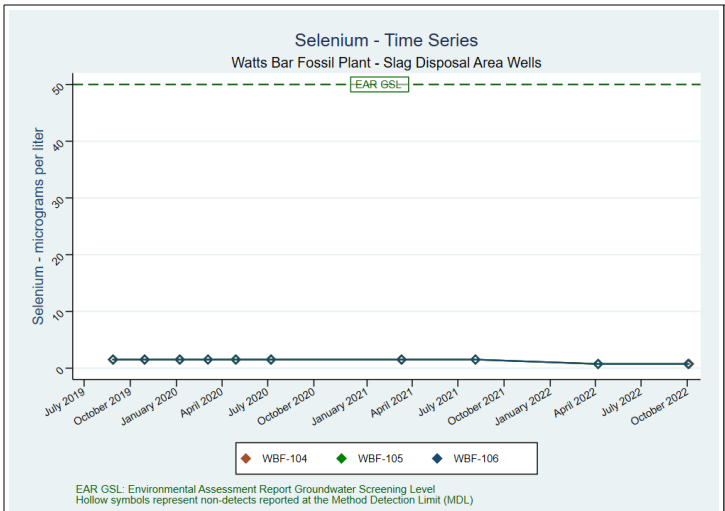

Lead - Time Series
Watts Bar Fossil Plant - Slag Disposal Area Wells
Lead - micrograms per liter
0
3
6
9
12
15
EAR GSL
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-104
WBF-105
WBF-106
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

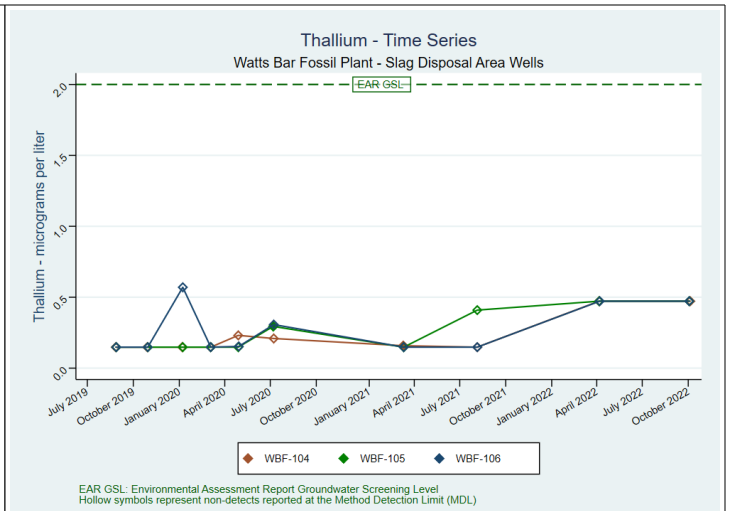

Lithium - Time Series
Watts Bar Fossil Plant - Slag Disposal Area Wells
Lithium - micrograms per liter
0
10
20
30
40
EAR GSL
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-104
WBF-105
WBF-106
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)


Mercury - Time Series
Watts Bar Fossil Plant - Slag Disposal Area Wells
Mercury - micrograms per liter
0.0
0.5
1.0
1.5
2.0
EAR GSL
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-104
WBF-105
WBF-106
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)


Molybdenum - Time Series
Watts Bar Fossil Plant - Slag Disposal Area Wells
Molybdenum - micrograms per liter
0
20
40
60
80
100
EAR GSL
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-104
WBF-105
WBF-106
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

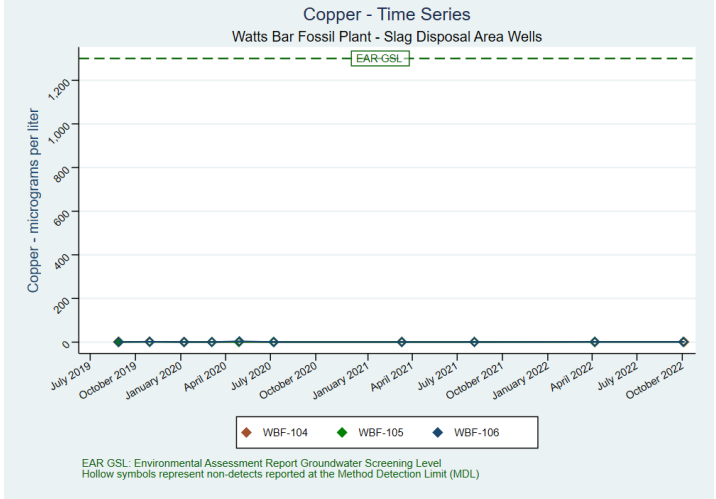

Radium 226+228 - Time Series
Watts Bar Fossil Plant - Slag Disposal Area Wells
Radium 226+228 - picocuries per liter
0
1
2
3
4
5
EAR GSL
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-104
WBF-105
WBF-106
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

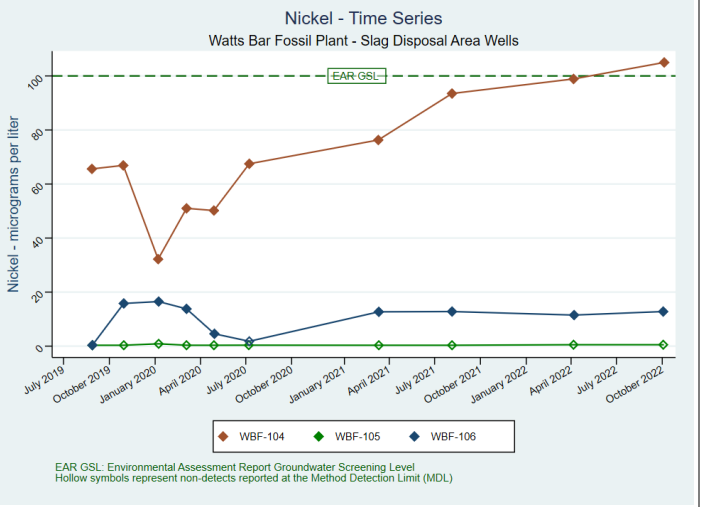

Selenium - Time Series
Watts Bar Fossil Plant - Slag Disposal Area Wells
EAR GSL
Selenium - micrograms per liter
0
10
20
30
40
50
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-104
WBF-105
WBF-106
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

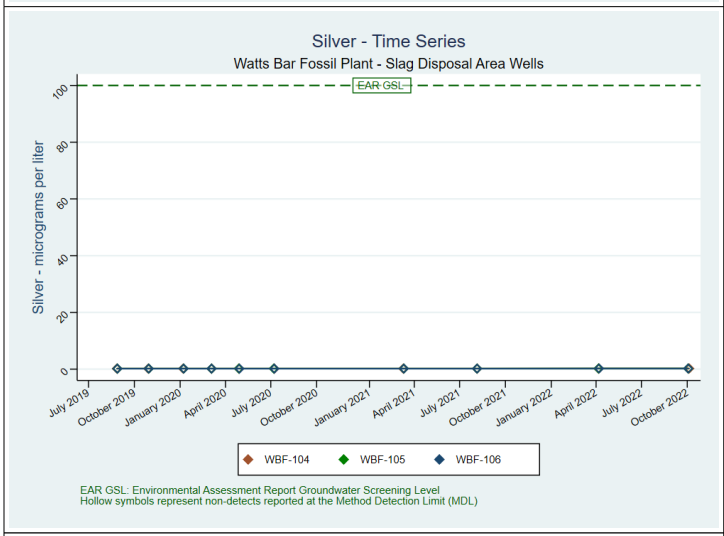

Thallium - Time Series
Watts Bar Fossil Plant - Slag Disposal Area Wells
EAR GSL
Thallium - micrograms per liter
0.0
0.5
1.0
1.5
2.0
July 2019
October 2019
January 2020
April 2020
July 2020
October 2020
January 2021
April 2021
July 2021
October 2021
January 2022
April 2022
July 2022
October 2022
WBF-104
WBF-105
WBF-106
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

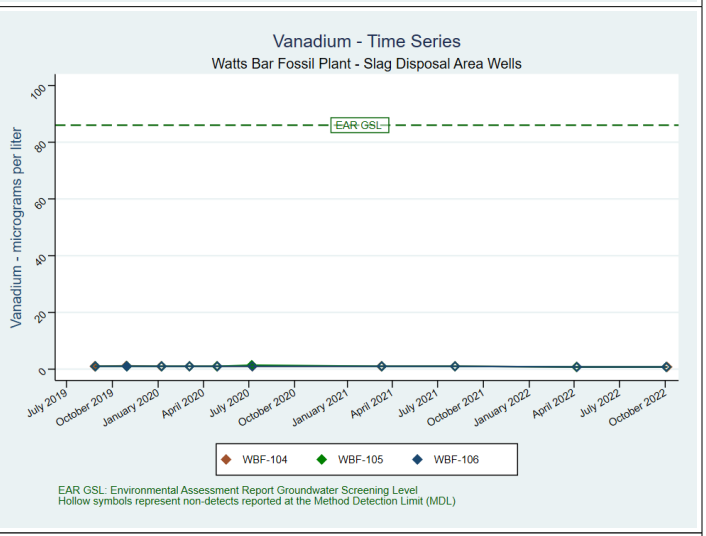
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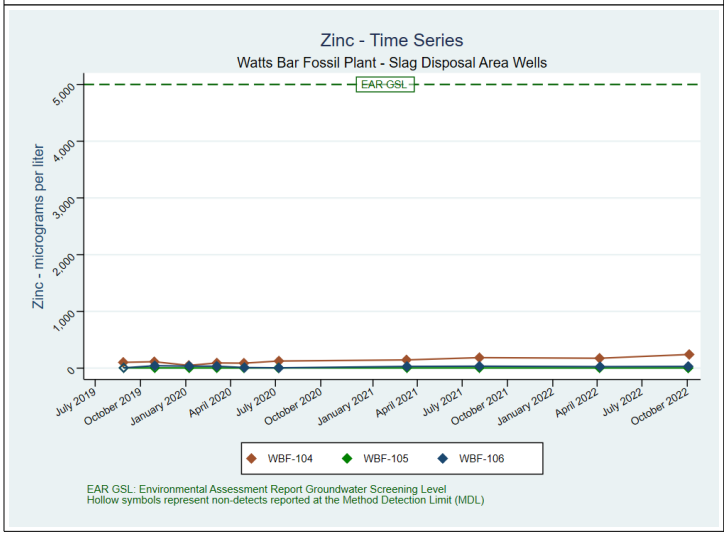
Time Series Plots
Slag Disposal Area Wells
TDEC Appendix I Parameters
Watts Bar Fossil Plant - Spring City, Tennessee







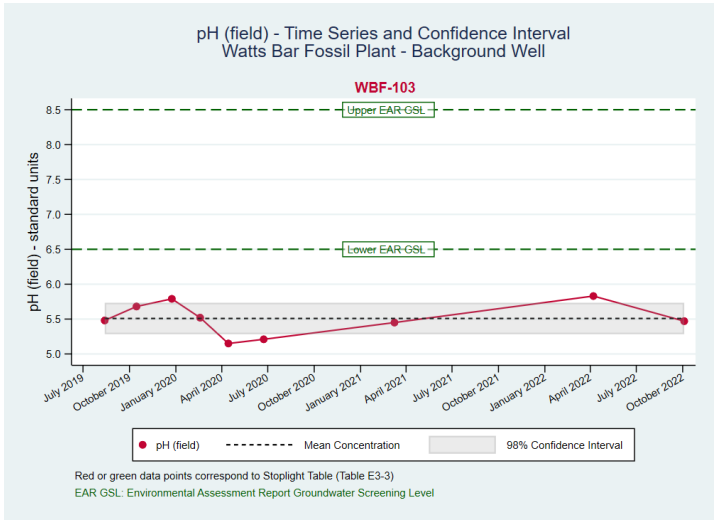




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ATTACHMENT E.3-D
LINEAR REGRESSION PLOTS

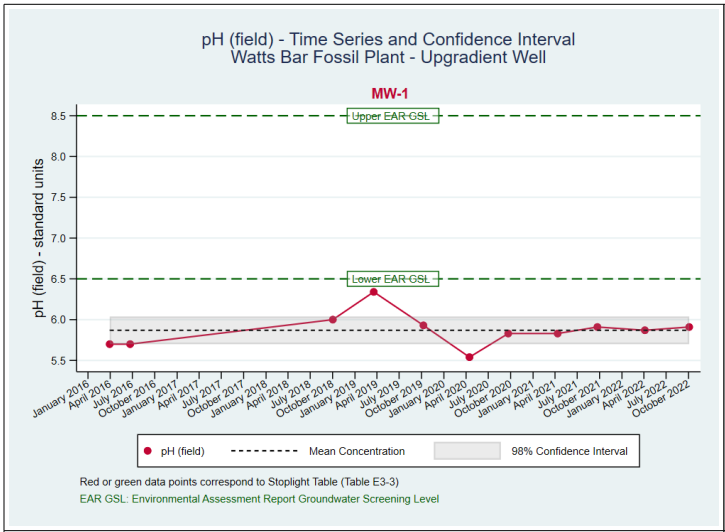
Regression Plots
Background Well
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

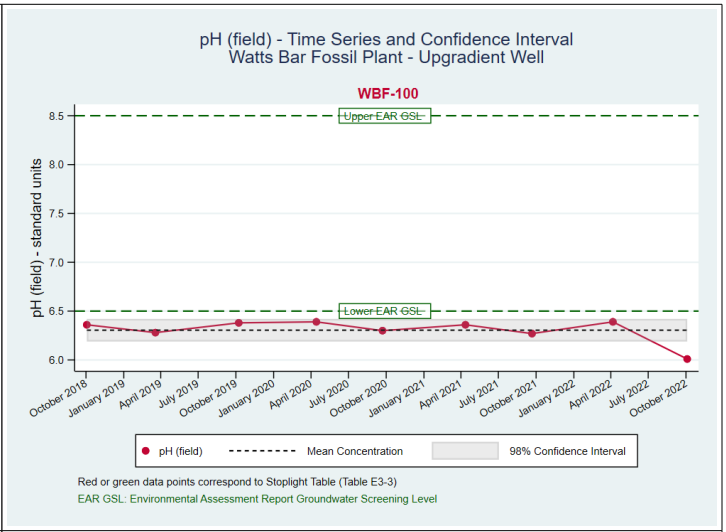


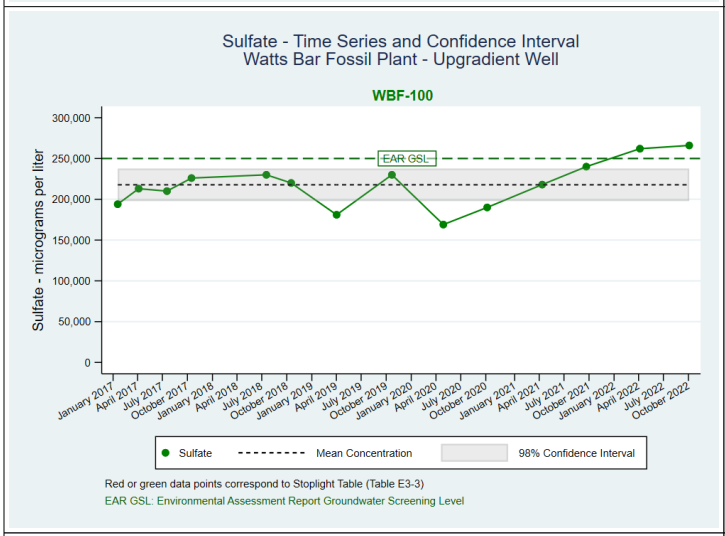
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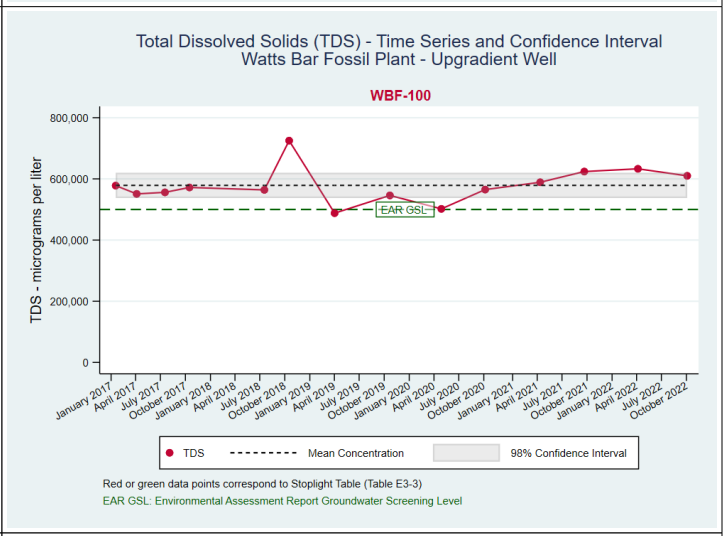
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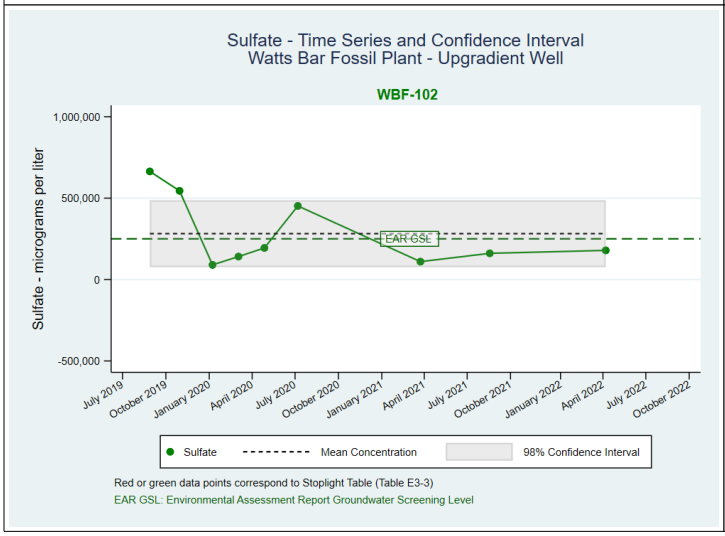
Regression Plots
Upgradient Wells
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

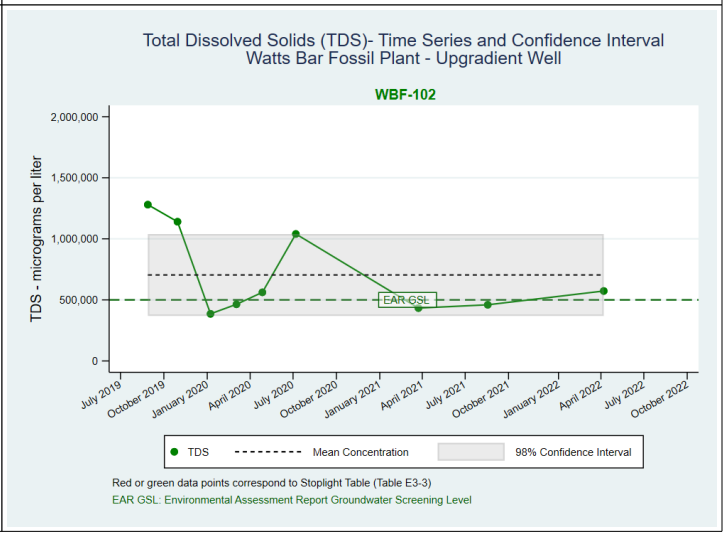






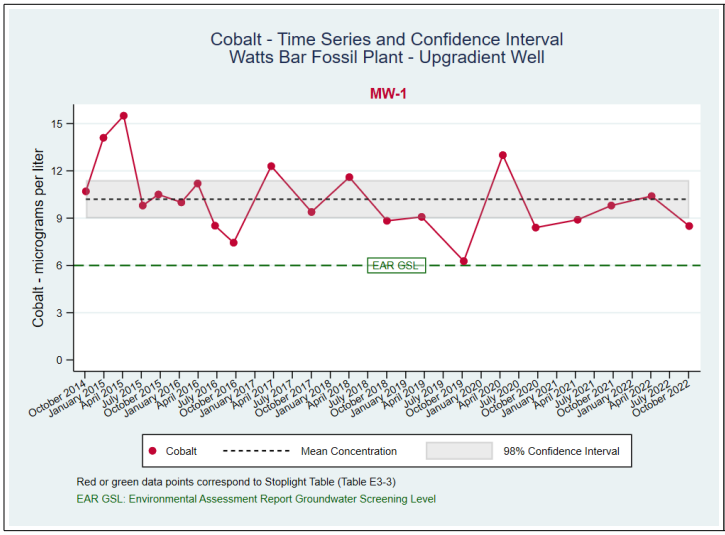


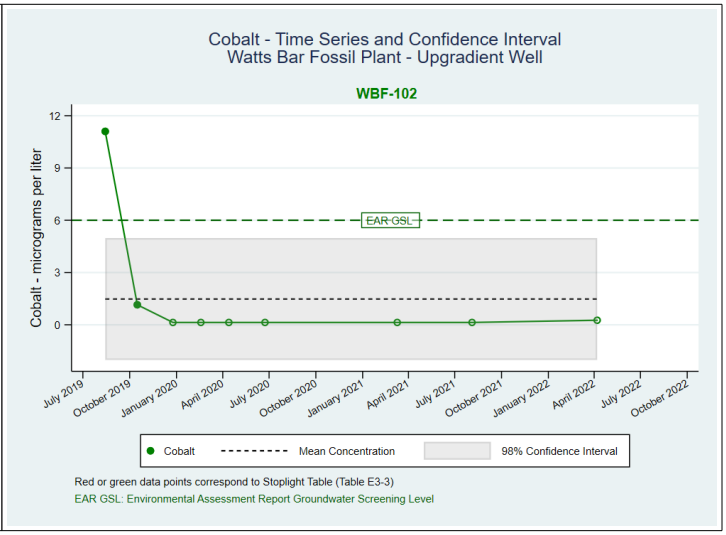




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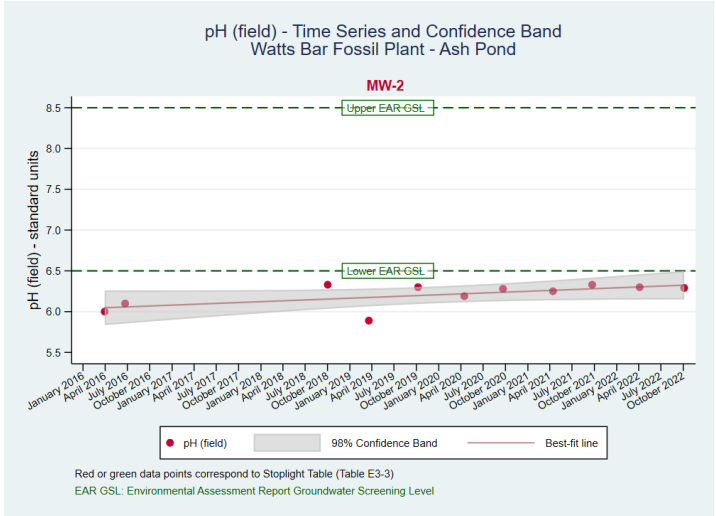
Regression Plots
Upgradient Wells
CCR Rule Appendix IV Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

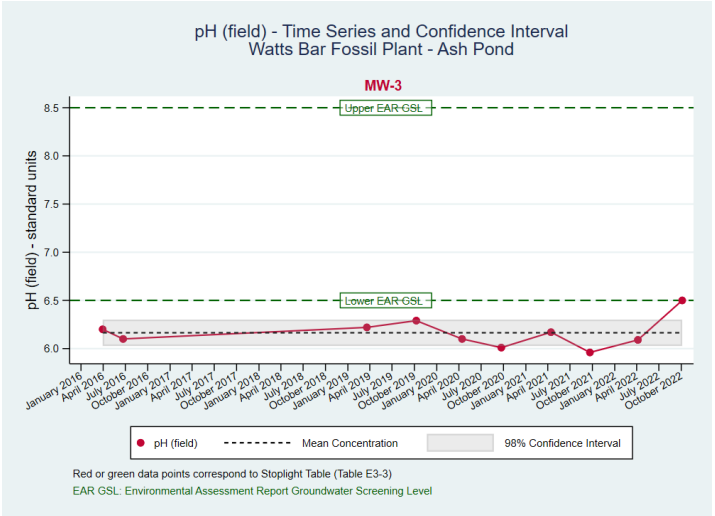


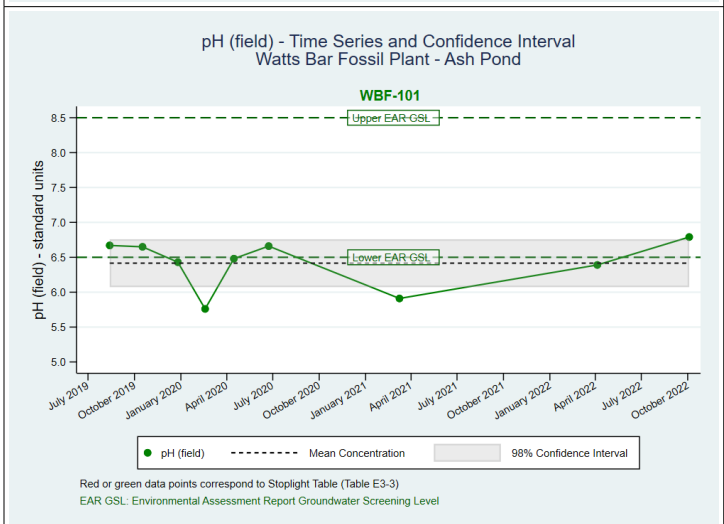


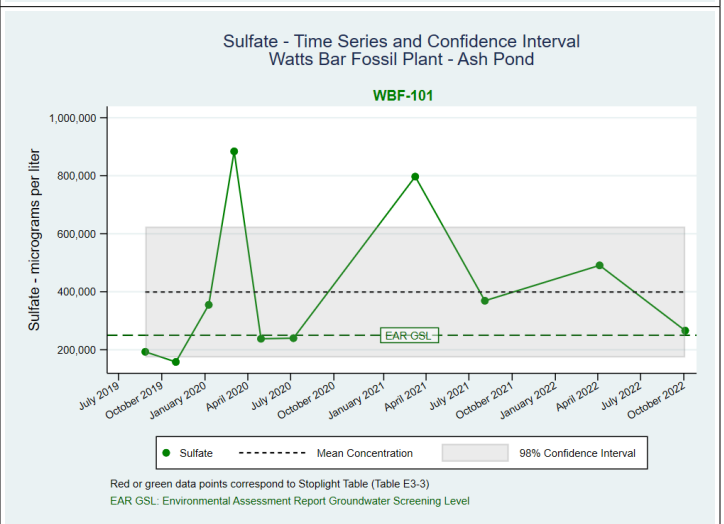
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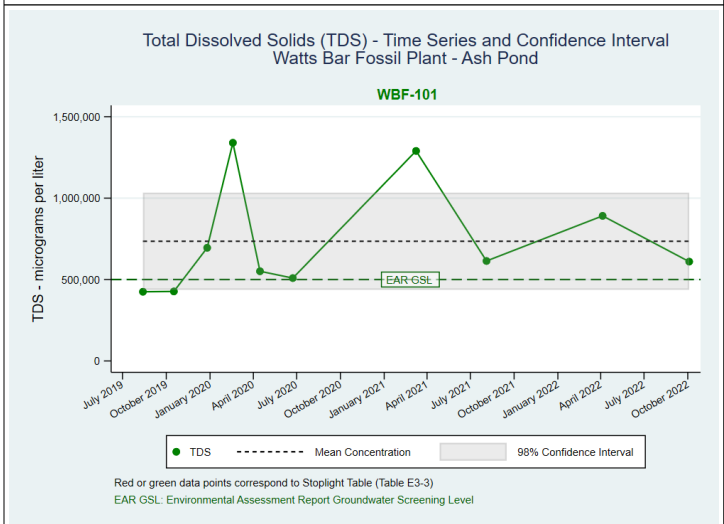
Regression Plots
Ash Pond
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee







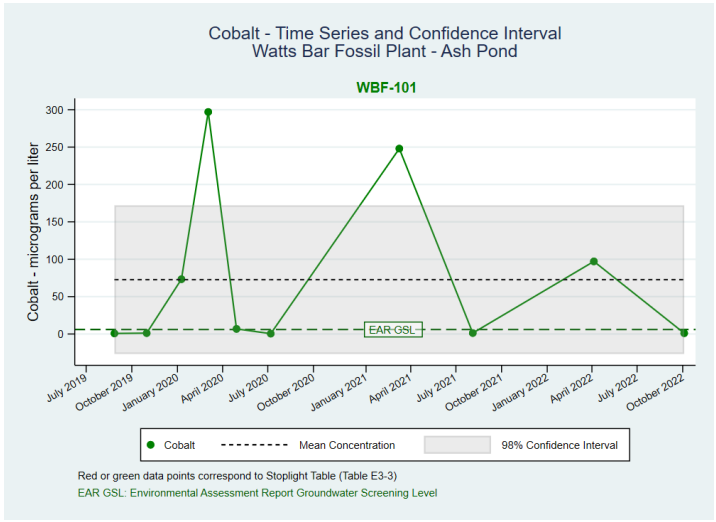




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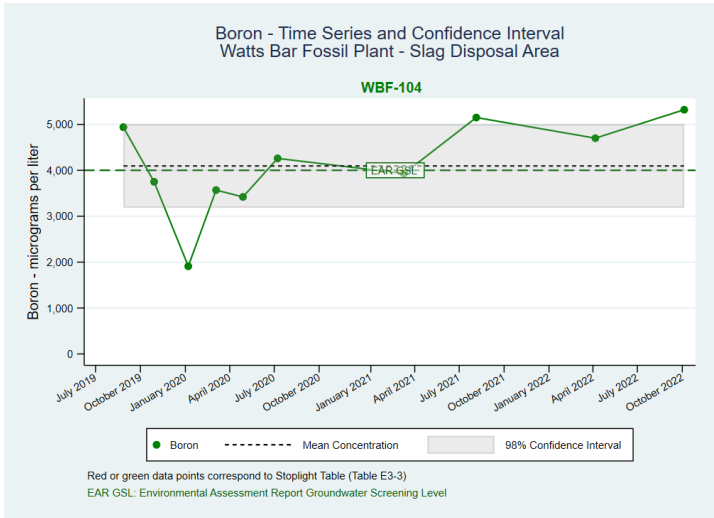
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CCR Rule Appendix IV Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

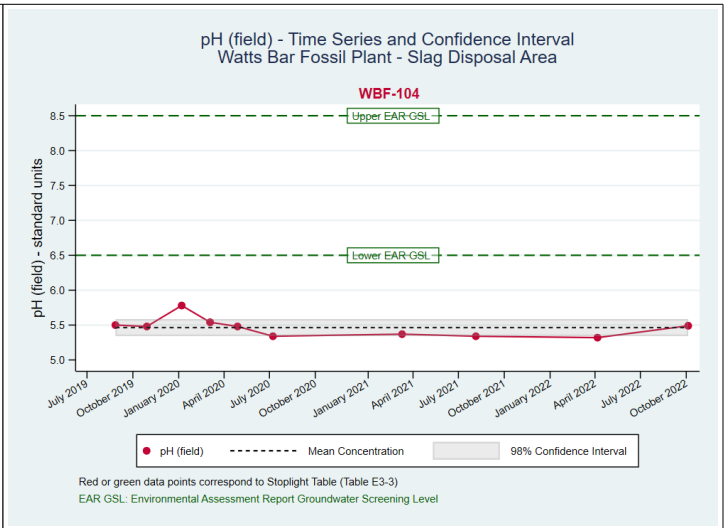


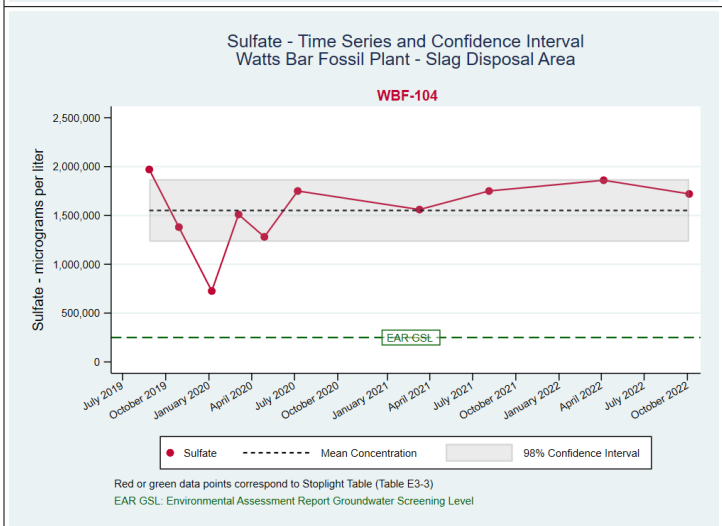
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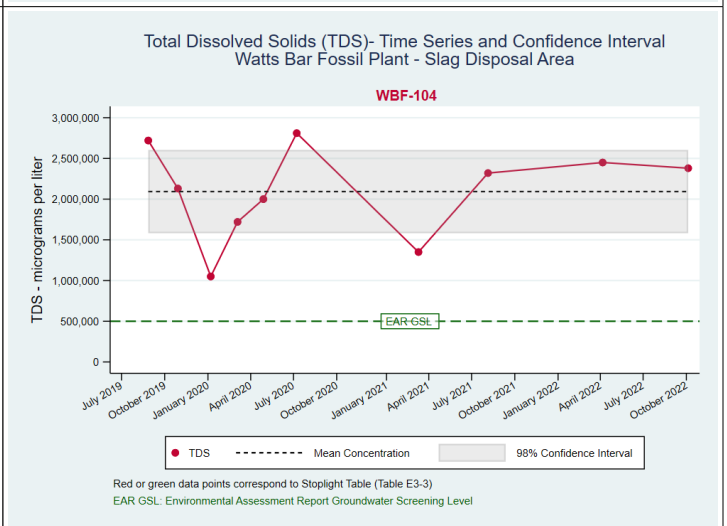
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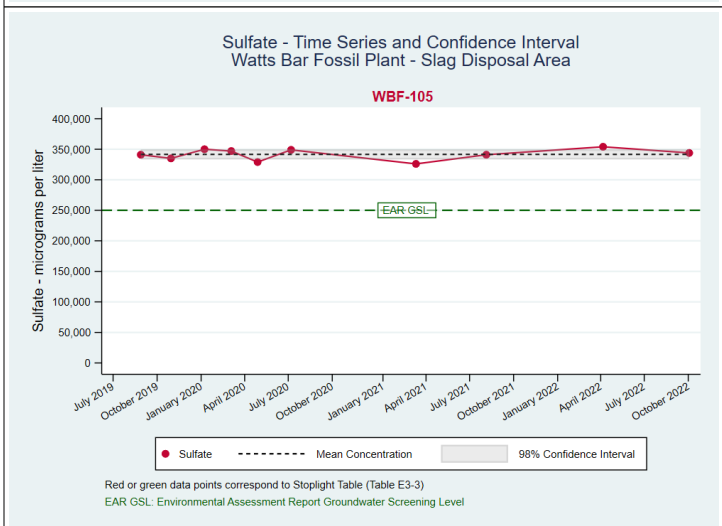
Regression Plots
Slag Disposal Area
CCR Rule Appendix III Parameters
Watts Bar Fossil Plant - Spring City, Tennessee

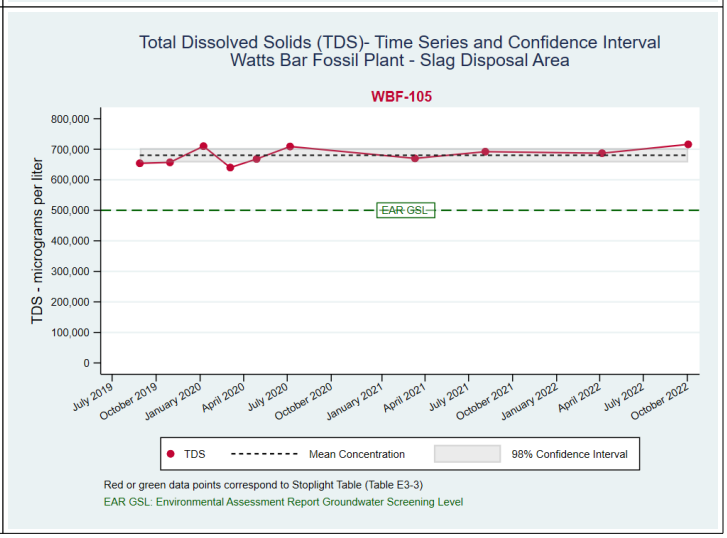


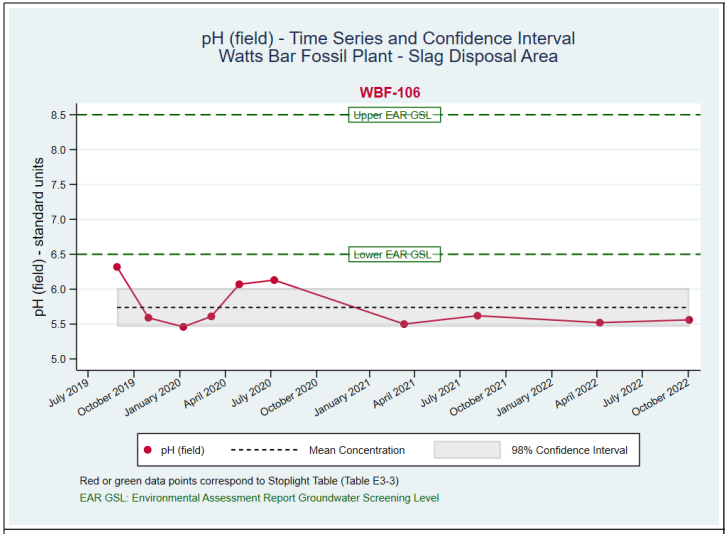


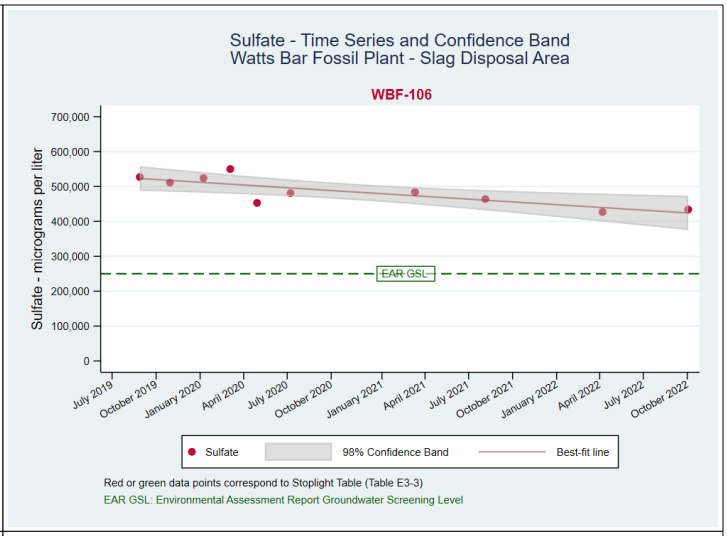


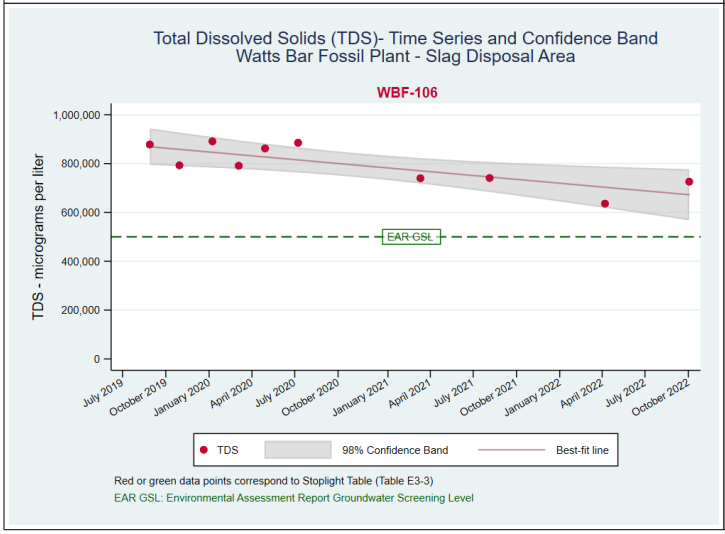






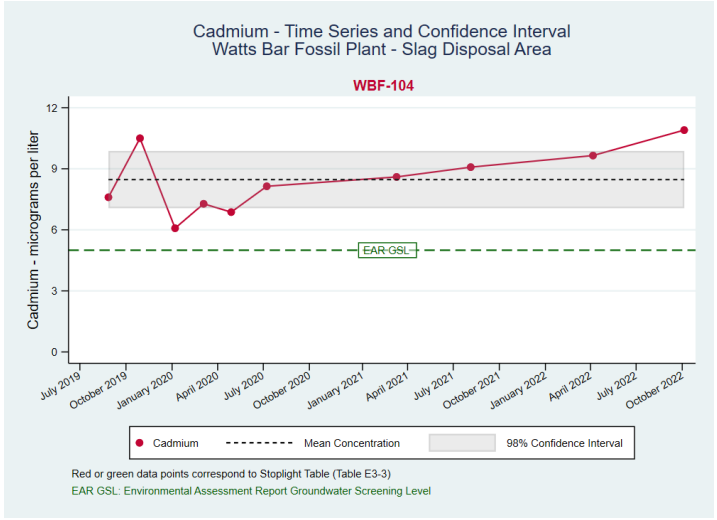


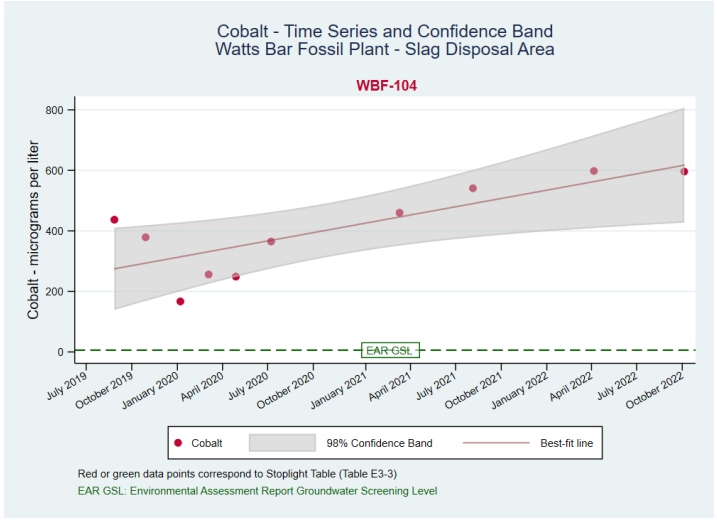


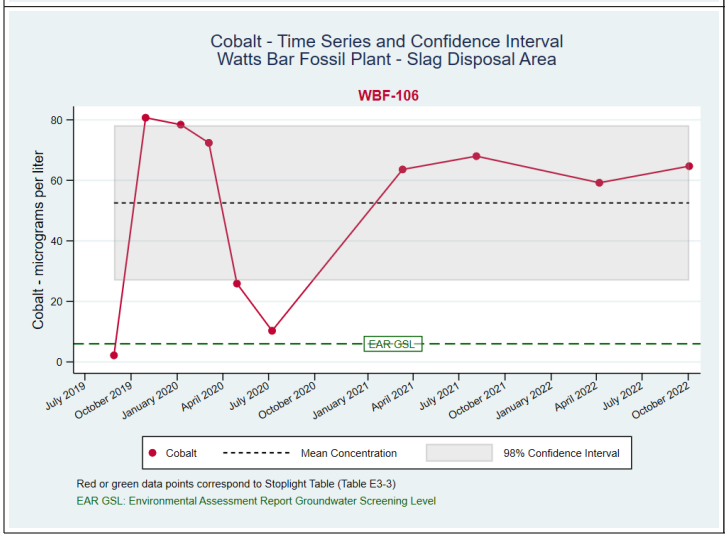


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Regression Plots
Slag Disposal Area
CCR Rule Appendix IV Parameters
Watts Bar Fossil Plant - Spring City, Tennessee



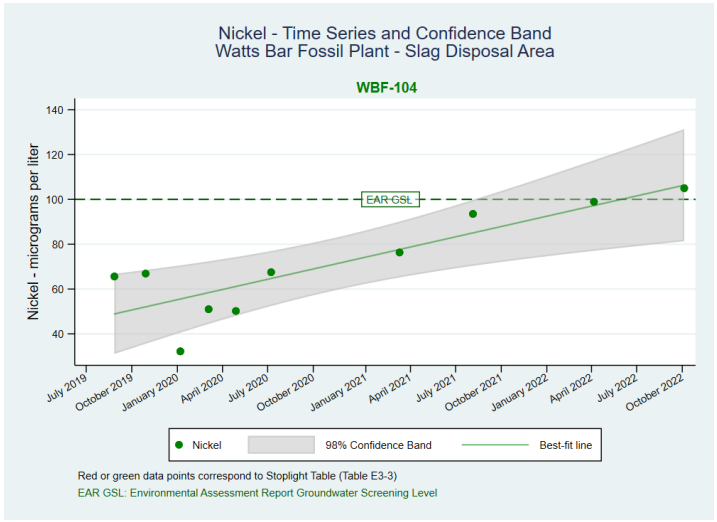




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Regression Plots
Slag Disposal Area
TDEC Appendix I Parameters
Watts Bar Fossil Plant - Spring City, Tennessee



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ATTACHMENT E.3-E
LINEAR REGRESSION RESULTS

Attachment E.3-E - Linear Regression Results
Groundwater Investigation - Watts Bar Fossil Plant - Spring City, Tennessee

Well	Constituent Type	Constituent	p-value	Trend summary[1]
WBF-103	CCR Rule Appendix III Parameters	pH (field)	0.7349	No trend detected
MW-1	CCR Rule Appendix III Parameters	pH (field)	0.6425	No trend detected
	CCR Rule Appendix IV Parameters	Cobalt	0.0765	No trend detected
WBF-100	CCR Rule Appendix III Parameters	pH (field)	0.1745	No trend detected
		Sulfate	0.0941	No trend detected
		Total dissolved solids	0.4268	No trend detected
WBF-102	CCR Rule Appendix III Parameters	Sulfate	0.1548	No trend detected
		Total dissolved solids	0.1784	No trend detected
	CCR Rule Appendix IV Parameters	Cobalt	0.2431	No trend detected
MW-2	CCR Rule Appendix III Parameters	pH (field)	0.0405	Increasing
MW-3	CCR Rule Appendix III Parameters	pH (field)	0.7873	No trend detected
WBF-101	CCR Rule Appendix III Parameters	pH (field)	0.8232	No trend detected
		Sulfate	0.7076	No trend detected
		Total dissolved solids	0.6272	No trend detected
	CCR Rule Appendix IV Parameters	Cobalt	0.941	No trend detected
WBF-104	CCR Rule Appendix III Parameters	Boron	0.0757	No trend detected
		pH (field)	0.1694	No trend detected
		Sulfate	0.2552	No trend detected
		Total dissolved solids	0.5816	No trend detected
	CCR Rule Appendix IV Parameters	Cadmium	0.0525	No trend detected
		Cobalt	0.0063	Increasing
	TDEC Appendix I Paramters	Nickel	0.0016	Increasing
WBF-105	CCR Rule Appendix III Parameters	Sulfate	0.5959	No trend detected
		Total dissolved solids	0.1088	No trend detected
WBF-106	CCR Rule Appendix III Parameters	pH (field)	0.1891	No trend detected
		Sulfate	0.0035	Decreasing
		Total dissolved solids	0.005	Decreasing
	CCR Rule Appendix IV Parameters	Cobalt	0.4628	No trend detected

Notes
CCR Rule - Title 40, Code of Federal Regulations, Part 257
1. Trend evaluated using linear regression. Slope considered significant when $p<0.05$.
2. Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV constituent. In this table, fluoride has been grouped with the Appendix III constituents only to avoid duplication of results.

APPENDIX E.4

STATISTICAL ANALYSIS OF SEEP INVESTIGATION

Originally Published as Appendix D of the Seep Sampling and Analysis Report

DRAFT

Appendix D – Statistical Analysis of Water Quality Parameters

Watts Bar Fossil Plant
Seep Investigation

May 21, 2021

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

Revision Record

Revision	Description	Date
0	Submittal to TVA	May 21, 2021

APPENDIX D – STATISTICAL ANALYSIS OF WATER QUALITY PARAMETERS

Sign-off Sheet

This document entitled Appendix D – Statistical Analysis of Water Quality Parameters was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____
Chris LaLonde, Associate Senior Statistician/Risk Assessor

Reviewed by _____
Rebekah Brooks, Principal Hydrogeologist

Approved by _____
Carole M. Farr, Senior Principal Geologist

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Attachment D.3 Normal Q-Q Plots
Attachment D.4 Measurement Results Plots, Tolerance Limits, and Areas of Interest

Abbreviations

α	alpha
AOC	Area of Concern
AOI	Area of Interest
CCR	Coal Combustion Residuals
DO	Dissolved Oxygen
H_a	Alternative hypothesis
H_o	Null hypothesis
µS/cm	MicroSiemens per Centimeter
mg/L	Milligrams per Liter
Q-Q Plot	Quantile-Quantile plot
SAP	Sampling and Analysis Plan
SAR	Sampling and Analysis Report
Stantec	Stantec Consulting Services Inc.
USEPA	United States Environmental Protection Agency
UTL	Upper Tolerance Level
WBF	Watts Bar Fossil Plant

APPENDIX D – STATISTICAL ANALYSIS OF WATER QUALITY PARAMETERS

May 21, 2021

1.0 INTRODUCTION

A statistical analysis of water quality parameter data collected in the Tennessee River adjacent to the Watts Bar Fossil Plant (WBF Plant) was conducted as part of the seep investigation. The statistical analysis was used to evaluate whether there are statistically significant differences between monitoring results collected “adjacent” to and “upstream” of the historical seep and identified AOI locations and between intermediate and upstream control areas for four water quality parameters (i.e., dissolved oxygen [DO], pH, specific conductance and temperature). This appendix to the WBF Plant Seep Sampling and Analysis Report (SAR) presents the statistical approach and methods used for this analysis and the analysis results.

2.0 OBJECTIVE

The objective of the statistical analysis is to identify statistically significant differences between four water quality parameter results (i.e., DO, pH, specific conductance, and temperature) measured “adjacent” to historical seep/AOI locations and results measured “upstream” of these location. As described in Section 3.2.1 of this SAR, six historical seep locations and the two identified AOIs adjacent to the Tennessee River were targeted for monitoring at the WBF Plant for the seep investigation. These locations were.combined (or clustered) for data analyses because of their close proximity (WBF-HSA1-5). The historical seep /AOI locations included in this statistical analysis are listed in Table D.1 and shown on Exhibits A.1, A.2, and A.3 (Appendix A).

Additional Areas of Interest (AOIs) will be identified only when statistically significant evidence indicates that: 1) water quality parameter results collected “adjacent” to the historical seep/AOI cluster are different than water quality parameter results collected “upstream” of these locations for all four parameters or 2) water quality parameter results collected adjacent to intermediate areas differ significantly from the upstream control area for all four parameters.

3.0 DATASETS

In accordance with the Seep Sampling and Analysis Plan (SAP), datasets were generated consisting of water quality parameter measurements for each of the four field parameters (i.e., DO, pH, specific conductance, and temperature) for the historical seep/AOI locations identified by Tennessee Valley Authority for evaluation. The data used in the statistical analysis were obtained in spreadsheet format from the "*Seep Investigation/ Surface Stream Field Parameter Measurement Forms"*, which were prepared in real time as the field investigation was being conducted. Statistical datasets for the water quality parameter results measured downstream, adjacent to, and upstream of the historical seep locations (Seeps A, #1-#5) and two AOIs identified during the accessible area inspection were aggregated (or "clustered") for the statistical analysis based on their close proximity (WBF-HSA1-5). A summary of the measurement location identifications and the number of measurements is provided in Table D.1.

Parameter measurements were also collected in intermediate areas, or inaccessible areas covered with riprap located upstream and downstream of WBF-HSA1-5. The distance between each measurement was typically 200 feet. Overall, this resulted in the collection of a total of eight measurements (four downstream and four upsteam of WBF-HSA1-5) in the intermediate areas .

Finally, data were also collected from an upstream control area. A total of 21 measurements were collected from the upstream control area. The distance between measurement locations was approximately five feet. The measurement locations are shown in Exhibit A.1 (Appendix A) and provided on Table B.1 (Appendix B).

4.0 STATISTICAL ANALYSIS METHODS

In accordance with the Seep SAP, the following statistical analysis methods were used to evaluate the water quality parameter measurement results:

- Formal hypothesis testing was used to identify statistically significant differences between adjacent and upstream monitoring data for clustered historical seep/AOI locations, WBF-HSA1-5, by comparison of mean/median parameter measurements between the datasets using parametric or non-parametric statistical methods
- Tolerance interval methods were utilized to assess significant differences between parameter measurements collected adjacent to the intermediate area and the upstream control area.
- Since statistically significant differences were identified for WBF-HSA1-5 for all four water quality parameters, tolerance interval methods were used to identify specific areas within WBF-HSA1-5 that may warrant additional investigation.

The statistical analysis was conducted in three phases: 1) exploratory data analysis/outlier screening, 2) testing of statistical assumptions, and 3) formal hypothesis testing. These phases are discussed below. Analyses were conducted using United States Environmental Protection Agency (USEPA) ProUCL (version 5.1.002) and STATA Statistics and Data Analysis (version 15.1).

4.1 EXPLORATORY DATA ANALYSIS/OUTLIER SCREENING

Initially, the monitoring data associated with historical seep/AOI locations were plotted on measurement result plots and in side-by-side box plots. Measurement result plots allow for the identification of trends, outliers, and to visually identify differences between water quality parameter measurements that were collected in a downstream to upstream direction. Box plots allow for the identification of outliers and provide a basic sense of the potential underlying statistical distributions. The measurement result and box plots are presented in Attachment D.1. In addition to graphical analysis, descriptive statistics were calculated for each water quality parameter for WBF-HSA1-5, intermediate areas, and the upstream control area. A summary of the descriptive statistics is presented in Attachment D.2.

Outliers are data points that are abnormally high or low as compared to the rest of the measurements and may represent anomalous data and/or data errors. Outliers may also represent natural variation of constituent concentrations in environmental systems. During the seep investigation, water quality parameters were measured at the intermediate areas, the upstream control area and downstream, adjacent and upstream of WBF-HSA1-5. Utilizing the complete set of data to screen for the presence of outliers allowed for evaluation of potential spatial variation in the natural ecosystem. Screening for outliers is a critical step as outliers can bias the statistical testing results.

Outliers were identified graphically using side by side box plots and measurement result plots (Attachment D.1). If suspect visual outliers were identified, then the data were analyzed to determine if they represent extreme outliers. The Tukey's procedure (Tukey 1977) as outlined in the USEPA



document*: "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Unified Guidance"* (USEPA 2009) – (Unified Guidance) can be used to identify extreme outliers. The Tukey's procedure is briefly outlined below:

***Lower extreme outlier*:** The value is less than: 25th percentile – (3 x interquartile range)

or

Upper extreme outlier: The value is greater than: 75th percentile + (3 x interquartile range)

where:

Interquartile Range = 75th percentile value – 25th percentile value

If an outlier was identified visually and considered extreme (Tukey's procedure), then formal statistical testing (Dixon's and/or Rosner tests) was conducted to determine if the data point(s) represents statistically significant outlier(s).

Utilizing the procedures outlined above, no outliers were identified and all water quality parameter measurements were used in the statistical analyses.

4.2 TEST OF STATISTICAL ASSUMPTIONS

In environmental applications, formal hypothesis testing is commonly used to compare mean/median values between two "populations". In the case of the investigation of the clustered historical seep/AOI locations, WBF-HSA1-5, at the WBF Plant, the populations can be defined as monitoring results collected ***adjacent*** to WBF-HSA1-5 and monitoring results collected immediately ***upstream*** of WBF-HSA1-5. In the case of the investigation of the intermediate areas, the population can be defined as monitoring results collected ***adjacent to the intermediate areas*** and monitoring results collected in the ***upstream control area***.

Parametric statistical tests must meet statistical assumptions of normality and equality of variance (homoscedasticity) between the populations. If the data fit or could be transformed to fit the normal distribution, two sample t-tests were used to identify statistically significant differences between monitoring data collected adjacent WBF-HSA1-5 and data collected immediately upstream. If the data set could not be transformed to a data set that was normally distributed, then non-parametric (distribution free) statistics were used to identify significant differences between adjacent and upstream measurements.

The assumption of normality was tested visually using Normal Quantile-Quantile (Q-Q) plots and statistically using the Shapiro-Wilks Test (alpha = 0.10). Normal Q-Q plots are presented in Attachment D.3. A data set that is not normally distributed can often be transformed to a data set that is normally distributed using simple mathematical transformations on the data. Ladder of power transformation techniques were used to try to normalize data sets that were originally identified as not-normally distributed. If a suitable transformation was identified, this transformation was applied to the data prior to



proceeding with the two-sample t-test. No data sets could be normalized using the ladder of powers methods.

The assumption of homoscedasticity was tested using the F-Test for the Equality of Two-Variances. In instances where variances were not equal, the Satterthwaite's degrees of freedom were used to adjust for unequal variances. The results of the evaluation of normality and equality of variances between the upstream and adjacent measurement locations are presented in Table D.2.

4.3 FORMAL HYPOTHESIS TESTING

The objective of formal hypothesis testing is to determine whether mean/median water quality parameter measurement results for the "adjacent" datasets are statistically different than the results for the "upstream" datasets. Hypothesis tests are standard statistical methods used to decide between two competing alternatives based on available data. Uncertainties arise when sample statistics are used as estimates of "true" but unknown population parameters (mean, standard deviation). Hypothesis testing provides the framework for managing these uncertainties and controlling potential decision errors (Ofungwu 2014).

Hypothesis tests are set up based on two competing alternatives. The null hypothesis (H_o) represents baseline conditions or conditions of no effects/differences. The null hypothesis can be represented mathematically as:

H_o: Mean Adjacent – Mean Upstream = 0; or Mean Adjacent = Mean Upstream

The alternative hypothesis (H_a) is simply the opposite of the null hypothesis and can be written as:

H_a: Mean Adjacent – Mean Upstream ≠ 0

If there is an *a priori* knowledge that a parameter's mean may be greater than or less than the upstream mean, the alternative hypothesis can be written as:

H_a: Mean Adjacent – Mean Upstream < 0 or Mean Adjacent – Mean Upstream > 0

The former alternative hypothesis is considered a two-sided test (e.g., it is unknown if the difference will be higher or lower and therefore, need to account for both possibilities). The later alternative hypotheses are considered a one-sided test (e.g., there is *a priori* knowledge of the direction of change – the parameter measurement is expected to be higher or lower when comparing adjacent to upstream monitoring data).

Appropriate hypothesis tests were established prior to examining the data. Two-sided tests were used to evaluate pH and temperature as there is no *a priori* knowledge that these parameters are expected to be higher or lower when comparing adjacent to upstream monitoring data. However, one-sided tests were used to evaluate DO and specific conductance based on the following assumptions: 1) the DO would be expected to be lower adjacent to an active seep in a similar area as opposed to DO in a surface stream due to aeration of the moving water and 2) the specific conductance would be expected to be higher



adjacent to an active seep as opposed to upstream due to expected higher concentrations of metals in water emanating from a Coal Combustion Residuals (CCR) unit.

The null and alternative hypotheses for the seep investigation are presented below:

- DO (milligrams/Liter)
    - H_o: Mean $DO_{Adjacent}$ – Mean $DO_{Upstream} = 0$
    - H_a: Mean $DO_{Adjacent}$ – Mean $DO_{Upstream} < 0$
- pH (Standard Units)
    - H_o: Mean $pH_{Adjacent}$ – Mean $pH_{Upstream} = 0$
    - H_a: Mean $pH_{Adjacent}$ – Mean $pH_{Upstream} \neq 0$
- Specific Conductance (microSiemens/centimeter)
    - H_o: Mean Specific Conductance $_{Adjacent}$ - Mean Specific Conductance $_{Upstream} = 0$
    - H_a: Mean Specific Conductance $_{Adjacent}$ – Mean Specific Conductance $_{Upstream} > 0$
- Temperature (degrees Celsius)
    - H_o: Mean $Temperature_{Adjacent}$ – Mean $Temperature_{Upstream} = 0$
    - H_a: Mean $Temperature_{Adjacent}$ – Mean $Temperature_{Upstream} \neq 0$.

Statistical hypothesis tests produce a p-value (probability value). The p-value represents the probability that the mean/median of the adjacent measurements is equal to the mean/median of the upstream measurements. If the p-value of a statistical test is ***small*** *(i.e., below the significance level)*, the normal procedure is to reject the H_o, accept the H_a, and conclude there is a ***statistically significant difference between adjacent and upstream monitoring results that is unlikely to have occurred by chance.***

The statistician establishes the “significance level” (alpha, α), which is typically set between 0.01 and 0.10. This can be thought of as an acceptable false positive rate (e.g., rejecting H_o when H_o is true, which is equivalent to finding a statistically significant difference between adjacent and upstream monitoring data, when in fact one does not exist).

The significance level for a single test needs to be adjusted in situations where multiple hypothesis tests are going to be conducted at a site. Conducting multiple statistical tests on a site increases the chances of getting a significant result simply by chance (e.g. false positive statistical test result). For example, four statistical tests were conducted at the WBF Plant to identify differences in adjacent and upstream water quality parameter monitoring data for the seep investigation; if alpha is set at 0.1 and the multiple testing is ignored, then the cumulative error rate can be calculated:

Cumulative error rate = $1-(1-0.1)^4 = 34\%$ chance of making false positive error

The Bonferroni correction was utilized to adjust the significance level to control the site-wide false positive rate described above. This method simply divides the desired overall significance level (α = 0.10) by the number of hypothesis tests conducted site-wide (4 parameters x 1 clustered historical seep/AOI location = 4 tests). For the WBF Plant, the adjustment yields an individual test significance level of 0.1/4 tests = 0.025. Therefore, to reject H_o and determine that there is a statistically significant difference between adjacent and upstream monitoring results that is unlikely to have occurred by chance, the p-value of the test needs to be less than 0.025.

4.4 TOLERANCE INTERVALS

Tolerance limits consist of two values expected to contain a pre-specified proportion of the underlying data population with a specified level of confidence. For example, for a 95% tolerance interval with a 95% confidence level, there is 95% confidence that, on average, 95% of the data population is contained within the interval. The one-sided Upper Tolerance Level (UTL) is commonly used in environmental monitoring and is constructed using background data (Ofungwu 2014).

The calculation of the UTL is straightforward:

$$UTL = \overline{x} \pm \tau s$$

Where:

$\overline{x}$ = mean constituent concentration in background/control dataset

s = standard deviation of constituent in background/control dataset

τ = tau multiplier - based on size of dataset, confidence (95%) and desired coverage (95%).

Tolerance intervals were calculated in two cases: 1) for comparison of data collected from the upstream control area against data collected adjacent to the intermediate areas, and 2) for comparison of measurements from individual adjacent locations within the HSA1-4 cluster with measurements directly upstream of this area, as described in Section 4.5.

Prior to calculating tolerance intervals, the data were tested for normality and for outliers using methods described previously. If the data set could not be transformed to a data set that was normally distributed, then non-parametric (distribution free) statistics were used to calculate tolerance intervals.

The statistical null hypothesis (H_o) is that mean parameter measurements collected from the intermediate areas lie within the tolerance interval, and the alternate hypothesis (H_a) is that the mean parameter measurements are outside of the tolerance interval. In order to test these hypotheses, 95% confidence intervals around the mean parameter measurements from the intermediate areas were estimated and compared to the upstream control area tolerance intervals.

Prior to calculating confidence intervals, the monitoring data collected adjacent to the intermediate area were tested for normality and for outliers using methods described previously. If the data set could not be



transformed to a data set that was normally distributed, then non-parametric (distribution free) statistics were used to calculate confidence intervals.

Confidence intervals were calculated based on the following equation:

$$Confidence\ Interval = \overline{x} \pm t_{1-\propto/2,n-1} * s/\sqrt{n}$$

Where:

$\overline{x}$ = mean parameter measurement in intermediate area

s = standard deviation of parameter measurement in intermediate area

n = number of measurements in Intermediate area dataset

$t_{(1-\propto/2,n-1)}$ = two tailed t value, with n-1 degrees of freedom (where α = 0.05)

Statistically significant differences were identified if the confidence interval calculated using the intermediate area dataset fell outside of the tolerance interval based on the upstream control area data set.

4.5 ADDITIONAL STATISTICAL ANALYSIS TO IDENTIFY POTENTIAL AOIS

Based on the findings of the analyses described above, statistically significant differences were identified for all four water quality parameters when comparing measurements collected adjacent to and upstream of WBF-HSA1-5. An additional statistical analysis was conducted to limit specific areas where statistically significant differences in water quality measurements may occur and to identify potential additional AOIs within the area covered by WBF-HSA1-5 that may warrant additional investigation.

The analysis was designed to answer the question: *Do individual water quality parameter measurements collected at locations adjacent to WBF-HSA1-5 look different (e.g. either higher or lower) than measurements collected immediately upstream of WBF-HSA1-5?* To answer this question, tolerance limits were calculated for all four water quality parameters using measurements collected immediately upstream of historical seep locations WBF-HSA1-5. These tolerance limits represent upstream conditions where impacts from a potential inaccessible seep location (i.e. riprap covered) are unlikely. Individual measurement results collected adjacent to WBF-HSA1-5 were then compared to the upstream tolerance limits to identify individual measurement locations where tolerance limits were exceeded.

The measurement result plots (Attachment D.1) provide evidence that there are individual measurement locations adjacent to the WBF-HSA1-5 area with lower measurements for DO and pH as compared to the other individual measurements collected adjacent to WBF-HSA1-5. Also, there are groupings of higher measurements for specific conductance and temperature as compared to other measurements collected adjacent to WBF-HSA1-5.



APPENDIX D – STATISTICAL ANALYSIS OF WATER QUALITY PARAMETERS

May 21, 2021

The distribution of the data for each water quality parameter collected adjacent to WBF-HSA1-5 was also evaluated using side-by-side box plots (Attachment D.1). Based on visual evidence from the side-by-side box plots, the distributions for DO and pH appeared negatively skewed relative to other water quality parameter measurement locations, suggesting lower measurements for DO and pH were predominant in these data distributions. Lower tolerance limits were estimated for DO and pH. Conversely, the data distributions for specific conductance and temperature appeared positively skewed, suggesting that higher measurements for specific conductance and temperature were predominate in the data distribution. Upper tolerance limits were estimated for SC and temperature.

Additional potential AOI(s) were identified when all four water quality parameters measurements at individual locations collected adjacent to WBF-HSA1-5 exceeded their respective tolerance limits.



5.0 STATISTICAL ANALYSIS RESULTS

The following sections describe the results of 1) the hypothesis testing comparing the water quality parameter results between the adjacent and upstream measurements at WBF-HSA1-5, 2) the interval testing comparing the water quality parameter results from the intermediate area to the upstream control area, and 3) the tolerance limit testing comparing water quality parameter results from individual adjacent locations within the WBF-HSA1-5 area to water quality measurement data collected immediately upstream of WBF-HSA1-5.

5.1 HYPOTHESIS TESTING RESULTS: ADJACENT AND UPSTREAM MEASUREMENT COMPARISONS AT WBF-HSA1-5

A historical seep is considered an AOI when the mean/median values of all four water quality parameters (DO, pH, specific conductance, and temperature) are found to be statistically different when comparing adjacent to upstream monitoring data. For pH and temperature, the difference between upstream and adjacent measurements may be either positive or negative. Specific conductance would be expected to increase in proximity to an active seep due to higher concentrations of metals in water emanating from a CCR unit, and DO would be expected to decrease as seep water from a similar area would show decreased DO relative to a surface stream. Therefore, only significant increases in specific conductance and significant decreases in DO in the adjacent areas, relative to the upstream areas were evaluated. Table D.3 provides a summary of the hypothesis testing results, including the p-values obtained using procedures described in preceding sections to identify significant differences between adjacent and upstream water quality parameter monitoring data at WBF-HSA1-5. Statistically significant differences were identified for all four parameters at WBF-HSA1-5; therefore, additional AOIs were identified for possible further investigation.

5.2 INTERVAL TESTING RESULTS: INTERMEDIATE AREA COMPARISON TO UPSTREAM CONTROL AREAS

Water quality parameter measurement results collected from the intermediate areas in the Tennesee River were evaluated against monitoring data collected from the upstream control area to identify any potential AOI.

For the intermediate areas to be considered an AOI, the mean values of all four water quality parameters were required to be statistically different when monitoring data collected adjacent to the intermediate areas were compared to data collected in the upstream control area. Table D.4 presents a summary of the interval testing results used to identify significant differences between the intermediate areas and the upstream control area monitoring data. Statistically significant differences were not identified for all four parameters comparing intermediate areas to the upstream control area; therefore, this analysis did not identify any additional AOIs for further investigation.



5.3 ADDITIONAL INTERVAL TESTING RESULTS: INDIVIDUAL LOCATION COMPARISON TO UPSTREAM LOCATIONS WITHIN WBF-HSA1-5

An additional statistical analysis was conducted to limit specific areas where statistically significant differences in water quality measurements may occur and to identify potential additional AOIs within the area covered by WBF-HSA1-5 that may warrant additional investigation. Individual water quality parameter measurement results collected adjacent to WBF-HSA1-5 were evaluated against tolerance limits calculated from data collected immediately upstream of WBF-HSA1-5 to identify additional potential AOIs.

Potential additional AOI(s) within the WBF-HSA1-5 cluster area were identified when all four water quality parameters measured at individual locations adjacent to WBF-HSA1-5 exceeded their respective tolerance limits. Based on this analysis, one previously identified AOI (AOI02) was confirmed, and two additional AOIs (AOI03 and AOI04) were identified within the WBF-HSA1-5 cluster area.

A total of nine individual measurement locations where all four water quality parameters were either above or below their respective tolerance limits were identified. These locations were observed in three distinct areas within the WBF-HSA1-5 cluster area , as listed below:

- AOI02 bracketed by measurement location 35 to measurement location 43
- AOI03 bracketed by measurement location 68 to measurement location 74
- AOI04 bracketed by measurement location 90 to measurement location 92.

Exhibit A.3 provides a map showing these three areas and the individual locations where the water quality parameter measurements exceeded the tolerance limits and the identified AOIs. Attachment D.4 provides measurement result plots, tolerance intervals, with shading indicating the measurement locations that bound the individual AOIs that warrant additional investigation. Table D.5 provides a summary of the statistical testing used to identify AOIs.

6.0 REFERENCES

Ofungwu, J., 2014. *Statistical Applications for Environmental Analysis and Risk Assessment*. Hoboken, New Jersey: John Wiley and Sons, Inc.

Tukey, J.W., 1977. *Exploratory Data Analysis*. Reading, Massachusetts: Addison-Wesely, 1977

U.S. Environmental Protection Agency, 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance*.



TABLES

TABLE D.1 – Summary of Water Quality Parameter Measurement Locations
Watts Bar Fossil Plant
April 2019

Historical Seep/AOI Cluster	Measurement Location IDs	Number of Measurements		
		Downstream	Adjacent	Upstream
Tennessee River				
WBF-HSA1-5	WBF-HSA1-5-D-5 to WBF-HSA1-5-U-111	10	85	12

Notes:

1. Historical Seep (HS) location and measurement location identications (IDs) are shown on Exhibits A.1 through A.3 in Appendix A.

TABLE D.2 – Tests of Normality and Equality of Variances between Adjacent and Upstream Monitoring Results
Watts Bar Fossil Plant
April 2019

	Historical Seep/AOI Cluster
	Tennessee River
Monitoring Parameters	**WBF-HSA1-5**
Number of Samples (Adjacent / Upstream)	85/12
Dissolved Oxygen	Not Normal
pH	Not Normal
Specific Conductance	Not Normal
Temperature	Not Normal

Notes:

HS	Historical Seep
Not Normal	Data Sets (adjacent and upstream) are not normally distributed (alpha=0.01)

TABLE D.3 – Summary of Statistical Hypothesis Testing
Watts Bar Fossil Plant
April 2019

Historical Seep/AOI Cluster	Number of Samples	p-value			
		DO	pH	Specific Conductance	Temperature
Tennessee River					
	Adjacent / Upstream	mg/L	SU	uS/cm	DEG C
WBF-HSA1-5	85/12	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

Notes:

DEG C	degrees Celsius
DO	Dissolved Oxygen
HS	Historical Seep
mg/L	milligrams per Liter
SU	Standard Units
SWFPR	site wide false positive rate
uS/cm	microSiemens per centimeter

1. The p-value represents the probability that the mean of the adjacent measurements is equal to the mean of the upstream measurements. If a p-value is small (i.e., below the significance level), it is indicative that there is a statistically significant difference between adjacent and upstream monitoring results that is unlikely to have occurred by chance.

2. Bonferroni method used to adjust significance level (SWFPR/No. of statistical tests). Adjusted to 0.10/4=0.025 (4 parameters x 1 HS)

3. Shaded values indicate a statistically significant difference between measurements collected adjacent and upstream of historical seep/AOI cluster WBF-HSA1-5 (p-value is below adjusted significance level).

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TABLE D.4 – Summary of Intermediate Area Statistical Testing
Watts Bar Fossil Plant
April 2019

Parameter	95 % Confidence Interval - Intermediate Area	Tolerance Interval	
		WBF-UC	Significant?
Dissolved Oxygen	(11.1 - 11.6)	(11.1 - 11.6)	NO
pH	(8.10 - 8.29)	(8.19 - 8.41)	NO
Specific Conductance	(154 - 166)	(152 - 156)[(a)]	NO
Temperature	(16.8 - 17.9)	(17.0 - 17.4)[(a)]	NO

Notes:

%	percent
WBF-UC	Upstream Control collected on 4/17/2019 in Tennessee River

[(a)] Data not normally distributed; reported values are non-parametric upper tolerance limits, reported as the minimum and maximum measurement. Level of confidence (65.9%)

1. Tolerance Interval: 95% tolerance interval with 95% coverage.

2. Shaded values are statistically significant differences if the confidence interval calculated using the intermediate area data set falls outside of the tolerance interval.

TABLE D.5: Summary of Statistical Testing to Identify Areas of Interest (AOI) Watts Bar Fossil Plant

Area of Interest	Measurement ID	Dissolved Oxygen	pH (field)	Specific Conductance (field)	Temperature Water (C)
	Tolerance Limit	LTL < 10.71	LTL < 8.142	UTL > 158.4	UTL > 16.9
AOI02	WBF-HSA1-5-A-35	**10.52**	**7.99**	**177.2**	**18.9**
	WBF-HSA1-5-A-36	**10.63**	**7.91**	**181.4**	16.9
	WBF-HSA1-5-A-37	**10.64**	**7.15**	**265.9**	**17.1**
	WBF-HSA1-5-A-38	**10.65**	**7.86**	**177.1**	16.9
	WBF-HSA1-5-A-39	**9.61**	**7.78**	**196.9**	16.9
	WBF-HSA1-5-A-40	**10.14**	**7.55**	**217.9**	**17.1**
	WBF-HSA1-5-A-41	10.93	**7.99**	**165.6**	16.8
	WBF-HSA1-5-A-42	**10.42**	**8.04**	**171.9**	16.9
	WBF-HSA1-5-A-43	**9.77**	**7.96**	**186.9**	**17**
AOI03	WBF-HSA1-5-A-68	**10.06**	**7.97**	**162.6**	**17**
	WBF-HSA1-5-A-69	11.16	**8.06**	**167.9**	**17**
	WBF-HSA1-5-A-70	11.09	**8.11**	**189.9**	**17.2**
	WBF-HSA1-5-A-71	**10.44**	8.17	**179.1**	**17**
	WBF-HSA1-5-A-72	11	8.22	**168.9**	**17.1**
	WBF-HSA1-5-A-73	**9.61**	**7.97**	**257.9**	**17**
	WBF-HSA1-5-A-74	**10.61**	**7.97**	**215.2**	**17.5**
AOI04	WBF-HSA1-5-A-90	**10.14**	**7.4**	**231**	**17.1**
	WBF-HSA1-5-A-91	10.88	**7.8**	**178**	**17**
	WBF-HSA1-5-A-92	**10.55**	**7.94**	**172.9**	**17.1**

Notes:

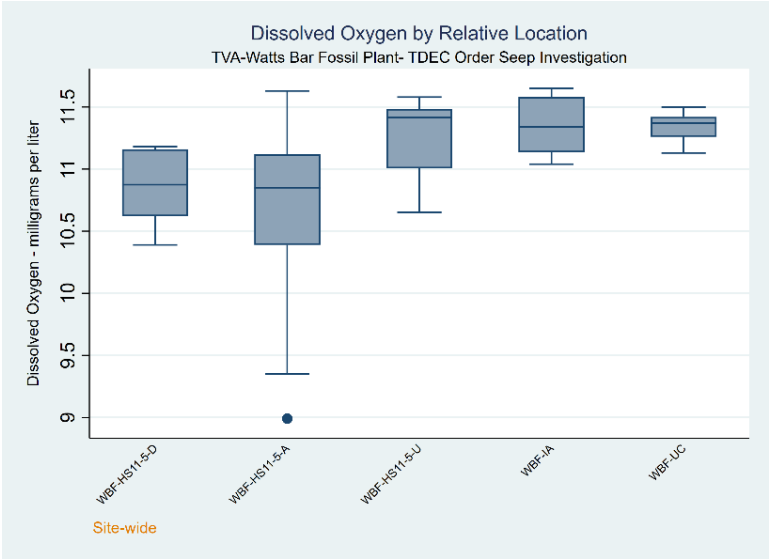
LTL: Lower Tolerance Limit
UTL: Upper Tolerance Limit
Bold and underlined indicates that individual parameter measurement exceeds its respective LTL or UTL
Bold, underlined and shaded indicates that all 4 parameters exceed their respective LTL or UTL

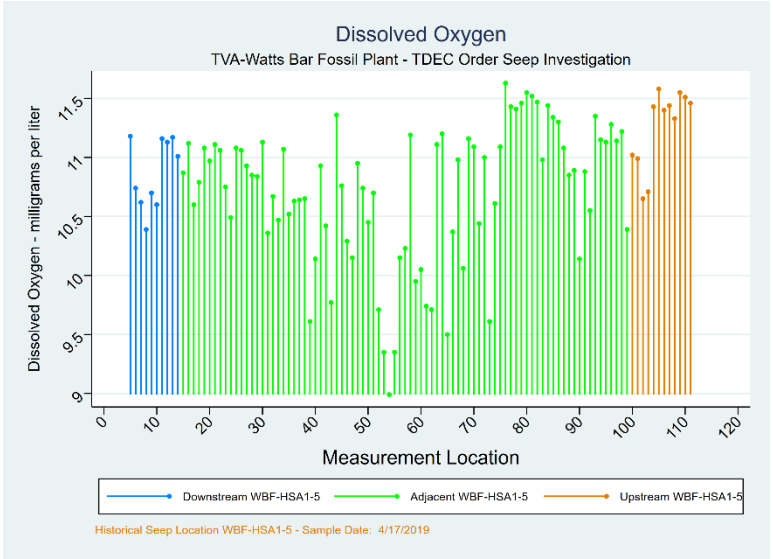
ATTACHMENTS

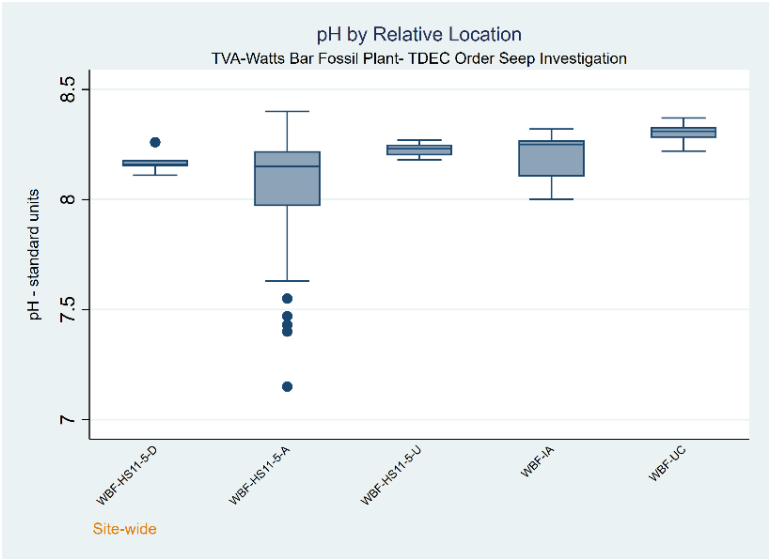
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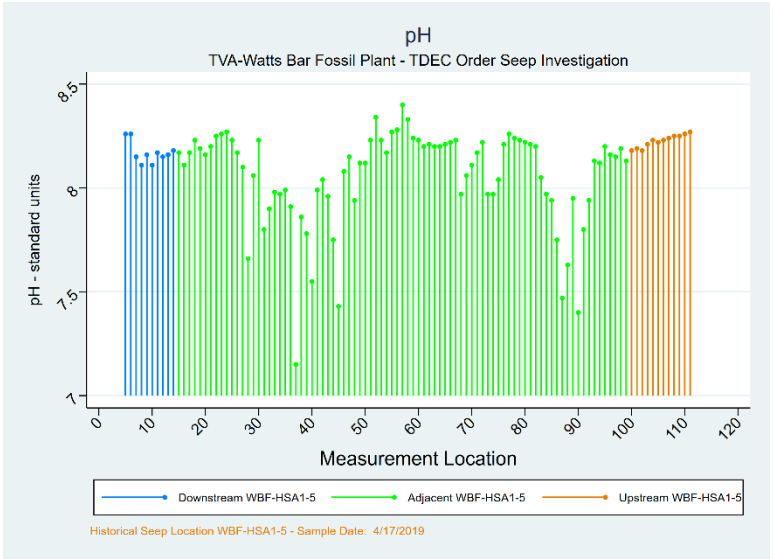
Measurement Results and Box Plots

Measurement Results and Box Plots

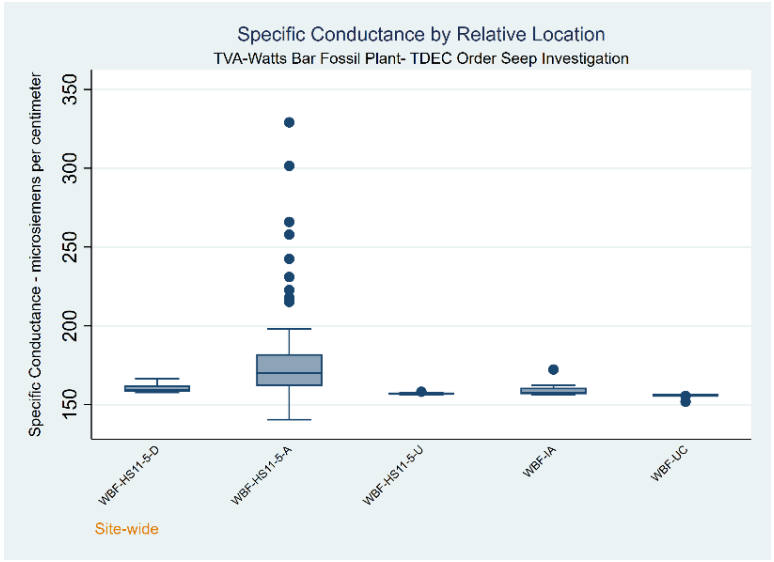


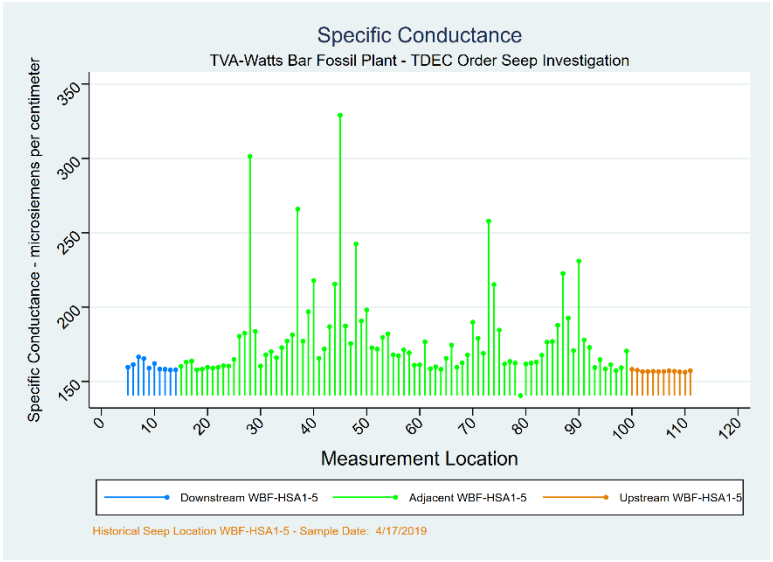


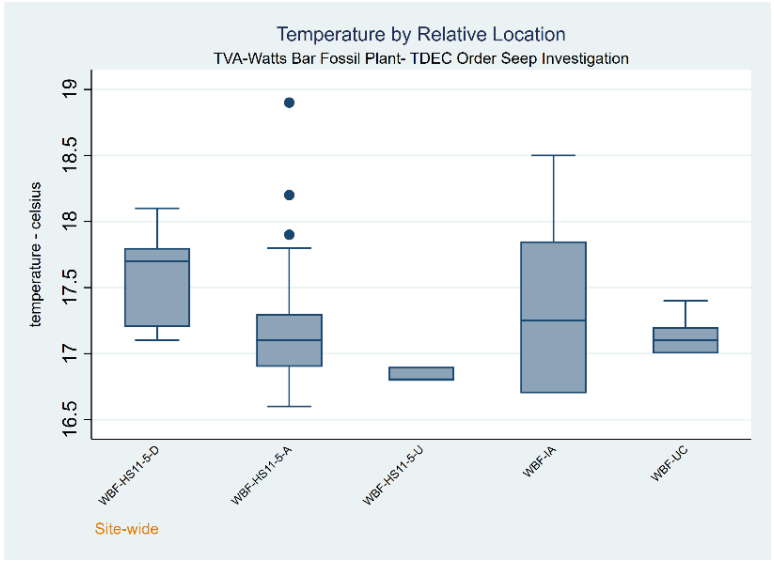


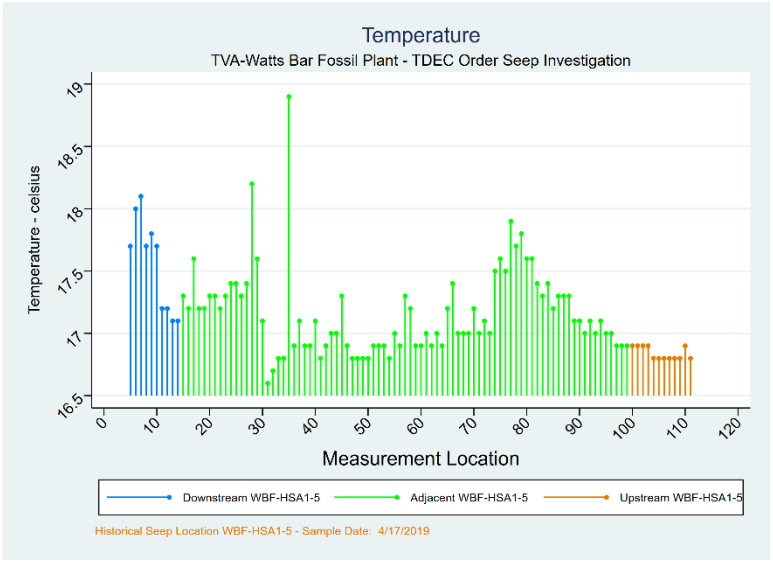


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Specific Conductance by Relative Location
TVA-Watts Bar Fossil Plant- TDEC Order Seep Investigation
Specific Conductance - microsiemens per centimeter
150
200
250
300
350
WBF-HS11-5-D
WBF-HS11-5-A
WBF-HS11-5-U
WBF-IA
WBF-UC
Site-wide


Specific Conductance
TVA-Watts Bar Fossil Plant - TDEC Order Seep Investigation
Specific Conductance - microsiemens per centimeter
150
200
250
300
350
0
10
20
30
40
50
60
70
80
90
100
110
120
Measurement Location
Downstream WBF-HSA1-5
Adjacent WBF-HSA1-5
Upstream WBF-HSA1-5
Historical Seep Location WBF-HSA1-5 - Sample Date: 4/17/2019


Temperature by Relative Location
TVA-Watts Bar Fossil Plant- TDEC Order Seep Investigation
temperature - celsius
16.5
17
17.5
18
18.5
19
WBF-HS11-5-D
WBF-HS11-5-A
WBF-HS11-5-U
WBF-IA
WBF-UC
Site-wide


Temperature
TVA-Watts Bar Fossil Plant - TDEC Order Seep Investigation
Temperature - celsius
16.5
17
17.5
18
18.5
19
0
10
20
30
40
50
60
70
80
90
100
110
120
Measurement Location
Downstream WBF-HSA1-5
Adjacent WBF-HSA1-5
Upstream WBF-HSA1-5
Historical Seep Location WBF-HSA1-5 - Sample Date: 4/17/2019

ATTACHMENT D.2

Summary of Descriptive Statistics

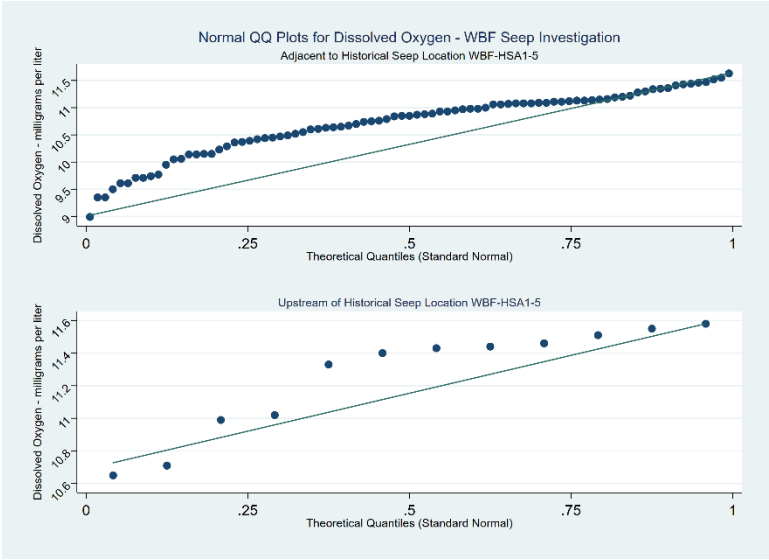
Summary of Descriptive Statistics Watts Bar Fossil Plant - Seep Investigation								
Historical Seep	**Relative Location to Historical Seep**	**Number of Samples**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**Median**	**95th Percentile**
Tennessee River								
Dissolved Oxygen (milligrams per Liter)								
WBF-HSA1-5	Downstream	10	10.39	11.18	10.87	0.29	10.875	11.18
	Adjacent	85	8.99	11.63	10.71	0.59	10.85	11.46
	Upstream	12	10.65	11.58	11.26	0.33	11.415	11.58
Upstream Control		21	11.13	11.5	11.35	0.11	11.37	11.49
Intermediate Areas		8	11.04	11.65	11.35	0.24	11.34	11.65
pH (Standard Units)								
WBF-HSA1-5	Downstream	10	8.11	8.26	8.17	0.05	8.16	8.26
	Adjacent	85	7.15	8.4	8.06	0.23	8.15	8.27
	Upstream	12	8.18	8.27	8.23	0.03	8.23	8.27
Upstream Control		21	8.22	8.37	8.30	0.04	8.31	8.36
Intermediate Areas		8	8	8.32	8.20	0.12	8.25	8.32
Specific Conductivity (microsiemens per centimeter)								
WBF-HSA1-5	Downstream	10	157.8	166.5	160.63	3.16	159.3	166.5
	Adjacent	85	140.5	329.1	179.29	30.73	170.1	242.5
	Upstream	12	156.3	158.2	156.99	0.52	156.85	158.2
Upstream Control		21	151.9	156.2	155.70	0.89	155.9	156.1
Intermediate Areas		8	156.4	172.3	159.85	5.40	157.6	172.3
Temperature (Celsius)								
WBF-HSA1-5	Downstream	10	17.1	18.1	17.56	0.38	17.7	18.1
	Adjacent	85	16.6	18.9	17.16	0.35	17.1	17.7
	Upstream	12	16.8	16.9	16.84	0.05	16.8	16.9
Upstream Control		21	17	17.4	17.11	0.12	17.1	17.3
Intermediate Areas		8	16.7	18.5	17.35	0.71	17.25	18.5

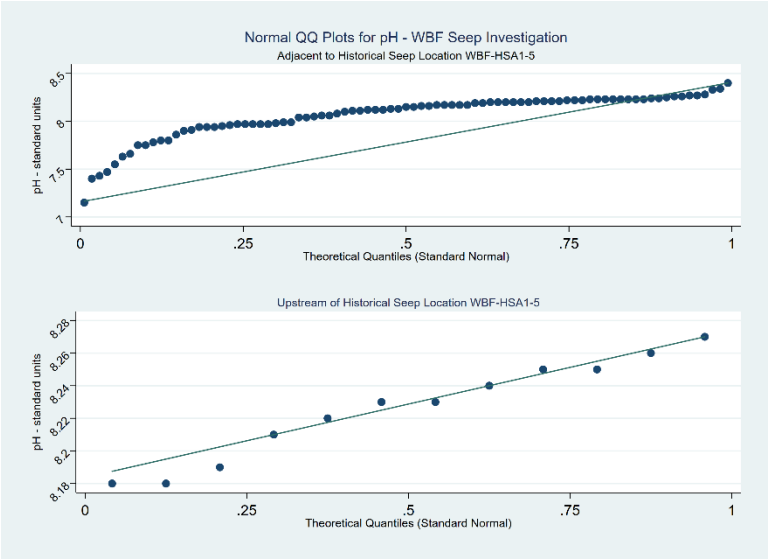
ATTACHMENT D.3

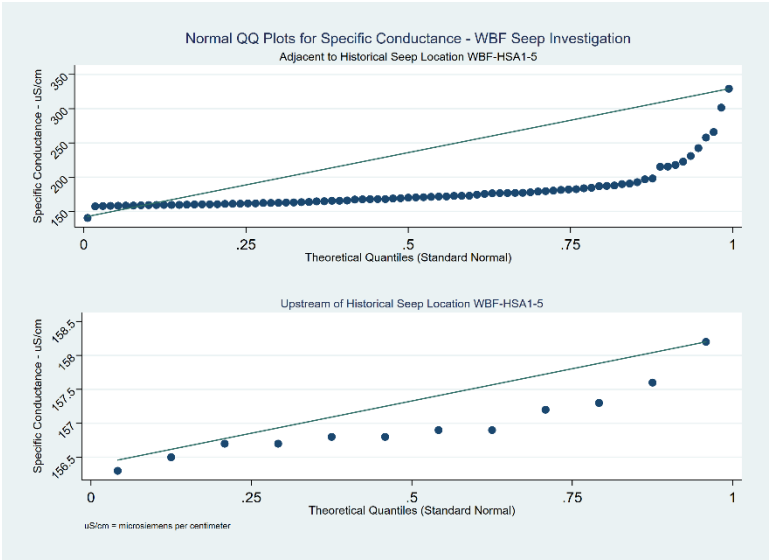
Normal Q-Q Plots

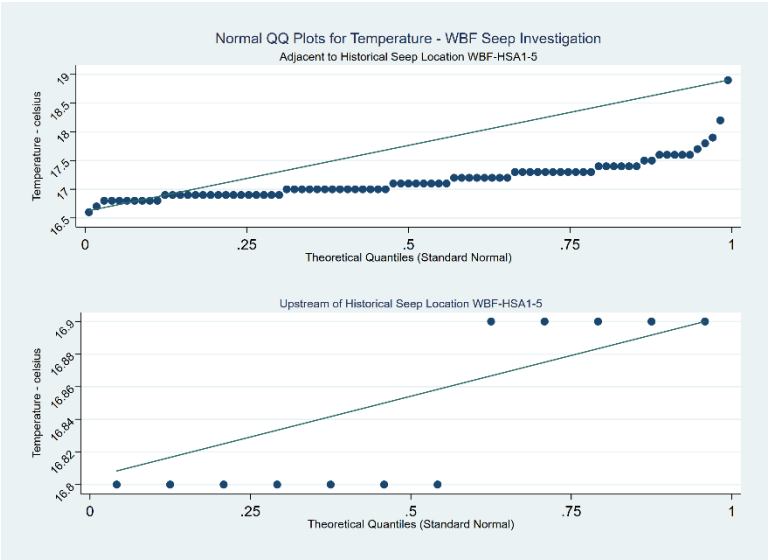
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Normal Q-Q Plots





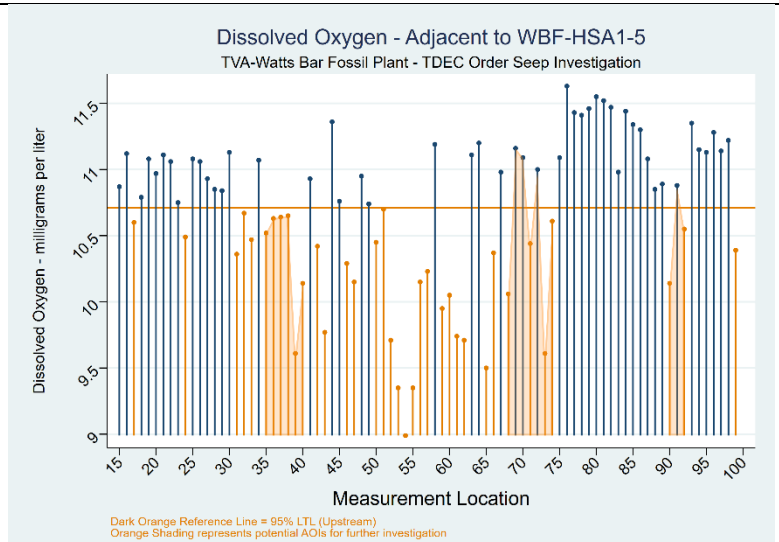


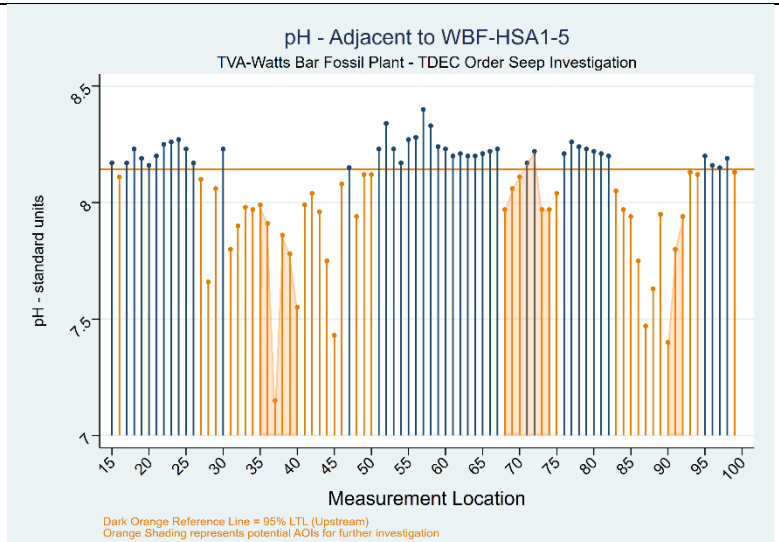


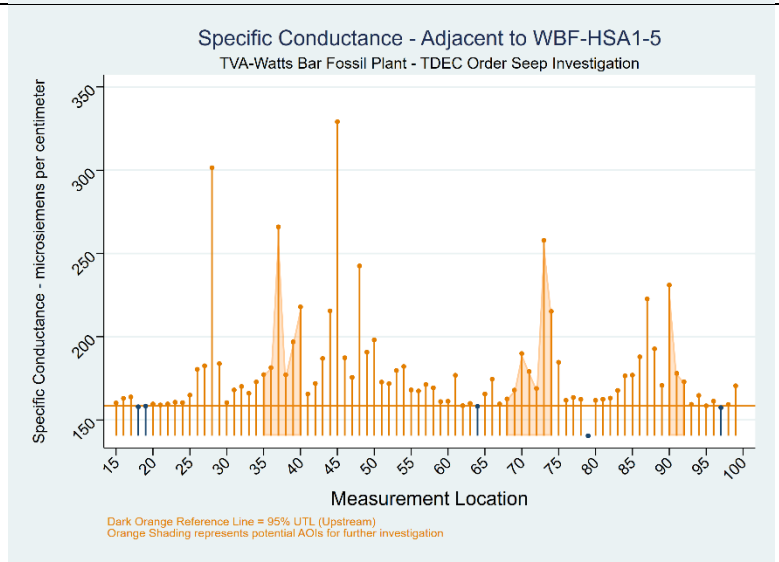
ATTACHMENT D.4

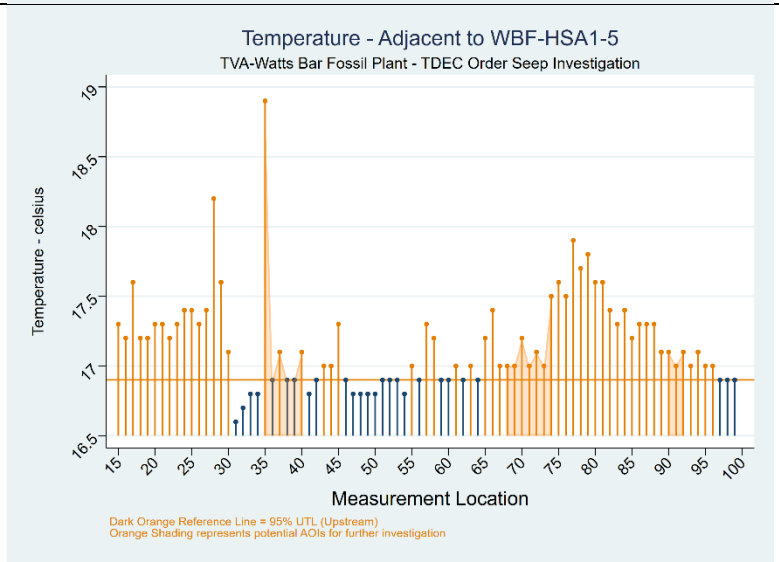
Measurement Results Plots, Tolerance Limits, and Areas of Interest

Measurement Results Plots, Tolerance Limits, and Areas of Interest









APPENDIX E.5

STATISTICAL ANALYSIS OF SURFACE STREAM DATA

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Appendix E.5 - Statistical Analysis of Surface Stream Data

TDEC Commissioner's Order:
Environmental Assessment Report
Watts Bar Fossil Plant
Spring City, Tennessee

March 31, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

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Lexington, Kentucky

REVISION LOG

Revision	Description	Date
0	Submittal to TDEC	November 7, 2023
1	Addresses January 31, 2024 TDEC Review Comments and Issued for TDEC	March 31, 2024

Sign-off Sheet

This document entitled Appendix E.5 - Statistical Analysis of Surface Stream Data was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

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Abbreviations

CASRN	Chemical Abstracts Service Registry Number
CCR	Coal Combustion Residuals
CCR Parameters	Constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations, Part 257
EAR	Environmental Assessment Report
EI	Environmental Investigation
ESV	Ecological Screening Value
ID	Identification
IQR	Interquartile Range
MDL	Method Detection Limit
NA	Not Available
PCA	Principal Component Analysis
SSL_{HH}	Site-specific Human Health Screening Levels
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority
µg/L	micrograms per Liter
WBF Plant	Watts Bar Fossil Plant

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this appendix on behalf of the Tennessee Valley Authority (TVA) to summarize the statistical analyses performed on surface stream data to support evaluations conducted for the Environmental Assessment Report (EAR) at the Watts Bar Fossil Plant (WBF Plant) located in Spring City, Tennessee. The surface stream samples were collected between July 2019 and November 2019 in one river body in proximity to the WBF Plant. Further details regarding the surface stream sampling and a summary of the analytical data are presented in Appendix J.1 and the *WBF Plant Surface Stream Sampling and Analysis Report* (Appendix J.2).

For the Environmental Investigation (EI), surface stream samples were collected from locations along sample transects from the Tennessee River in proximity to the WBF Plant coal combustion residual (CCR) management units. Sample transects/location names, locations relative to WBF Plant CCR management units, and the numbers of samples collected from each water body are presented in Table E.5-1. Fourteen samples were collected from the Discharge Channel; however, these samples were not included in the statistical analysis because conditions in the Discharge Channel are not representative of natural surface stream conditions and the Discharge Channel is regulated under a National Pollutant Discharge Elimination System permit (#TN0005789). The constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04 (CCR Parameters) included in the statistical analysis are presented in Table E.5-2.

Table E.5-1 – Surface Stream Sample Transect/Locations, WBF Plant

Water Body	Transect/Location Name	Location Relative to CCR Management Units	Number of Samples
Tennessee River	TR01, TR02	Upstream	34
	TR03, TR04, TR05	Adjacent	46
	TR06, TR07	Downstream	33

Table E.5-2 – CCR Parameters Evaluated in Statistical Analysis

CCR Parameter	CASRN
CCR Rule Appendix III Parameters	
Boron	7440-42-8
Calcium	7440-70-2
Chloride	16887-00-6
Fluoride[1] (also Appendix IV)	16984-48-8
pH	Not Available (NA)
Sulfate	14808-79-8
Total Dissolved Solids	NA
CCR Rule Appendix IV Parameters	
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Lead	7439-92-1
Lithium	7439-93-2
Mercury	7439-97-6
Molybdenum	7439-98-7
Radium-226+228	13982-63-3/ 15262-20-1
Selenium	7782-49-2
Thallium	7440-28-0
TDEC Appendix I Parameters	
Copper	7440-50-8
Nickel	7440-02-0
Silver	7440-22-4
Vanadium	7440-62-2
Zinc	7440-66-6
Other	
Hardness	NA
Iron	7439-89-6
Magnesium	7439-95-4
Manganese	7439-96-5
Total Suspended Solids	NA

Notes:
CASRN: Chemical Abstracts Service Registry Number
CCR Rule - Title 40, Code of Federal Regulations, Part 257
NA – Not available
TDEC - Tennessee Department of Environment and Conservation
[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV CCR Parameter. In this table, and in the results figures and tables for this report, fluoride has been grouped with the Appendix III CCR Parameters only to avoid duplication.

The following sections present the methods and results from the general exploratory data analysis using summary statistics, data plots, and outlier screening, and a comparison of surface stream results to Site-specific Ecological Screening Values (ESVs) and Human Health Screening Levels (SSL_{HH}) that were developed for the EAR. The site specific ESVs and SSL_{HH} for surface stream data are provided in Table 1-2 and Appendix A.2.

Additional statistical analyses (principal component analysis [PCA] and hypothesis testing) were performed if the following conditions were satisfied: 1) CCR parameter concentrations were above ESVs

or SSL_{HH} and 2) data were collected from transects/locations adjacent and from transects/locations either upstream or downstream to the WBF Plant CCR management units. Since CCR parameter concentrations were not above ESVs or SSL_{HH} in the surface stream datasets, no additional statistical analyses were conducted.

2.0 METHODS

The statistical evaluation for the surface stream data collected at the WBF Plant for the EI was conducted in three parts: 1) exploratory data analysis, 2) comparison of results to site-specific ESVs and to generic $SSL_{HH,}$ and 3) additional statistical analysis, when warranted.

2.1 EXPLORATORY DATA ANALYSIS

Exploratory data analysis is the initial step of statistical analysis. It utilizes simple summary statistics (e.g. mean, median, standard deviation and percentiles) and graphical representations to identify characteristics of an analytical dataset, such as the center of the data (mean, median), variation, distribution, spatial or temporal patterns, presence of outliers, and randomness.

2.1.1 Summary Statistics

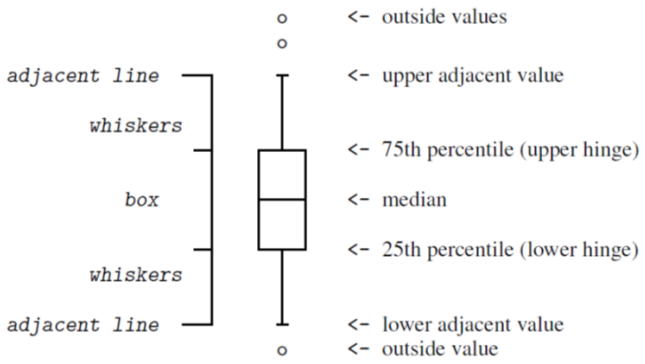
Summary statistics were calculated for each CCR Parameter and aggregated by the transect's position relative to the WBF Plant CCR management units (upstream, adjacent and downstream). Summary statistics also were calculated for the following additional water quality parameters: hardness, iron, magnesium, manganese, and total suspended solids. Summary statistics include information such as the total numbers of available samples, the frequencies of detection, ranges of reporting limits, minimum and maximum detected concentrations, mean concentrations, standard deviations, median concentrations and the 95th percentile concentrations. Where applicable, summary statistics were calculated for the results for both total and dissolved metal results. Summary statistics tables are presented in Attachment E.5-A.

2.1.2 Exploratory Data Plots

Exploratory data plots (box plots and transect plots) were constructed using the surface stream results for total metals to support a visual review of the data. Box plots were used to identify the center of the data, distribution, and variability, and to visually identify potential outliers. The diagram below graphically depicts the basics of the construction of the box plots (StataCorp LLC 2017).

APPENDIX E.5 - STATISTICAL ANALYSIS OF SURFACE STREAM DATA

March 31, 2024



The box portion of the plot is the interquartile range (IQR), which represents the middle 50 percent of data, with the bottom of the box being the 25th percentile and the top of the box being the 75th percentile. The line inside the box is the median concentration. The top of the upper "whisker" represents the first observed concentration above the 75th percentile, whereas the bottom of the lower "whisker" represents the first observed concentration below the 25th percentile (upper adjacent value and lower adjacent value, respectively). Values that lie outside of the adjacent values represent outside (or outlier) concentrations (i.e. concentrations at the upper and lower ends of the distribution of the data). The method detection limit (MDL) was used as the reported value in order to construct the box plot when analytical results were reported as non-detects.

Box plots were prepared that compared results by transect in the Tennessee River. Transects, ordered by relative location to the WBF Plant CCR management units (upstream, adjacent, downstream), were useful in assessing upstream to downstream patterns within the water body, as well as data distribution, variability, and potential outliers. Box plots for CCR Rule Appendix III, CCR Rule Appendix IV, and TDEC Appendix I CCR Parameters are presented in Attachment E.5-B.

Transect plots were constructed that showed individual sample results aggregated by transect, position relative to the WBF Plant CCR management units (upstream, adjacent, or downstream), and relative position within the water body (right bank, center channel, or left bank).

- Tennessee River: Right Bank = Fossil Plant Bank; Left Bank = Opposite Bank

The symbols used in the transect plots indicate whether the reported result is a detected concentration (solid symbol) or a non-detect reported at the MDL (hollow symbol).

Multiple transect plots were constructed for each CCR Parameter. Individual plots were constructed with a reference line for the SSL_{HH} using analytical results collected in the Tennessee River, because the Tennessee River is a potable water source, as described in Appendix J.1. Transect plots with a reference line for the site-specific ESVs were constructed using analytical results collected in the Tennessee River. In many cases, the sample results were much lower than either SSL_{HH} or ESVs, so including the reference lines induced a scaling effect which obscured patterns in the data. A third plot was produced for each CCR Parameter without a reference line in order to better identify patterns.

Transect plots provide more detailed information than side-by-side box plots and allow a more rigorous evaluation of the data. These plots are particularly useful in identifying potential patterns in the dataset (trends), frequency of detection, outliers, spatial differences relative to the WBF Plant CCR management units (upstream, adjacent, and downstream), and differences relative to the position in the water body (plant-side bank versus opposite-side bank or center channel). The transect plots are presented in Attachment E.5-C.

2.1.3 Outlier Screening

Outliers are data points that are abnormally high or low as compared to other measurements and may represent anomalous data or data errors. Outliers may also represent natural variations of CCR Parameter concentrations in environmental systems. Screening for outliers is an important step because outliers can bias statistical estimates, statistical testing results, and inferences.

Outlier values were initially screened visually using the side-by-side box plots. If suspected visual outliers were identified, then Tukey's procedure was used to identify extreme outliers (Tukey 1977). This method relies on the IQR, which is defined as the 75th percentile value minus the 25th percentile value. Values were identified as potential outliers as follows:

- **Lower extreme outliers** are less than the 25th percentile minus 3 x IQR
- **Upper extreme outliers** are greater than the 75th percentile plus 3 x IQR.

Finally, when the potential outliers were identified visually and by Tukey's procedure, then statistical testing for outliers (Rosner's Test) was conducted to determine if those data points were statistically significant outliers.

Following confirmation of the outliers as statistically significant, a desktop evaluation was conducted to verify that the data points were not errors (e.g., laboratory or transcriptional errors). Field forms, data validation reports and other variables in the dataset that could influence analytical results also were evaluated at this point. If a verifiable error was discovered, the outlier was removed and, if possible, replaced with a corrected value.

In the absence of a verifiable error, additional lines of evidence were reviewed to determine final outlier disposition (e.g., frequency of detection, spatial and temporal variability). If an outlier was identified as suitable for removal from further statistical analysis, a clear and defensible rationale based on multiple lines of evidence was provided. In addition, values that were identified as outliers and removed from further evaluation in the present statistical analysis were retained in the historical database and will be reevaluated for inclusion or exclusion in future statistical analyses of this dataset. The results of the outlier screening for the WBF Plant surface stream dataset are provided in Section 3.1.

2.2 COMPARISON OF SURFACE STREAM RESULTS TO ESVS AND SSL_{HH}

The analytical results for total metals in the surface stream dataset for all sampled water bodies were compared to water body specific ESVs, as provided in Table 1-2 and Appendix A.2. In addition, surface stream data from the Tennessee River were compared to generic SSL_{HH} values (also provided in Appendix A.2) because it is used as a potable water source. Results were summarized graphically using transect plots and in tabular format in Tables in Appendix J.1.

When an analytical sample result for a CCR Parameter was above the ESV and data were collected from transects/locations adjacent and from transect/locations upstream and/or downstream to the WBF Plant CCR management units, additional statistical evaluation of that CCR parameter was applied in the EAR. This additional evaluation included:

- Formal hypothesis testing to identify differences between upstream, adjacent, and downstream results, and
- PCA to identify the variables and individual samples that explain the greatest proportion of variability (provide the greatest amount of information) in the datasets.

No additional statistical analyses were conducted (PCA and hypothesis testing) for the surface stream datasets as described in Section 3.2.

3.0 RESULTS AND DISCUSSION

3.1 SUMMARY STATISTICS, EXPLORATORY DATA PLOTS, AND OUTLIER SCREENING

Summary statistics tables are presented in Attachment E.5-A, box plots are presented in Attachment E.5-B, and transect plots are presented in Attachment E.5-C. Box plots and transect plots that were used to identify the potential statistical outliers are presented in Attachment E.5-D. The summary statistics and exploratory data plots were aggregated by transect location relative to the WBF Plant CCR management units (upstream, adjacent, downstream) and sample position in the water body (plant-side bank, center channel, and opposite-side bank).

The outlier screening method described in Section 2.1.3 identified one outlier that was determined to be suitable for removal from further statistical analysis (Table E.5-3). This outlier was initially identified using exploratory data plots (see Attachment E.5-D) and confirmed as a statistical outlier using Rosner's Outlier Test (p-value<0.01) and the Tukey's Extreme Outlier Test. Subsequently, additional lines of evidence were reviewed to determine final outlier disposition (e.g., frequency of detection, spatial and temporal variability).

For the outlier identified for exclusion from further statistical analysis in Table E.5-3, this exclusion was supported by a spatial review that compared the magnitude of the outlier result to the distribution of

concentrations for that parameter in surface water at the sampled locations in the Tennessee River. This spatial comparison was supported by a visual review of the box-plots and transect plots for these parameters in surface stream samples as presented in Appendix E.5-D. The results of this spatial review indicated that the outlier in Table E.5-3 represents a value that is considerably separated from all other surface stream concentrations for that parameter for samples collected in the vicinity of the WBF Plant from Tennessee River. As such, this result was an outlier not only for the individual sampling location where it was collected, but it was also an outlier in the context of a much larger dataset. Inclusion of outliers that are well-separated from the dominant data in statistical analysis can distort calculated decision statistics, which may in turn lead to incorrect remediation decisions (USEPA 2022). It is preferable to compute environmental statistics based on datasets that represent the main population (USEPA 2022). Therefore, it was determined that inclusion of the outlier in Table E.5-3 in further statistical analysis would obscure statistical interpretation of the available surface stream data and this value was removed from further statistical analysis in the EAR (i.e., excluded from the summary statistics, box-plots, and transect plots presented in Attachments E.5-A, E.5-B, and E.5-C, respectively). However, this outlier remains in the historical dataset and will require reevaluation for inclusion/exclusion if these data are analyzed in future reports.

Furthermore, since the outlier identified in Table E.5-3 was identified in the dissolved fraction of the sample, an additional comparison was done to the total results from the same sample. This comparison revealed that the dissolved fraction result was an order of magnitude higher than the total fraction result (Table E.5-3). This indicates a data error, since the dissolved fraction of a substance cannot, by definition, exceed the total concentration of that substance. Therefore, the outlier result identified in Table E.5-3 was removed from further statistical analysis in the EAR (i.e., excluded from the summary statistics, box-plots, and transect plots presented in Attachments E.5-A, E.5-B, and E.5-C, respectively). However, this outlier remains in the historical dataset and will require reevaluation for inclusion/exclusion if these data are analyzed in future reports.

March 31, 2024

Table E.5-3 - Statistically Significant Outliers – WBF Plant, Surface Stream

CCR Parameter	Water body	Sample Location	Sample ID	Lowest Applicable Ecological Screening Value (ESV) or Human Health Screening Level (SSL_{HH})	Does Outlier Exceed Lowest Applicable ESV or SSL_{HH}?	Outlier Value (Dissolved)	Total Value
Copper	Tennessee River	TR02 (Upstream of CUF Plant)	WBF-STR-TR02-LB-MID-20190709	7.0 µg/L	Yes	23.7 µg/L	1.12 µg/L

Notes:
ID - identification
µg/L – micrograms per Liter

3.2 COMPARISON OF SURFACE STREAM RESULTS TO ESVS AND SSL_{HH}

There were no sample results above chronic ESVs, acute ESVs, or SSL_{HH} from surface stream sampling in the Tennessee River.

4.0 REFERENCES

StataCorp. (2017). Stata Graphics Reference Manual Stata: Release 15. Statistical Software. College Station, TX: StataCorp LLC.

Tukey, J.W. (1977). *Exploratory Data Analysis*. Reading, Massachusetts: Addison-Wesley. 1977.

United States Environmental Protection Agency (USEPA) (2022). ProUCL Version 5.2.0 Technical Guide: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. Washington DC. USEPA Office of Research and Development.

ATTACHMENT E.5-A - SUMMARY STATISTICS BY WATER BODY

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Summary Statistics - Tennessee River
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Gradient	Fraction	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
						Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters											
Boron	Upstream	D	3/34	(30.3 - 38.6)	91.2%	33.4	41	31.1	2.24	34.7	38.6
		T	2/34	(30.3 - 38.6)	94.1%	31.7	42.4	30.7	2.06	31	38.6
	Adjacent	D	8/46	(30.3 - 38.6)	82.6%	31.9	81.2	33.9	9.67	38.6	50.4
		T	10/46	(30.3 - 38.6)	78.3%	34.5	168	39.9	27	38.6	104
	Downstream	D	1/33	(30.3 - 54.9)	97.0%	45.4	45.4	30.8	2.63	38.6	41.3
		T	2/33	(30.3 - 39.5)	93.9%	38.8	51	31.2	3.8	36.3	39.1
Calcium	Upstream	D	34/34	--	0.0%	20,900	24,100	22,400	760	22,200	23,600
		T	34/34	--	0.0%	20,900	24,000	22,300	885	22,400	23,900
	Adjacent	D	46/46	--	0.0%	20,500	24,800	22,500	1,090	22,900	24,100
		T	46/46	--	0.0%	20,600	24,500	22,600	921	22,900	24,100
	Downstream	D	33/33	--	0.0%	20,600	24,700	22,400	1,300	22,400	24,300
		T	33/33	--	0.0%	20,700	24,700	22,600	1,320	22,500	24,600
Chloride	Upstream	N	34/34	--	0.0%	3,990	30,400	6,500	6,130	4,540	14,800
	Adjacent	N	46/46	--	0.0%	3,980	6,620	5,190	1,160	4,240	6,590
	Downstream	N	33/33	--	0.0%	4,040	6,410	5,160	919	4,740	6,310
Sulfate	Upstream	N	34/34	--	0.0%	8,170	56,400	12,300	11,100	9,380	28,000
	Adjacent	N	46/46	--	0.0%	8,160	11,800	9,690	1,420	8,780	11,500
	Downstream	N	33/33	--	0.0%	8,310	11,200	9,780	1,090	9,860	11,000
TDS	Upstream	N	34/34	--	0.0%	82,000	129,000	95,100	9,450	93,000	108,000
	Adjacent	N	46/46	--	0.0%	86,000	137,000	101,000	10,600	98,500	121,000
	Downstream	N	33/33	--	0.0%	79,000	115,000	94,500	9,420	92,000	110,000
CCR Rule Appendix IV Parameters											
Antimony	Upstream	D	0/34	(0.378 - 0.408)	100.0%	--	--	--	--	0.378	0.378
		T	0/34	(0.378 - 0.378)	100.0%	--	--	--	--	0.378	0.378
	Adjacent	D	0/46	(0.378 - 0.378)	100.0%	--	--	--	--	0.378	0.378
		T	0/46	(0.378 - 0.378)	100.0%	--	--	--	--	0.378	0.378
	Downstream	D	2/33	(0.378 - 0.633)	93.9%	0.378	0.467	0.381	0.0155	0.378	0.414
		T	4/33	(0.378 - 0.378)	87.9%	0.394	0.585	0.392	0.0467	0.378	0.479
Arsenic	Upstream	D	25/34	(0.498 - 0.648)	26.5%	0.418	0.907	0.544	0.107	0.563	0.718
		T	34/34	--	0.0%	0.462	0.921	0.625	0.107	0.608	0.78
	Adjacent	D	37/46	(0.512 - 0.768)	19.6%	0.376	0.844	0.565	0.112	0.578	0.776
		T	46/46	--	0.0%	0.491	0.927	0.654	0.102	0.623	0.788
	Downstream	D	33/33	--	0.0%	0.384	0.668	0.525	0.0693	0.521	0.658
		T	33/33	--	0.0%	0.445	0.888	0.589	0.0889	0.583	0.717
Barium	Upstream	D	34/34	--	0.0%	25	28.6	26.8	0.812	26.9	28
		T	34/34	--	0.0%	25.6	30.6	28.5	1.16	28.6	30.3
	Adjacent	D	46/46	--	0.0%	23.8	29.6	26.1	1.34	26	28.4
		T	46/46	--	0.0%	24.8	46.6	28.6	2.98	28.4	30
	Downstream	D	33/33	--	0.0%	21.6	28.7	25.9	1.7	26.2	28.1
		T	33/33	--	0.0%	24.3	31.1	28.1	1.89	28.4	30.6
Beryllium	Upstream	D	13/34	(0.155 - 0.182)	61.8%	0.182	0.504	0.193	0.0691	0.169	0.286
		T	13/34	(0.155 - 0.182)	61.8%	0.195	0.431	0.208	0.0758	0.155	0.333
	Adjacent	D	7/46	(0.155 - 0.327)	84.8%	0.229	0.321	0.174	0.0447	0.176	0.3
		T	9/46	(0.155 - 0.32)	80.4%	0.17	0.368	0.176	0.0472	0.182	0.295
	Downstream	D	3/33	(0.155 - 0.244)	90.9%	0.169	0.216	0.159	0.0131	0.169	0.217
		T	7/33	(0.155 - 0.907)	78.8%	0.359	0.846	0.25	0.181	0.155	0.773
Cadmium	Upstream	D	1/34	(0.125 - 0.125)	97.1%	0.17	0.17	0.126	0.0076	0.125	0.125
		T	1/34	(0.125 - 0.125)	97.1%	0.141	0.141	0.125	0.0027	0.125	0.125
	Adjacent	D	1/46	(0.125 - 0.125)	97.8%	0.13	0.13	0.125	0.000729	0.125	0.125
		T	0/46	(0.125 - 0.125)	100.0%	--	--	--	--	0.125	0.125
	Downstream	D	0/33	(0.125 - 0.125)	100.0%	--	--	--	--	0.125	0.125
		T	2/33	(0.125 - 0.125)	93.9%	0.152	0.153	0.127	0.00656	0.125	0.136
Chromium	Upstream	D	0/34	(1.53 - 3.1)	100.0%	--	--	--	--	1.53	2.1
		T	0/34	(1.53 - 2.74)	100.0%	--	--	--	--	1.53	2.35
	Adjacent	D	10/46	(1.53 - 5.2)	78.3%	1.67	2.14	1.63	0.19	1.54	2.39
		T	10/46	(1.53 - 2.98)	78.3%	1.84	11.9	1.89	1.52	1.53	2.63
	Downstream	D	0/33	(1.53 - 2.71)	100.0%	--	--	--	--	1.53	2.39
		T	0/33	(1.53 - 6.61)	100.0%	--	--	--	--	1.53	3.96

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Summary Statistics - Tennessee River
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Gradient	Fraction	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
						Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Cobalt	Upstream	D	13/34	(0.075 - 0.075)	61.8%	0.075	0.169	0.0837	0.0182	0.075	0.111
		T	34/34	--	0.0%	0.099	0.233	0.149	0.0336	0.142	0.213
	Adjacent	D	15/46	(0.075 - 0.075)	67.4%	0.085	0.143	0.0849	0.0181	0.075	0.132
		T	43/46	(0.139 - 0.151)	6.5%	0.1	0.224	0.15	0.0283	0.145	0.212
	Downstream	D	5/33	(0.075 - 0.075)	84.9%	0.085	0.106	0.0782	0.00818	0.075	0.1
		T	33/33	--	0.0%	0.087	0.272	0.134	0.0359	0.13	0.183
Fluoride	Upstream	N	34/34	--	0.0%	51.6	326	74.1	62.4	56.8	161
	Adjacent	N	46/46	--	0.0%	52.4	82.4	60.4	6.17	59.2	73.7
	Downstream	N	25/33	(51.5 - 62.2)	24.2%	52.3	81.9	60.3	8.44	58	75.7
Lead	Upstream	D	3/34	(0.128 - 0.131)	91.2%	0.203	1.03	0.161	0.154	0.128	0.233
		T	28/34	(0.128 - 0.128)	17.7%	0.133	0.31	0.16	0.0331	0.154	0.2
	Adjacent	D	2/46	(0.128 - 0.128)	95.7%	0.155	0.184	0.13	0.00899	0.128	0.128
		T	41/46	(0.128 - 0.218)	10.9%	0.132	0.375	0.185	0.0525	0.178	0.301
	Downstream	D	1/33	(0.128 - 0.128)	97.0%	0.138	0.138	0.128	0.00171	0.128	0.128
		T	21/33	(0.128 - 0.128)	36.4%	0.128	0.244	0.159	0.0347	0.148	0.231
Lithium	Upstream	D	7/34	(3.14 - 3.39)	79.4%	3.38	6.64	3.41	0.739	3.39	4.74
		T	8/34	(3.14 - 3.39)	76.5%	3.57	5.82	3.43	0.651	3.39	4.97
	Adjacent	D	8/46	(3.14 - 3.39)	82.6%	3.15	5.2	3.29	0.433	3.39	4.25
		T	10/46	(3.14 - 3.39)	78.3%	3.18	4.89	3.31	0.411	3.39	4.32
	Downstream	D	2/33	(3.14 - 3.39)	93.9%	3.34	3.46	3.16	0.0703	3.34	3.39
		T	3/33	(3.14 - 3.39)	90.9%	3.51	4.22	3.2	0.206	3.39	3.54
Mercury	Upstream	D	0/34	(0.101 - 0.101)	100.0%	--	--	--	--	0.101	0.101
		T	0/34	(0.101 - 0.101)	100.0%	--	--	--	--	0.101	0.101
	Adjacent	D	0/46	(0.101 - 0.101)	100.0%	--	--	--	--	0.101	0.101
		T	0/46	(0.101 - 0.101)	100.0%	--	--	--	--	0.101	0.101
	Downstream	D	0/33	(0.101 - 0.101)	100.0%	--	--	--	--	0.101	0.101
		T	0/33	(0.101 - 0.101)	100.0%	--	--	--	--	0.101	0.101
Molybdenum	Upstream	D	0/34	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
		T	2/34	(0.61 - 0.61)	94.1%	0.613	0.659	0.612	0.00828	0.61	0.611
	Adjacent	D	1/46	(0.61 - 0.61)	97.8%	0.703	0.703	0.612	0.0136	0.61	0.61
		T	0/46	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
	Downstream	D	0/33	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
		T	0/33	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
Radium-226+228	Upstream	T	2/34	(0.498 - 1.089)	94.1%	0.497	0.746	0.506	0.0454	0.599	0.79
	Adjacent	T	2/46	(0.451 - 1.291)	95.7%	0.589	0.666	0.466	0.0489	0.637	0.998
	Downstream	T	3/33	(0.492 - 0.923)	90.9%	0.725	0.755	0.527	0.0856	0.715	0.921
Selenium	Upstream	D	0/34	(1.51 - 2.62)	100.0%	--	--	--	--	2.62	2.62
		T	0/34	(1.51 - 2.62)	100.0%	--	--	--	--	2.62	2.62
	Adjacent	D	0/46	(1.51 - 2.62)	100.0%	--	--	--	--	2.62	2.62
		T	0/46	(1.51 - 2.62)	100.0%	--	--	--	--	2.62	2.62
	Downstream	D	0/33	(1.51 - 2.62)	100.0%	--	--	--	--	2.62	2.62
		T	0/33	(1.51 - 2.62)	100.0%	--	--	--	--	2.62	2.62
Thallium	Upstream	D	5/34	(0.128 - 0.148)	85.3%	0.163	0.319	0.141	0.0375	0.138	0.21
		T	3/34	(0.128 - 0.148)	91.2%	0.381	0.505	0.156	0.0914	0.128	0.406
	Adjacent	D	1/46	(0.128 - 0.28)	97.8%	0.457	0.457	0.135	0.048	0.128	0.148
		T	2/46	(0.128 - 0.148)	95.7%	0.16	0.221	0.131	0.0142	0.138	0.148
	Downstream	D	2/33	(0.128 - 0.148)	93.9%	0.151	0.226	0.132	0.0171	0.148	0.149
		T	4/33	(0.128 - 0.148)	87.9%	0.152	0.437	0.145	0.0579	0.128	0.229
TDEC Appendix I Parameters											
Copper	Upstream	D	20/34	(0.627 - 1.27)	41.2%	0.699	23.7	1.65	3.87	0.911	2.31
		T	34/34	--	0.0%	0.741	1.48	1.05	0.188	1.06	1.43
	Adjacent	D	21/46	(0.627 - 1.46)	54.4%	0.706	2.2	0.832	0.253	0.904	1.43
		T	43/46	(1.15 - 1.48)	6.5%	0.657	2.45	1.15	0.277	1.14	1.53
	Downstream	D	25/33	(0.774 - 1.03)	24.2%	0.7	1.83	1.01	0.299	0.898	1.59
		T	33/33	--	0.0%	0.807	1.44	1.05	0.166	1.02	1.32
Nickel	Upstream	D	4/34	(0.312 - 1.42)	88.2%	0.325	0.341	0.316	0.00869	0.335	1.16
		T	7/34	(0.312 - 1.56)	79.4%	0.317	0.453	0.339	0.0408	0.416	1.35
	Adjacent	D	7/46	(0.312 - 1.75)	84.8%	0.339	0.431	0.326	0.0298	0.336	1.46
		T	23/46	(0.312 - 1.86)	50.0%	0.323	0.62	0.395	0.0884	0.417	1.72
	Downstream	D	7/33	(0.312 - 1)	78.8%	0.342	0.441	0.325	0.0293	0.336	0.416
		T	20/33	(0.312 - 1.48)	39.4%	0.369	0.506	0.398	0.058	0.429	0.807

Summary Statistics - Tennessee River
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Gradient	Fraction	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
						Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Silver	Upstream	D	2/34	(0.121 - 0.177)	94.1%	0.211	0.268	0.128	0.0287	0.121	0.189
		T	0/34	(0.121 - 0.177)	100.0%	--	--	--	--	0.121	0.177
	Adjacent	D	0/46	(0.121 - 0.177)	100.0%	--	--	--	--	0.121	0.177
		T	1/46	(0.121 - 0.177)	97.8%	0.27	0.27	0.124	0.0217	0.121	0.177
	Downstream	D	0/33	(0.121 - 0.177)	100.0%	--	--	--	--	0.121	0.177
		T	0/33	(0.121 - 0.177)	100.0%	--	--	--	--	0.121	0.177
Vanadium	Upstream	D	14/34	(0.899 - 1.8)	58.8%	1.02	2.09	1.07	0.265	1.07	1.77
		T	16/34	(0.995 - 2.04)	52.9%	1	1.4	1.13	0.137	1.26	1.86
	Adjacent	D	36/46	(0.899 - 1.88)	21.7%	0.917	1.92	1.25	0.219	1.31	1.81
		T	30/46	(0.955 - 2.24)	34.8%	1.06	2.4	1.42	0.288	1.56	1.83
	Downstream	D	18/33	(0.899 - 0.991)	45.5%	0.899	2.16	1.12	0.282	1.02	1.48
		T	22/33	(0.991 - 2.09)	33.3%	1.05	2.26	1.28	0.292	1.26	2.02
Zinc	Upstream	D	2/34	(3.22 - 3.22)	94.1%	4.9	14.8	3.61	1.97	3.22	3.81
		T	3/34	(3.22 - 3.22)	91.2%	3.48	3.68	3.25	0.111	3.22	3.54
	Adjacent	D	5/46	(3.22 - 3.22)	89.1%	3.59	5.65	3.37	0.478	3.22	4.5
		T	18/46	(3.22 - 3.22)	60.9%	3.33	9.55	4.01	1.52	3.22	7.34
	Downstream	D	0/33	(3.22 - 3.22)	100.0%	--	--	--	--	3.22	3.22
		T	6/33	(3.22 - 3.22)	81.8%	3.56	6.57	3.43	0.62	3.22	4.2
Other Analyzed Constituents											
Hardness	Upstream	N	34/34	--	0.0%	76,200	86,100	81,400	2,930	81,700	85,300
	Adjacent	N	46/46	--	0.0%	75,500	90,500	81,800	3,790	81,700	87,900
	Downstream	N	33/33	--	0.0%	72,400	86,900	79,400	3,150	78,500	84,300
Iron	Upstream	D	5/34	(14.1 - 19.5)	85.3%	15.9	119	19.1	18.5	19.5	35.1
		T	34/34	--	0.0%	73.8	203	128	38.5	129	187
	Adjacent	D	8/46	(14.1 - 19.5)	82.6%	18.4	77.1	18.5	11.9	19.5	45.2
		T	46/46	--	0.0%	69.1	221	139	40.9	142	198
	Downstream	D	5/33	(14.1 - 19.5)	84.9%	22.1	87.1	20.6	17.4	19.5	60.4
		T	33/33	--	0.0%	75.6	323	174	57.9	165	286
Magnesium	Upstream	D	34/34	--	0.0%	5,670	7,070	6,270	426	6,110	6,900
		T	34/34	--	0.0%	5,760	7,030	6,260	436	6,090	6,950
	Adjacent	D	46/46	--	0.0%	4,970	7,390	6,140	687	6,040	7,170
		T	46/46	--	0.0%	4,880	7,310	6,160	669	6,010	7,240
	Downstream	D	33/33	--	0.0%	4,460	6,840	5,510	509	5,740	5,990
		T	33/33	--	0.0%	4,600	7,090	5,590	582	5,790	6,490
Manganese	Upstream	D	34/34	--	0.0%	1.72	54.3	9.57	11.5	5.6	32.6
		T	34/34	--	0.0%	42.4	103	71.6	23.8	83.2	102
	Adjacent	D	44/46	(1.35 - 1.35)	4.4%	1.42	55.3	8.2	10.5	4.9	34.4
		T	46/46	--	0.0%	41.3	99.7	68.8	21.8	77.4	96.1
	Downstream	D	30/33	(1.35 - 1.35)	9.1%	1.46	58.6	7.48	13.1	3.19	40
		T	33/33	--	0.0%	41.3	98.1	68.7	20.1	67.2	96.1
TSS	Upstream	N	34/34	--	0.0%	2,800	5,500	4,490	523	4,500	5,110
	Adjacent	N	46/46	--	0.0%	3,500	5,900	4,570	471	4,500	5,580
	Downstream	N	33/33	--	0.0%	2,700	8,200	5,050	1,370	4,700	7,600

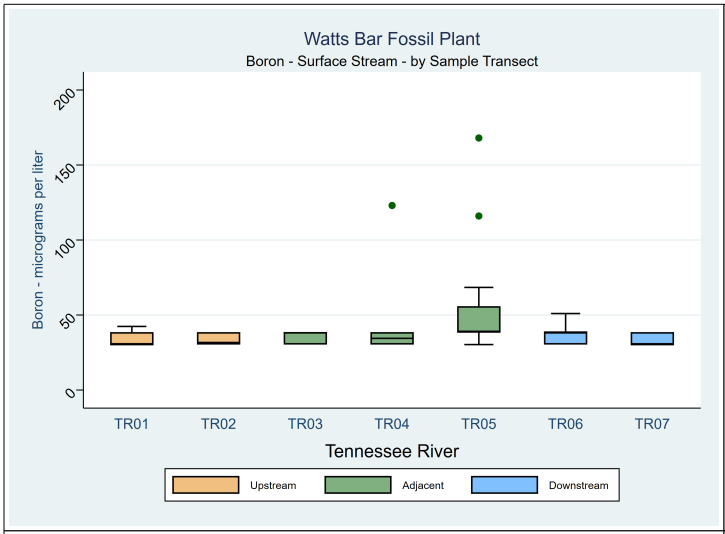
Notes:
CCR Rule - Title 40, Code of Federal Regulations, Part 257
TDEC - Tennessee Department of Environment and Conservation
% - percent
"--" - Not Applicable
TDS - Total Dissolved Solids
TSS - Total Suspended Solids

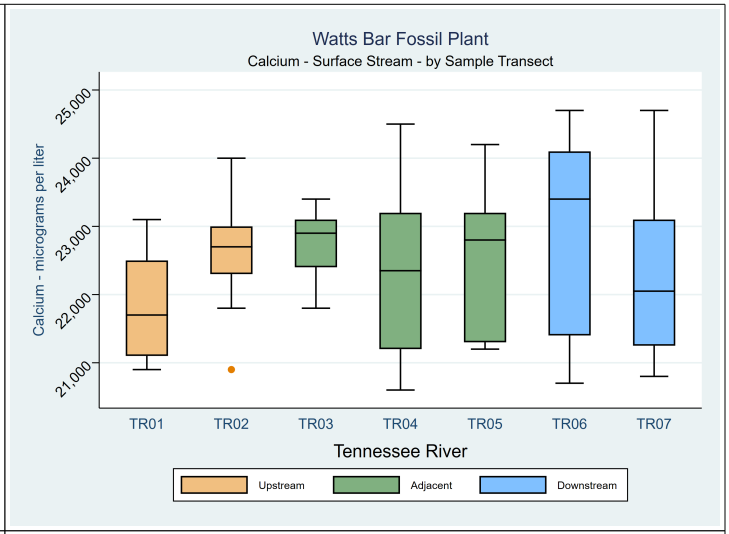
Statistical data sets were aggregated by location of transect relative to the CCR management units (upstream, adjacent downstream) and sample fraction (total, dissolved, or normal)
Except for Radium 226 + 228, all units micrograms per liter (µg/L)
Units for Radium 226+228 are picocuries per liter (pCi/L)
Fractions reported include dissolved (D), total (T), and normal (N)
All non-detects reported at the laboratory reporting limit
For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM).

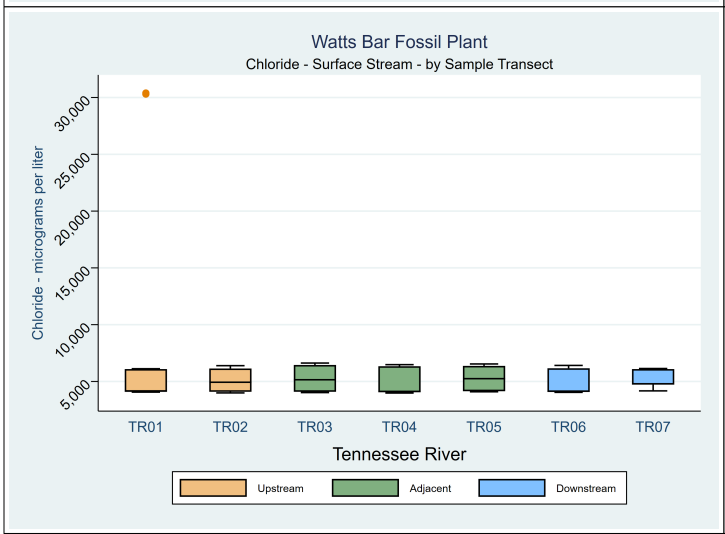
ATTACHMENT E.5-B - BOX PLOTS

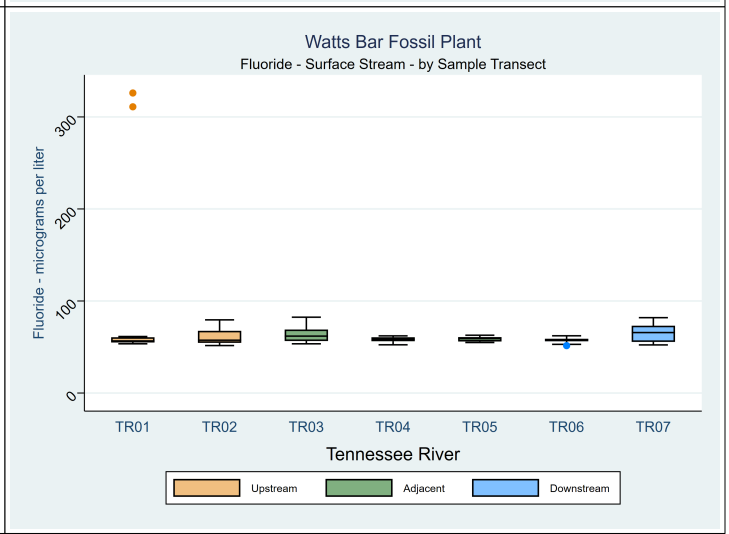
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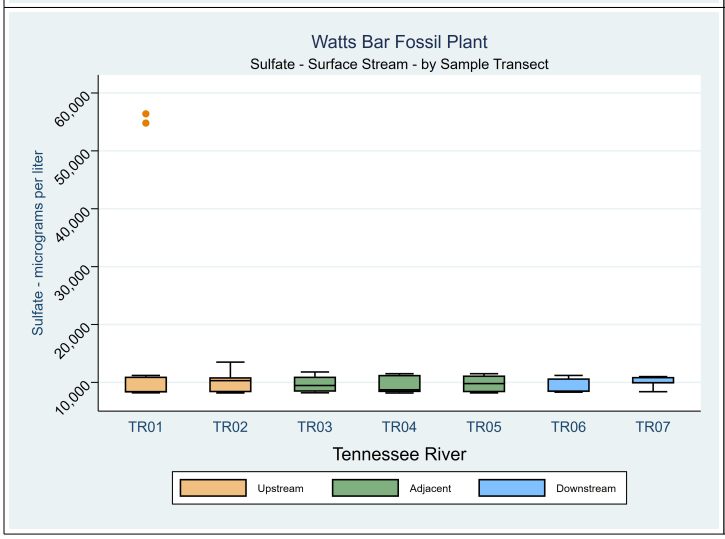
Box Plots
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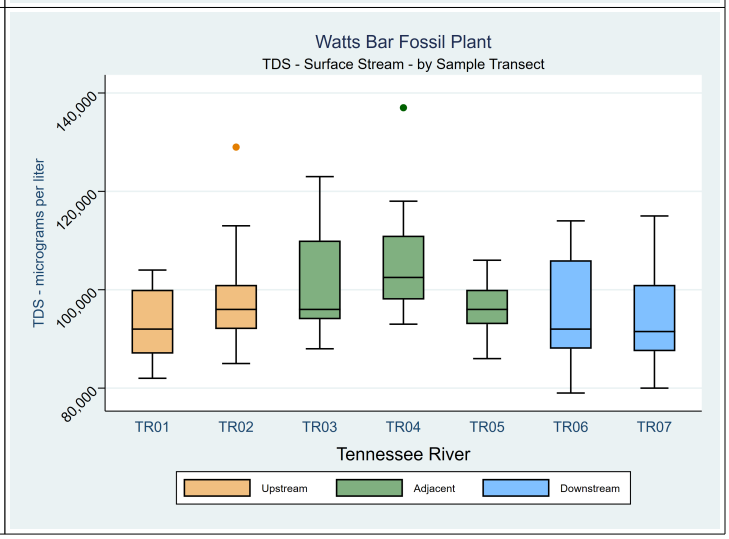






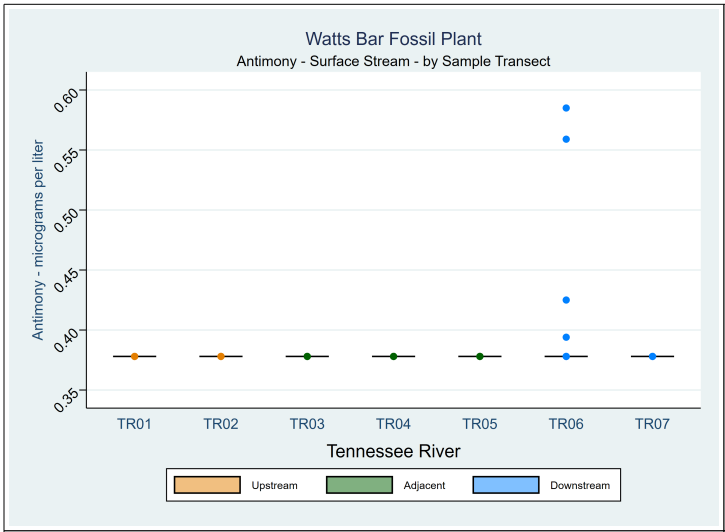


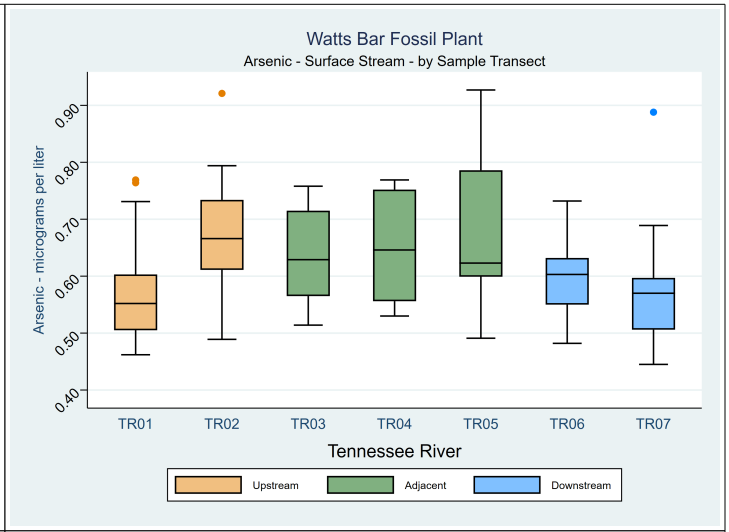


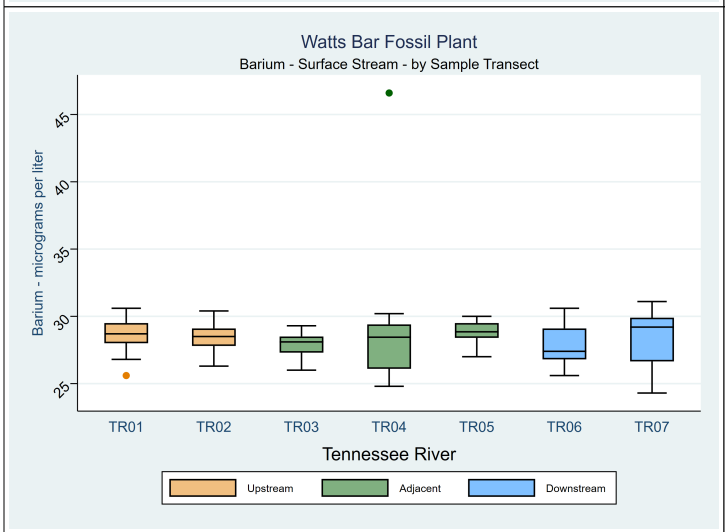


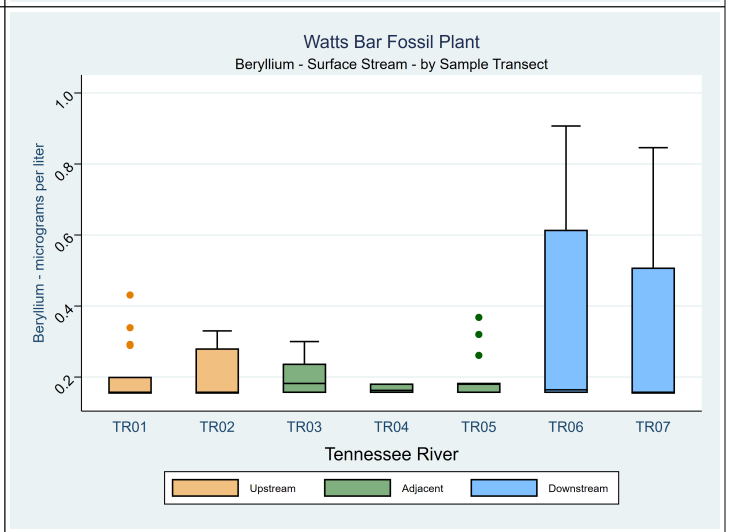
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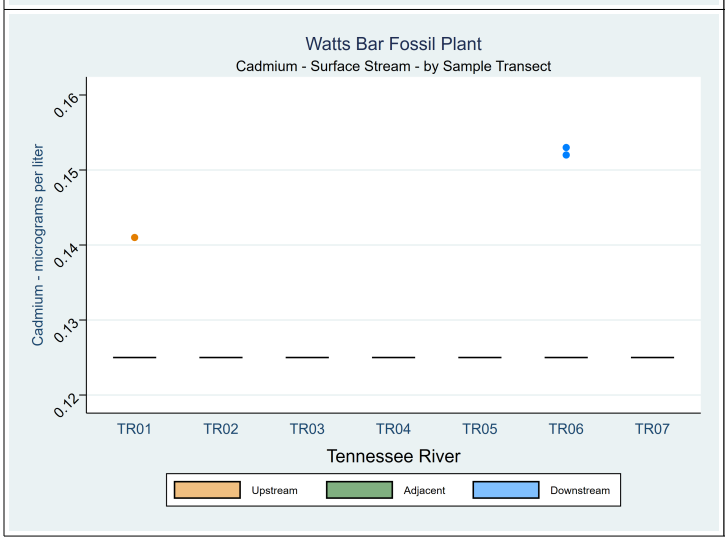
Box Plots
CCR Rule Appendix IV Parameters
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

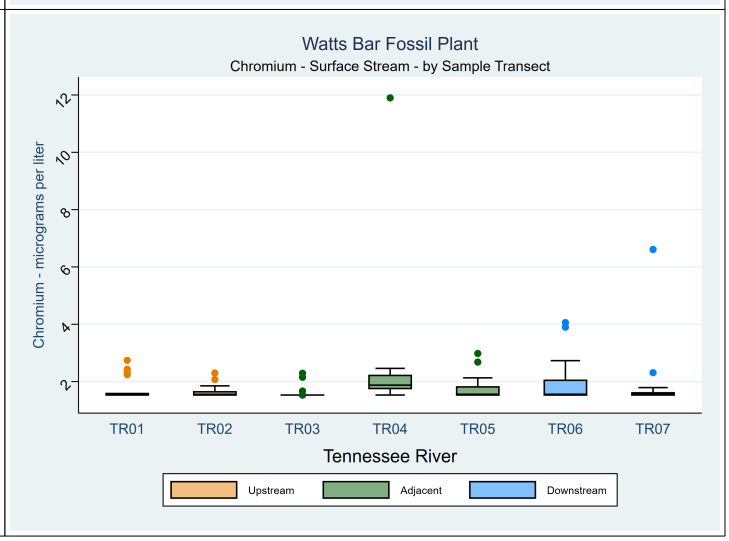




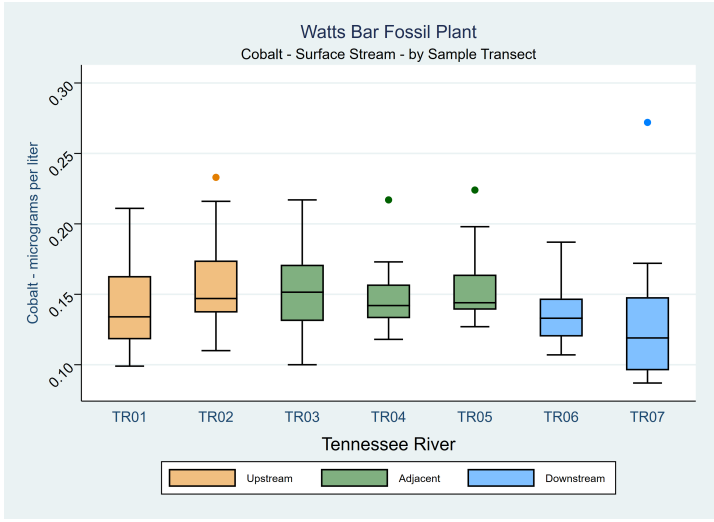


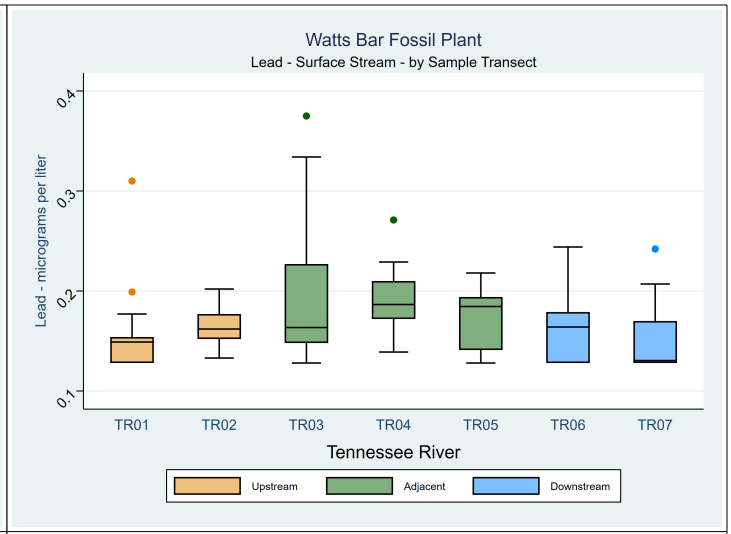


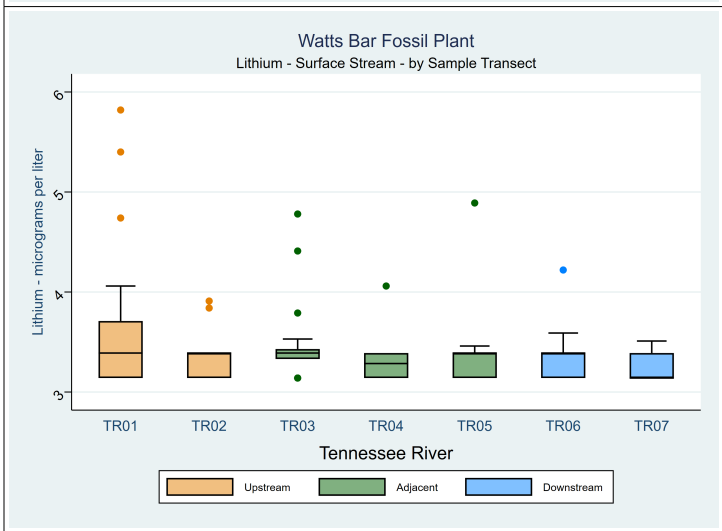


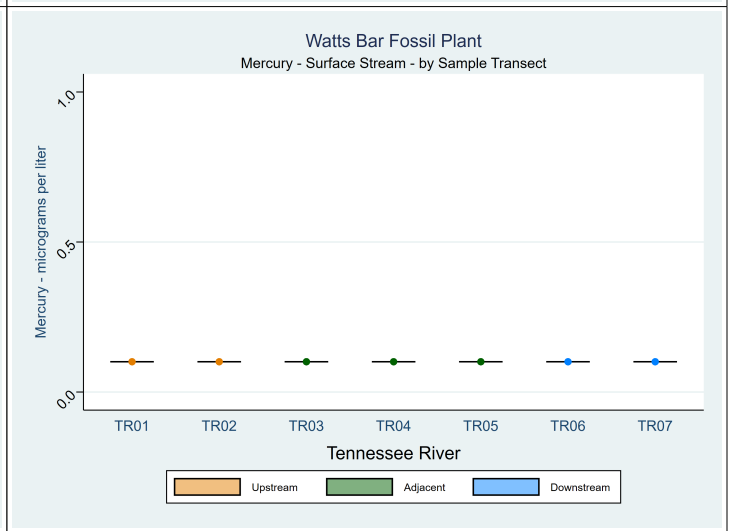


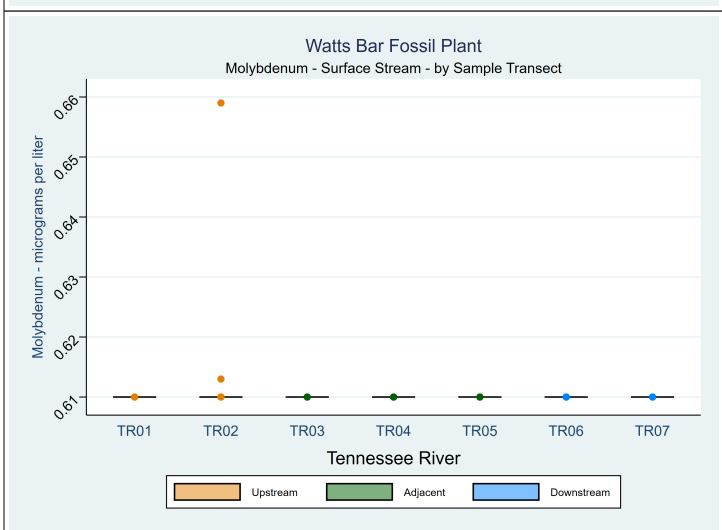
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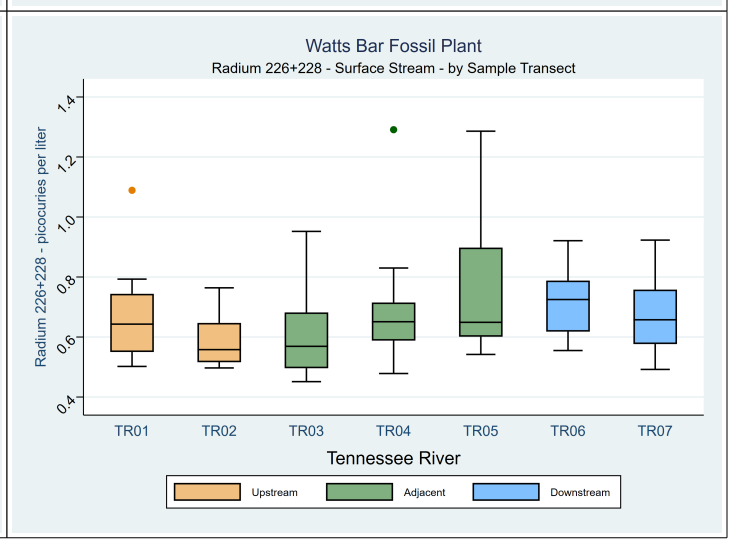

Watts Bar Fossil Plant
Cobalt - Surface Stream - by Sample Transect
Cobalt - micrograms per liter
0.10
0.15
0.20
0.25
0.30
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Tennessee River
Upstream
Adjacent
Downstream


Watts Bar Fossil Plant
Lead - Surface Stream - by Sample Transect
Lead - micrograms per liter
0.1
0.2
0.3
0.4
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Tennessee River
Upstream
Adjacent
Downstream

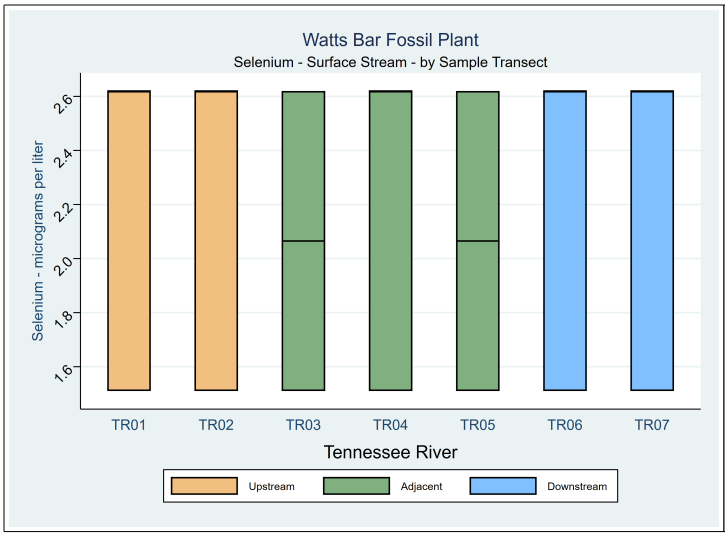

Watts Bar Fossil Plant
Lithium - Surface Stream - by Sample Transect
Lithium - micrograms per liter
3
4
5
6
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Tennessee River
Upstream
Adjacent
Downstream

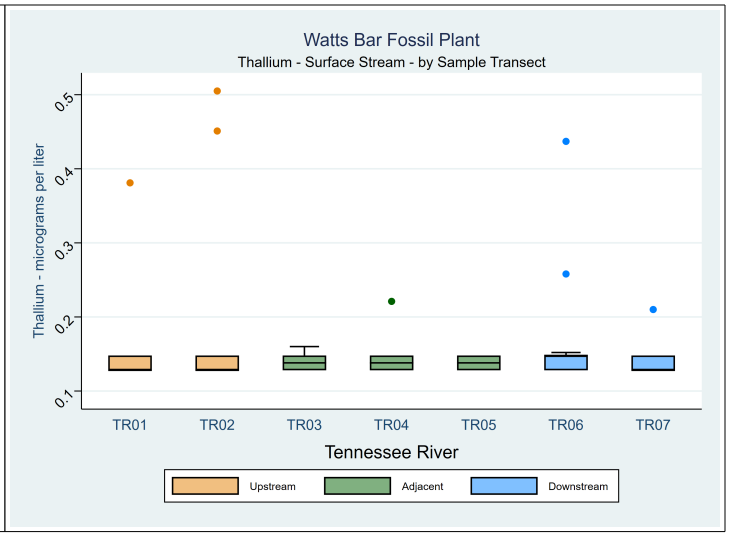

Watts Bar Fossil Plant
Mercury - Surface Stream - by Sample Transect
Mercury - micrograms per liter
0.0
0.5
1.0
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Tennessee River
Upstream
Adjacent
Downstream


Watts Bar Fossil Plant
Molybdenum - Surface Stream - by Sample Transect
Molybdenum - micrograms per liter
0.61
0.62
0.63
0.64
0.65
0.66
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Tennessee River
Upstream
Adjacent
Downstream


Watts Bar Fossil Plant
Radium 226+228 - Surface Stream - by Sample Transect
Radium 226+228 - picocuries per liter
0.4
0.6
0.8
1.0
1.2
1.4
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Tennessee River
Upstream
Adjacent
Downstream

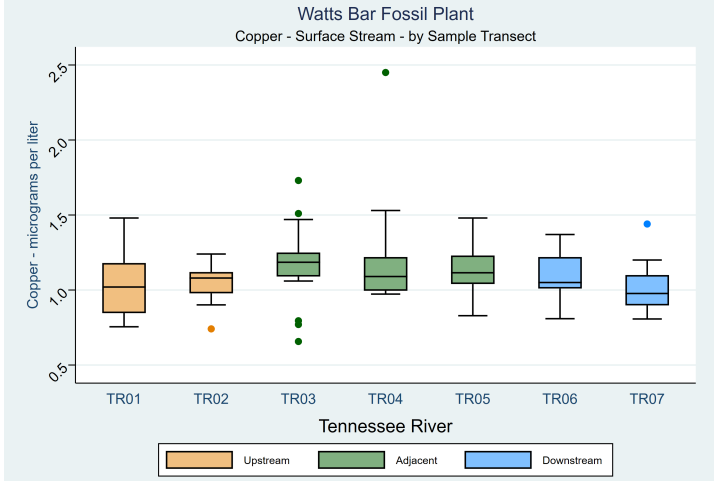
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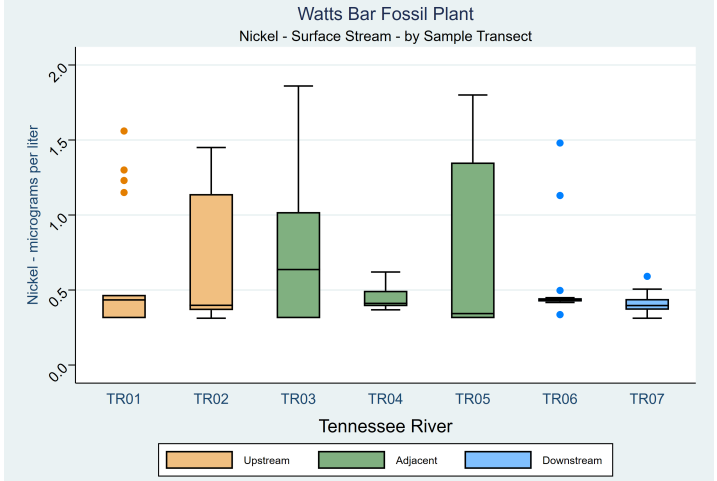

Watts Bar Fossil Plant
Selenium - Surface Stream - by Sample Transect
Selenium - micrograms per liter
1.6
1.8
2.0
2.2
2.4
2.6
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Tennessee River
Upstream
Adjacent
Downstream

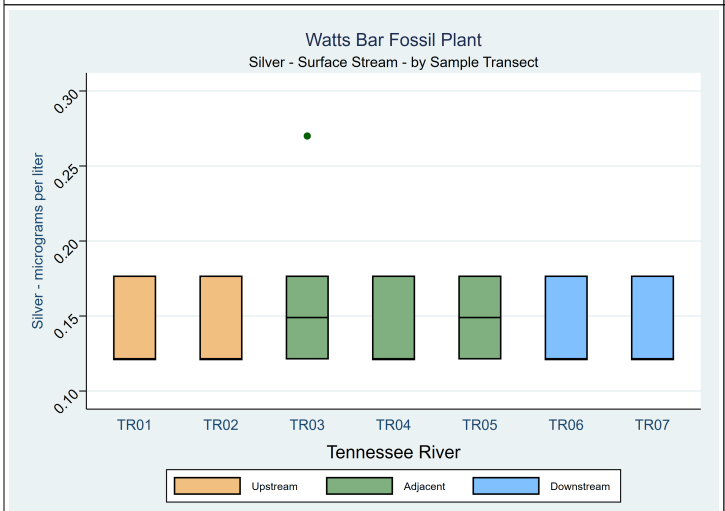

Watts Bar Fossil Plant
Thallium - Surface Stream - by Sample Transect
Thallium - micrograms per liter
0.1
0.2
0.3
0.4
0.5
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Tennessee River
Upstream
Adjacent
Downstream

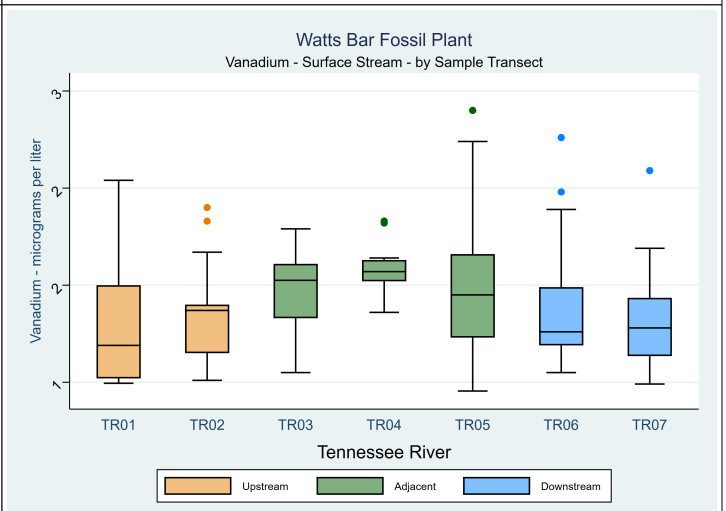
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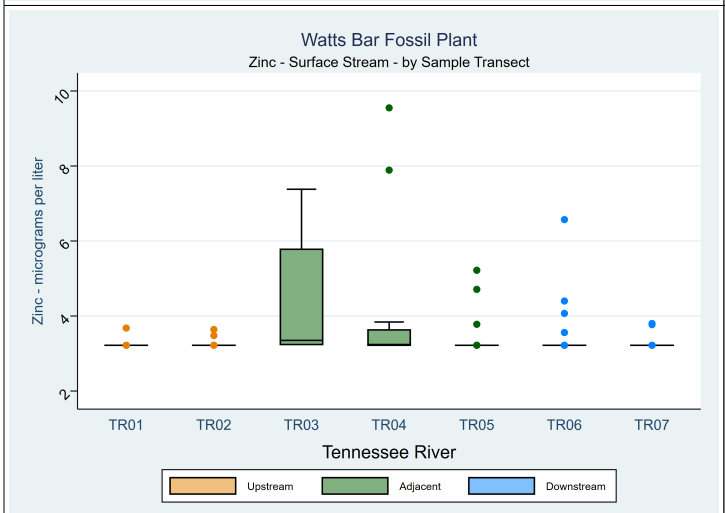
Box Plots
TDEC Appendix I Parameters
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee









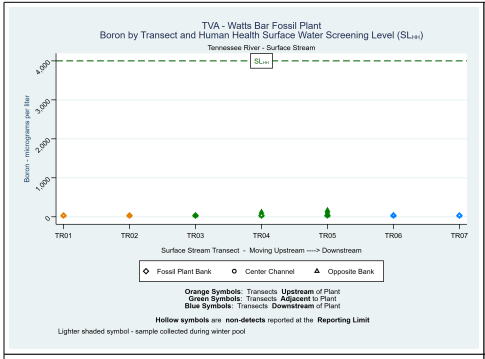


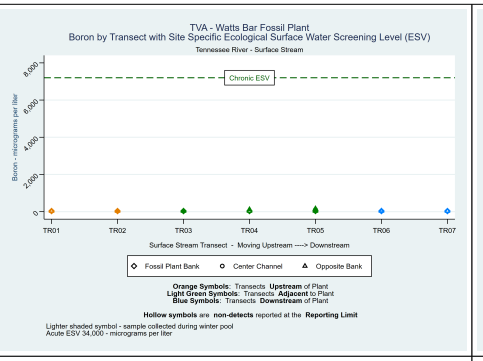
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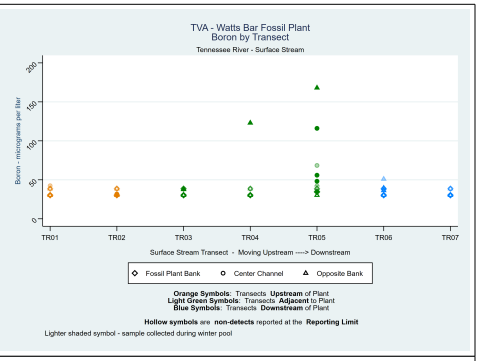
ATTACHMENT E.5-C - TRANSECT PLOTS

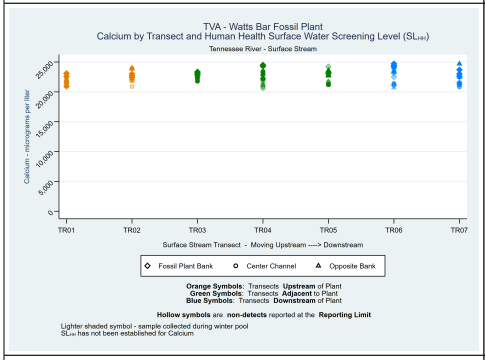
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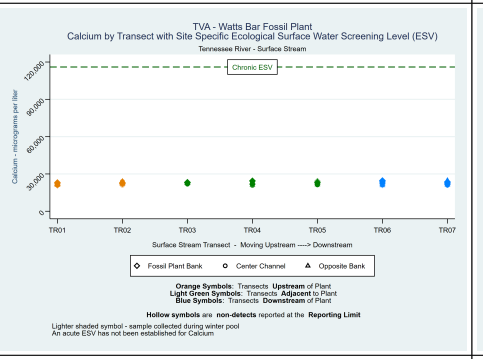
Transect Plots
CCR Rule Appendix III Parameters
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

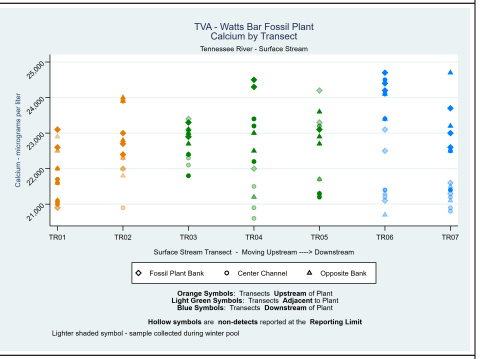


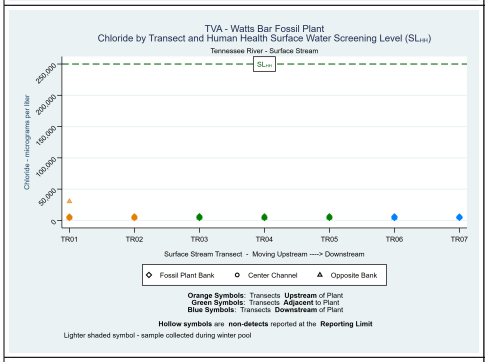


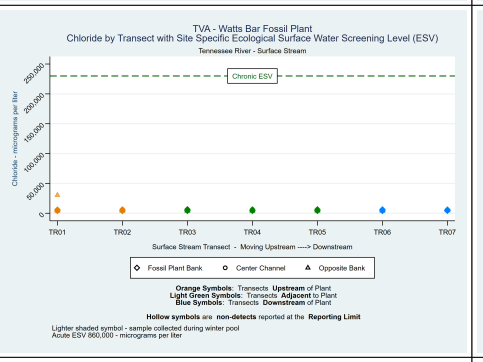


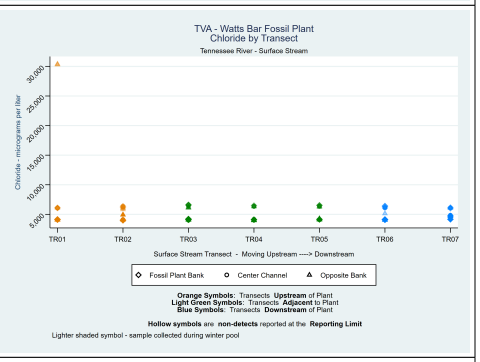


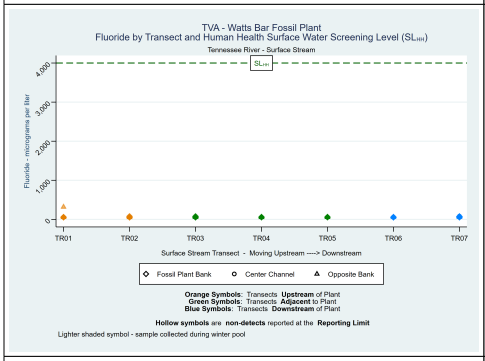


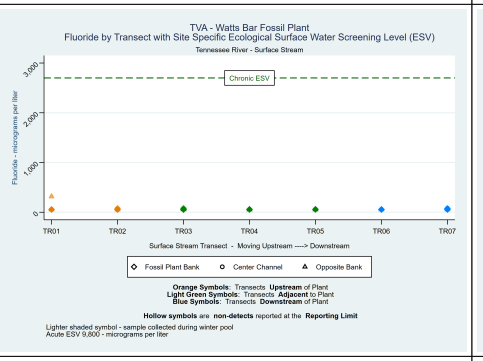


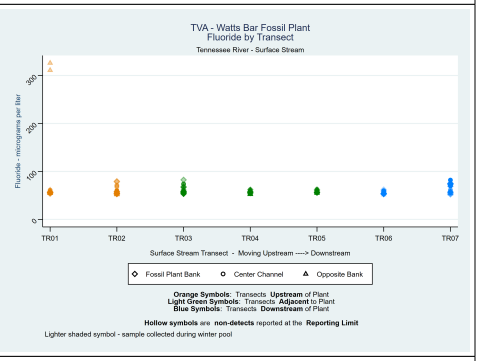






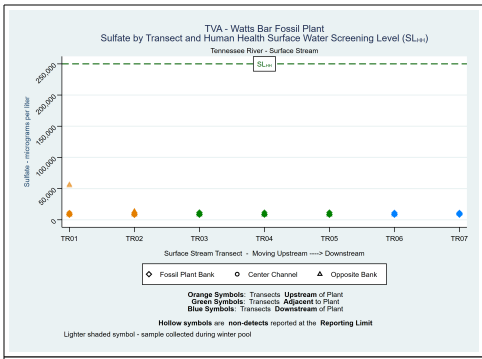


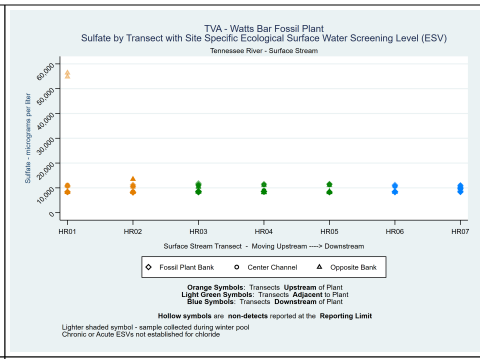


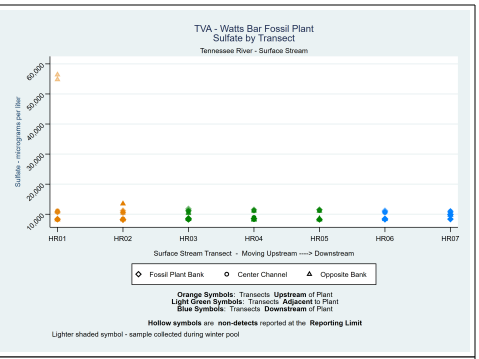


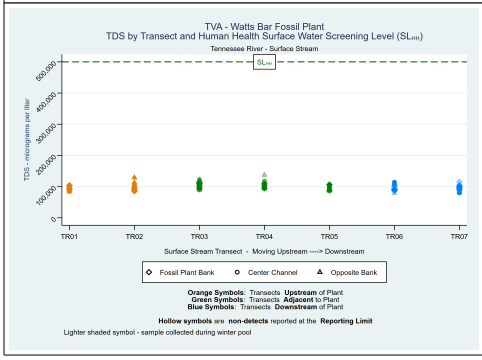
Place-holder for pH Field	Place-holder for pH Field	Place-holder for pH Field

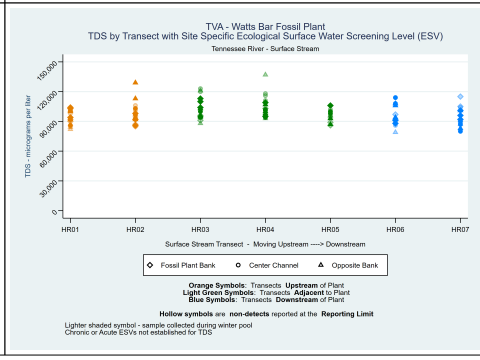
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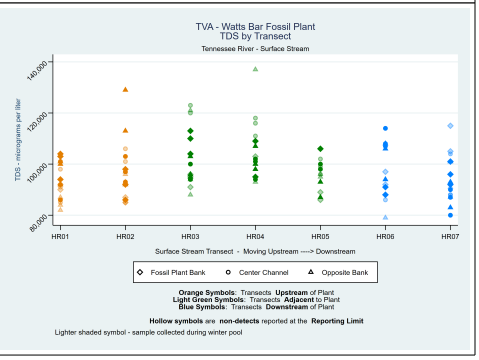

TVA - Watts Bar Fossil Plant
Sulfate by Transect and Human Health Surface Water Screening Level (SLHH)
Tennessee River - Surface Stream
SLHH
Sulfate - micrograms per liter
250,000
200,000
150,000
100,000
50,000
0
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool


TVA - Watts Bar Fossil Plant
Sulfate by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Sulfate - micrograms per liter
60,000
50,000
40,000
30,000
20,000
10,000
0
HR01
HR02
HR03
HR04
HR05
HR06
HR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Chronic or Acute ESVs not established for chloride


TVA - Watts Bar Fossil Plant
Sulfate by Transect
Tennessee River - Surface Stream
Sulfate - micrograms per liter
60,000
50,000
40,000
30,000
20,000
10,000
HR01
HR02
HR03
HR04
HR05
HR06
HR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

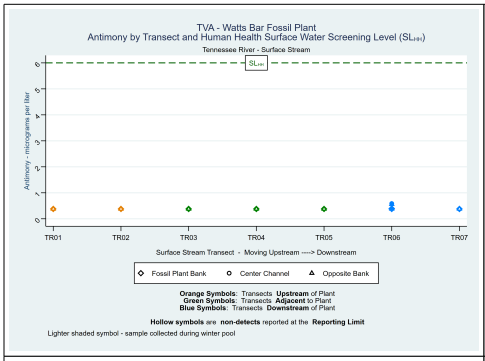

TVA - Watts Bar Fossil Plant
TDS by Transect and Human Health Surface Water Screening Level (SLHH)
Tennessee River - Surface Stream
SLHH
TDS - micrograms per liter
500,000
400,000
300,000
200,000
100,000
0
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

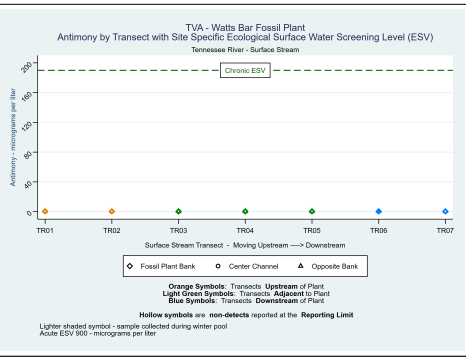

TVA - Watts Bar Fossil Plant
TDS by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
TDS - micrograms per liter
150,000
120,000
90,000
60,000
30,000
0
HR01
HR02
HR03
HR04
HR05
HR06
HR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Chronic or Acute ESVs not established for TDS

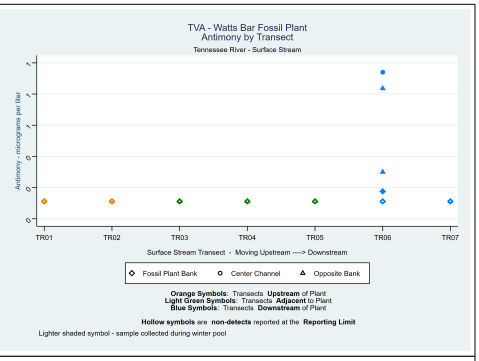

TVA - Watts Bar Fossil Plant
TDS by Transect
Tennessee River - Surface Stream
TDS - micrograms per liter
140,000
120,000
100,000
80,000
HR01
HR02
HR03
HR04
HR05
HR06
HR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

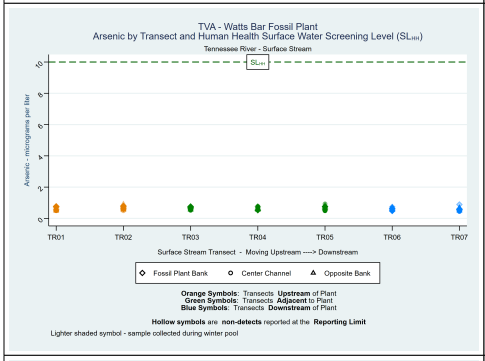
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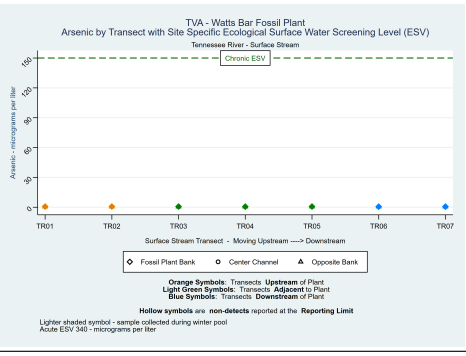
Transect Plots
CCR Rule Appendix IV Parameters
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

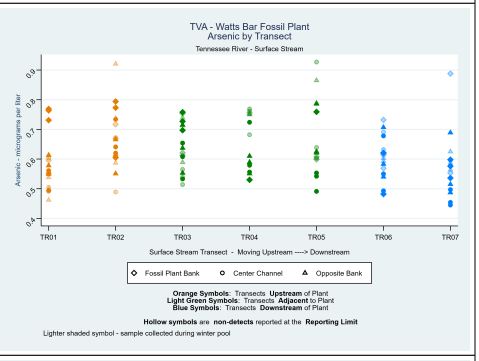


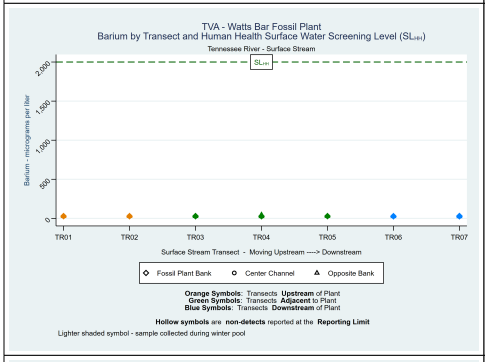


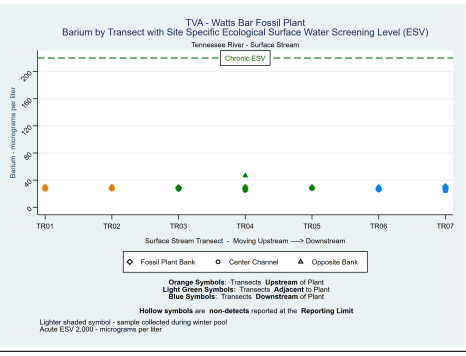


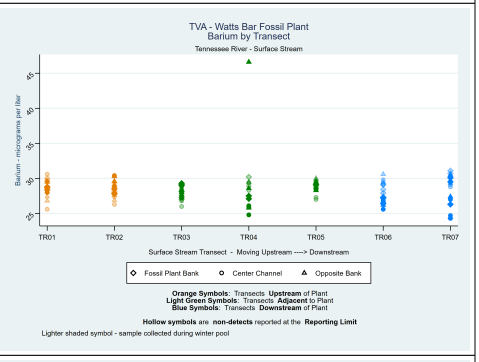


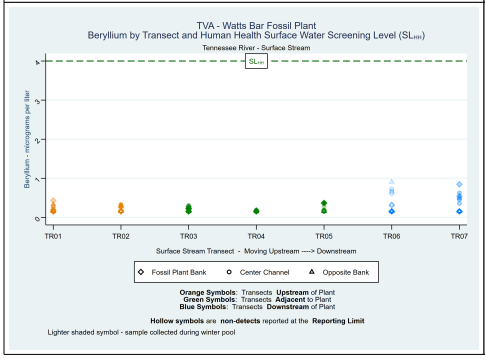


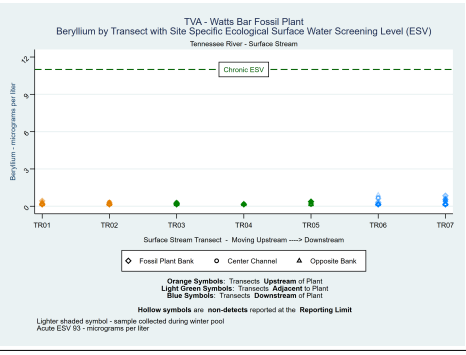


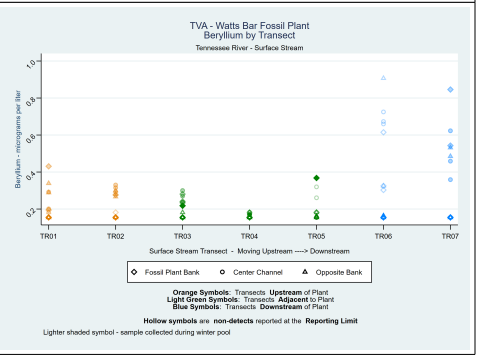




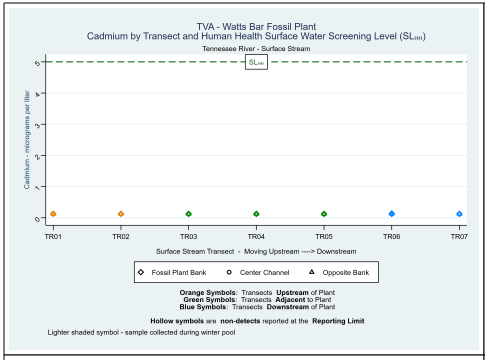


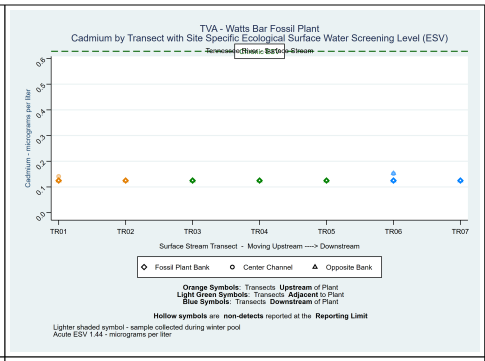


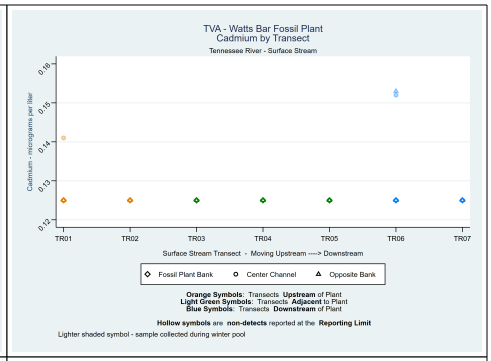


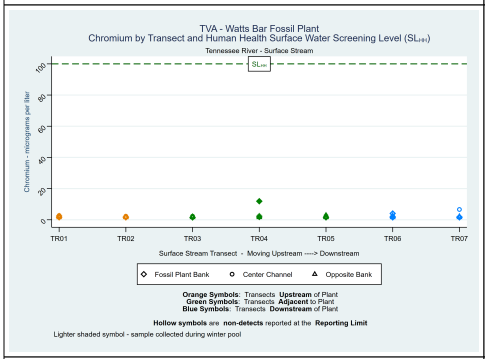


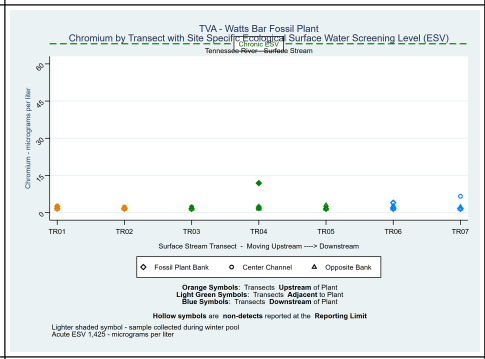
DRAFT

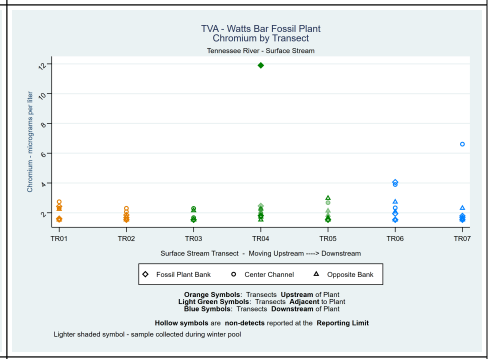

TVA - Watts Bar Fossil Plant
Cadmium by Transect and Human Health Surface Water Screening Level (SLHH)
Tennessee River - Surface Stream
SLHH
Cadmium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

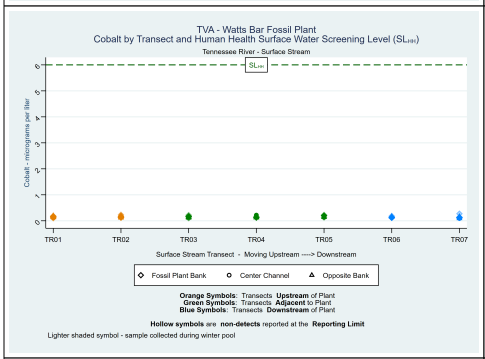

TVA - Watts Bar Fossil Plant
Cadmium by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Cadmium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 1.44 - micrograms per liter

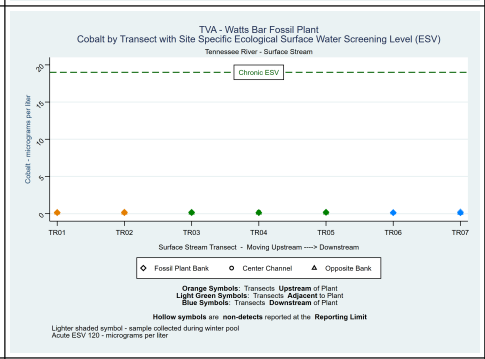

TVA - Watts Bar Fossil Plant
Cadmium by Transect
Tennessee River - Surface Stream
Cadmium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

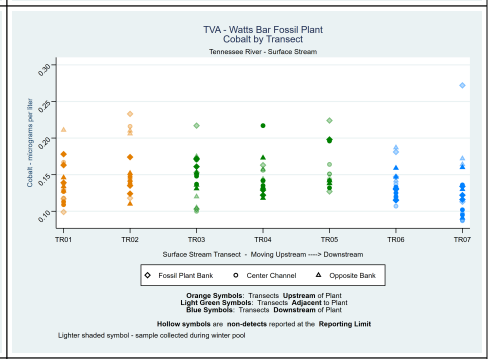

TVA - Watts Bar Fossil Plant
Chromium by Transect and Human Health Surface Water Screening Level (SLHH)
Tennessee River - Surface Stream
SLHH
Chromium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

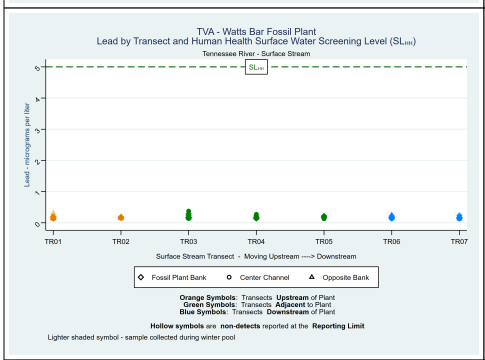

TVA - Watts Bar Fossil Plant
Chromium by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Chromium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 1,425 - micrograms per liter

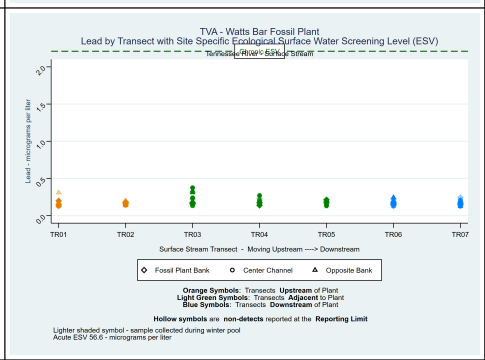

TVA - Watts Bar Fossil Plant
Chromium by Transect
Tennessee River - Surface Stream
Chromium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

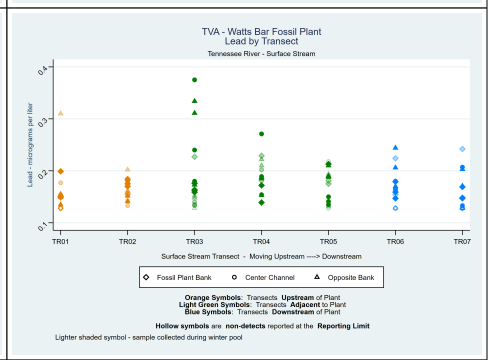

TVA - Watts Bar Fossil Plant
Cobalt by Transect and Human Health Surface Water Screening Level (SLHH)
Tennessee River - Surface Stream
SLHH
Cobalt - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

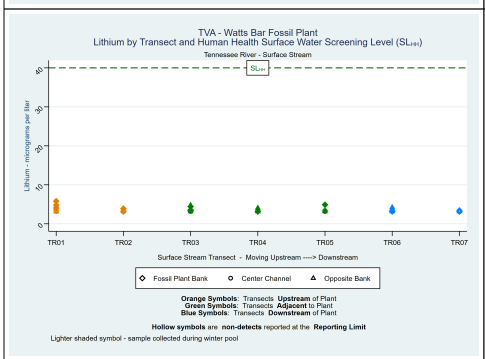

TVA - Watts Bar Fossil Plant
Cobalt by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Cobalt - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 120 - micrograms per liter

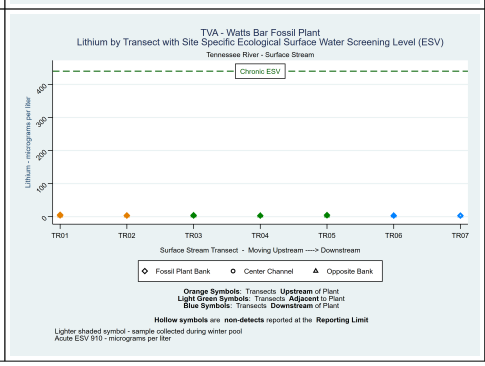

TVA - Watts Bar Fossil Plant
Cobalt by Transect
Tennessee River - Surface Stream
Cobalt - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

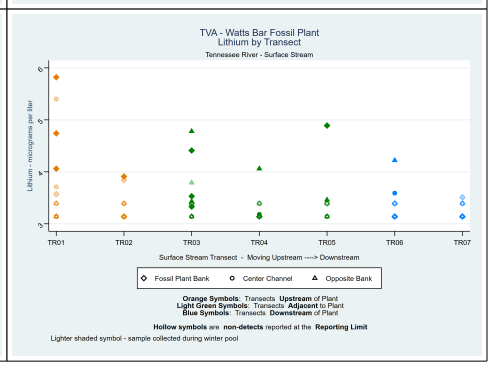

TVA - Watts Bar Fossil Plant
Lead by Transect and Human Health Surface Water Screening Level (SLHH)
Tennessee River - Surface Stream
SLHH
Lead - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool


TVA - Watts Bar Fossil Plant
Lead by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Lead - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 56.6 - micrograms per liter

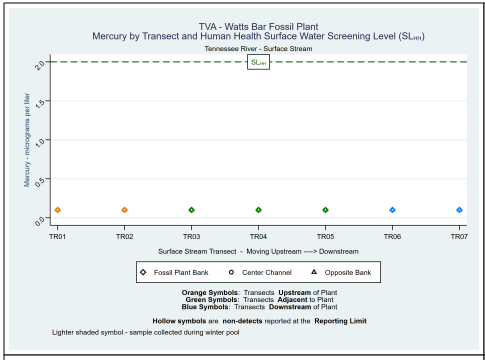

TVA - Watts Bar Fossil Plant
Lead by Transect
Tennessee River - Surface Stream
Lead - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

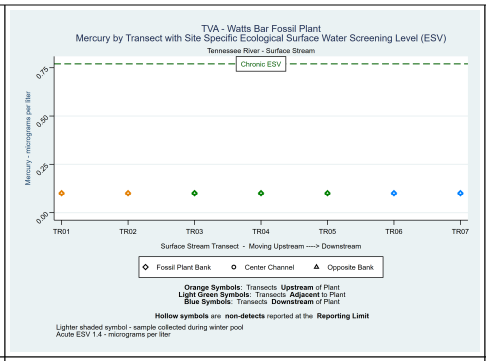

TVA - Watts Bar Fossil Plant
Lithium by Transect and Human Health Surface Water Screening Level (SLHH)
Tennessee River - Surface Stream
SLHH
Lithium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

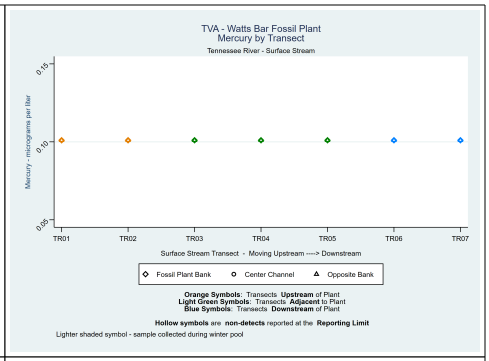

TVA - Watts Bar Fossil Plant
Lithium by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Lithium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 910 - micrograms per liter

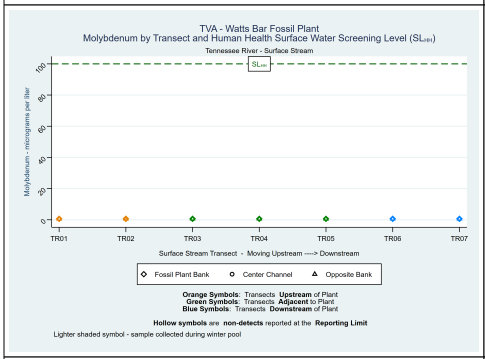

TVA - Watts Bar Fossil Plant
Lithium by Transect
Tennessee River - Surface Stream
Lithium - micrograms per liter
TR01 TR02 TR03 TR04 TR05 TR06 TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

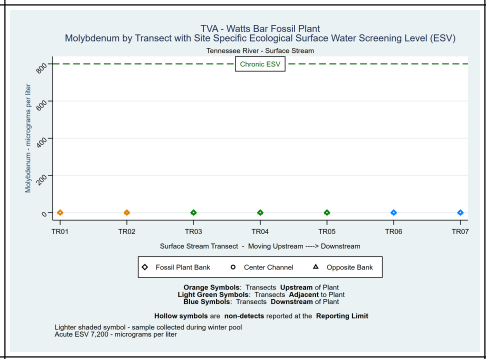
DRAFT

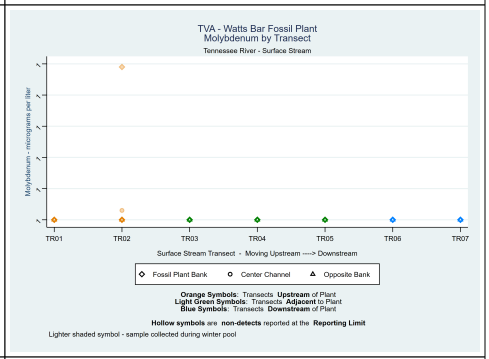

TVA - Watts Bar Fossil Plant
Mercury by Transect and Human Health Surface Water Screening Level (SL_HH)
Tennessee River - Surface Stream
SL_HH
Mercury - micrograms per liter
0.0
0.5
1.0
1.5
2.0
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

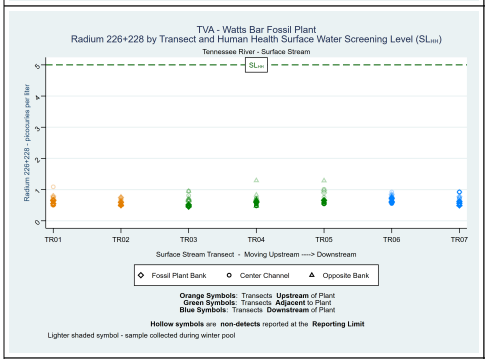

TVA - Watts Bar Fossil Plant
Mercury by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Mercury - micrograms per liter
0.00
0.25
0.50
0.75
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 1.4 - micrograms per liter

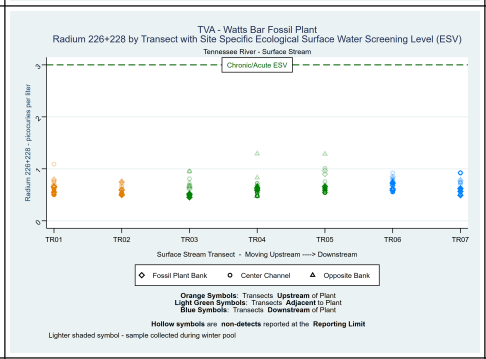

TVA - Watts Bar Fossil Plant
Mercury by Transect
Tennessee River - Surface Stream
Mercury - micrograms per liter
0.05
0.10
0.15
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

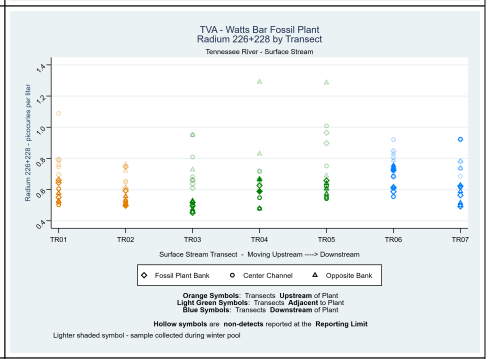

TVA - Watts Bar Fossil Plant
Molybdenum by Transect and Human Health Surface Water Screening Level (SL_HH)
Tennessee River - Surface Stream
SL_HH
Molybdenum - micrograms per liter
0
20
40
60
80
100
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

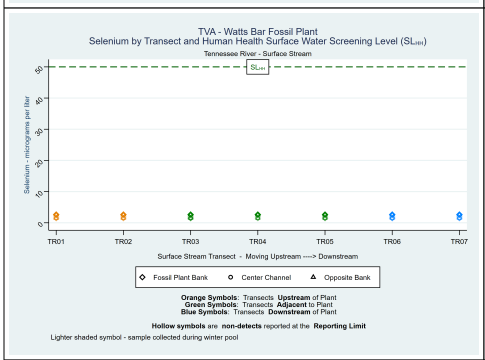

TVA - Watts Bar Fossil Plant
Molybdenum by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Molybdenum - micrograms per liter
0
200
400
600
800
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 7,200 - micrograms per liter

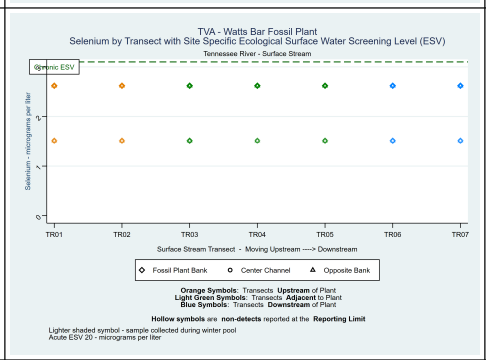

TVA - Watts Bar Fossil Plant
Molybdenum by Transect
Tennessee River - Surface Stream
Molybdenum - micrograms per liter
1
1
1
1
1
1
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

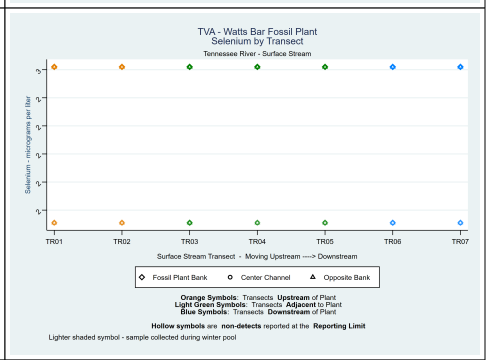

TVA - Watts Bar Fossil Plant
Radium 226+228 by Transect and Human Health Surface Water Screening Level (SL_HH)
Tennessee River - Surface Stream
SL_HH
Radium 226+228 - picocuries per liter
0
1
2
3
4
5
6
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

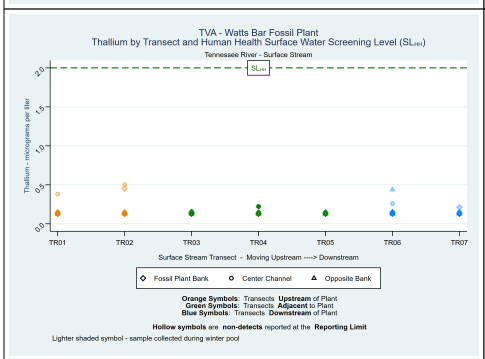

TVA - Watts Bar Fossil Plant
Radium 226+228 by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic/Acute ESV
Radium 226+228 - picocuries per liter
0
1
2
3
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

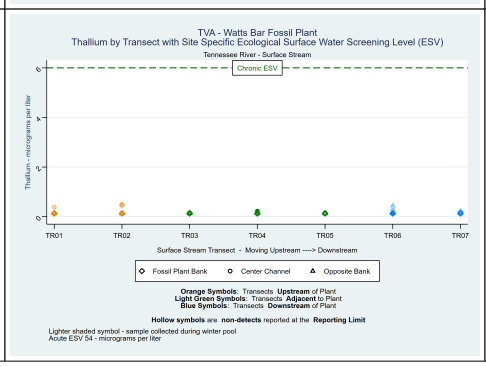

TVA - Watts Bar Fossil Plant
Radium 226+228 by Transect
Tennessee River - Surface Stream
Radium 226+228 - picocuries per liter
0
1
2
3
4
5
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

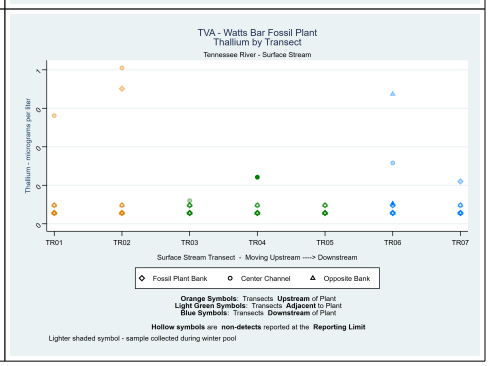

TVA - Watts Bar Fossil Plant
Selenium by Transect and Human Health Surface Water Screening Level (SL_HH)
Tennessee River - Surface Stream
SL_HH
Selenium - micrograms per liter
0
10
20
30
40
50
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool


TVA - Watts Bar Fossil Plant
Selenium by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Selenium - micrograms per liter
0
1
2
3
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 20 - micrograms per liter


TVA - Watts Bar Fossil Plant
Selenium by Transect
Tennessee River - Surface Stream
Selenium - micrograms per liter
2
3
4
5
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

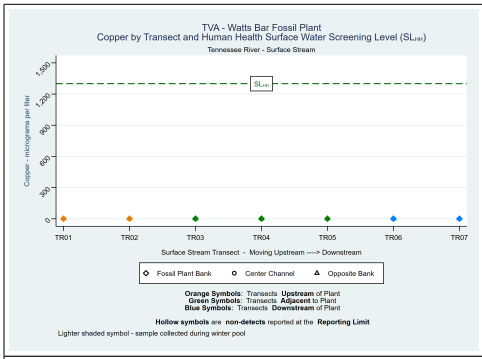

TVA - Watts Bar Fossil Plant
Thallium by Transect and Human Health Surface Water Screening Level (SL_HH)
Tennessee River - Surface Stream
SL_HH
Thallium - micrograms per liter
0.0
0.5
1.0
1.5
2.0
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

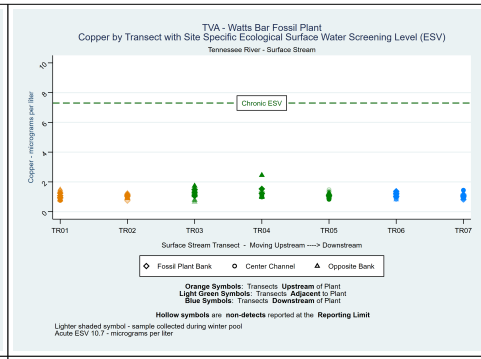

TVA - Watts Bar Fossil Plant
Thallium by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic ESV
Thallium - micrograms per liter
0
2
4
6
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool
Acute ESV 54 - micrograms per liter

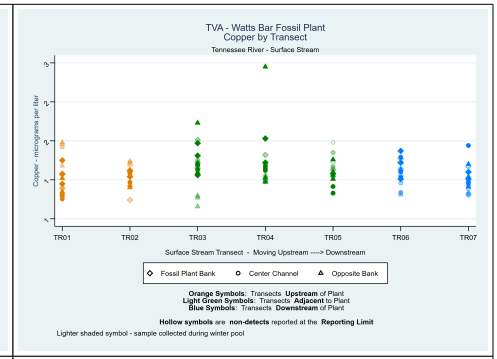

TVA - Watts Bar Fossil Plant
Thallium by Transect
Tennessee River - Surface Stream
Thallium - micrograms per liter
0
0
0
0
0
1
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

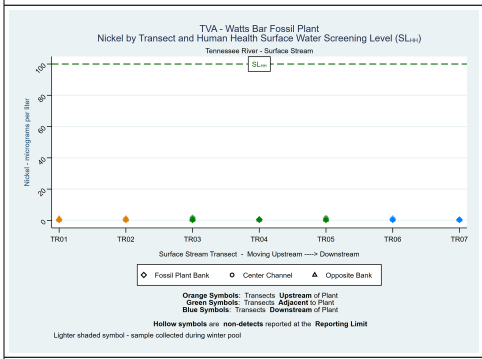
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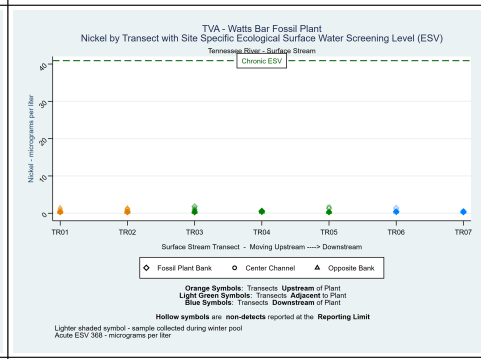
Transect Plots
TDEC Appendix I Parameters
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

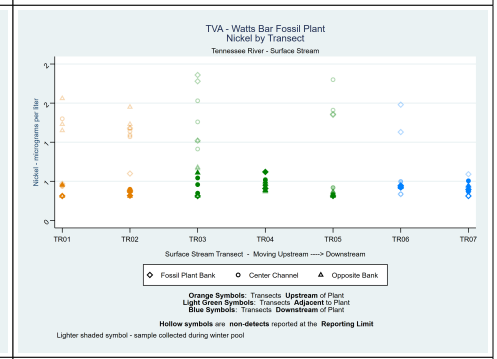


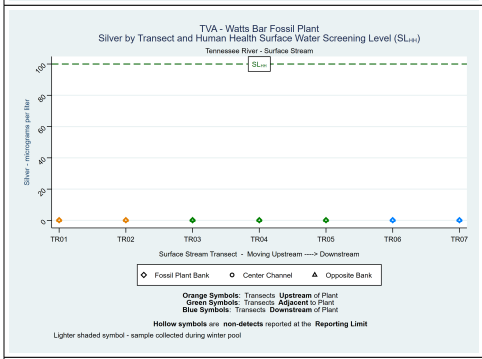


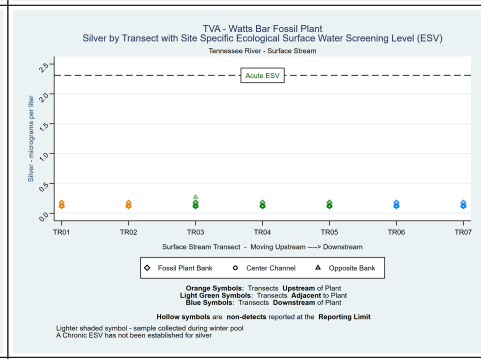


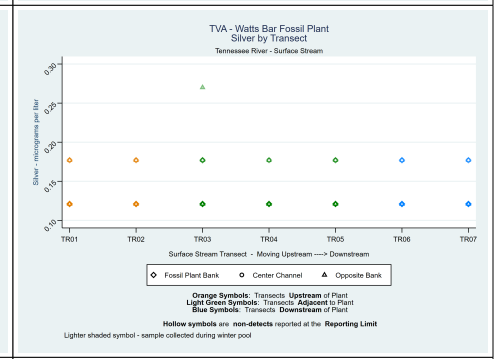


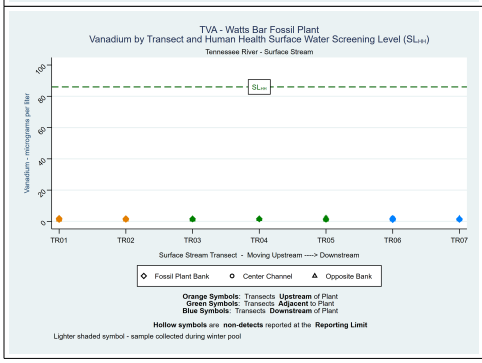


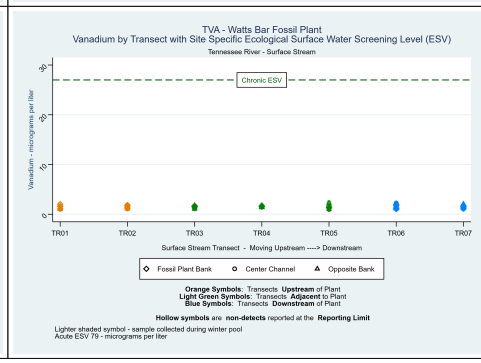


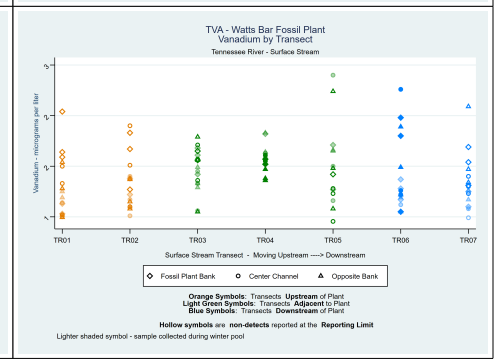




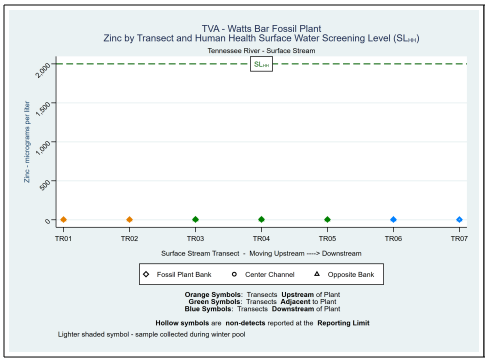


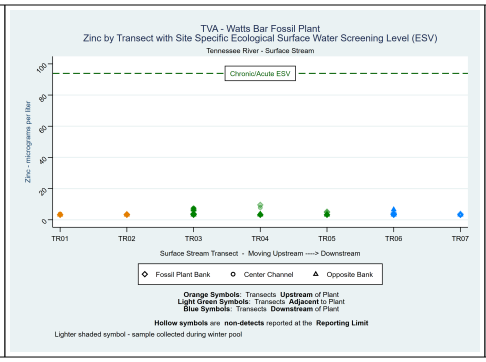


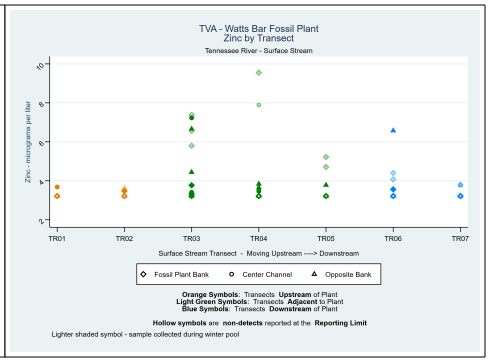




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TVA - Watts Bar Fossil Plant
Zinc by Transect and Human Health Surface Water Screening Level (SLHH)
Tennessee River - Surface Stream
SLHH
Zinc - micrograms per liter
2,000
1,500
1,000
500
0
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

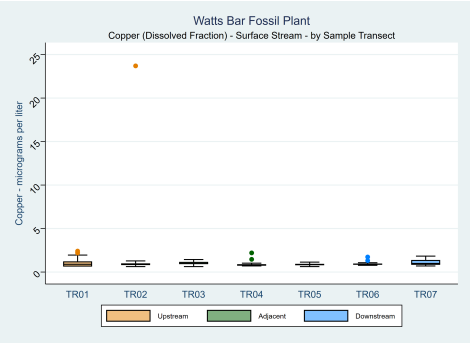

TVA - Watts Bar Fossil Plant
Zinc by Transect with Site Specific Ecological Surface Water Screening Level (ESV)
Tennessee River - Surface Stream
Chronic/Acute ESV
Zinc - micrograms per liter
100
80
60
40
20
0
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

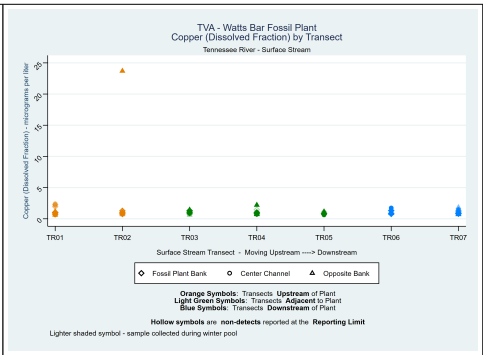

TVA - Watts Bar Fossil Plant
Zinc by Transect
Tennessee River - Surface Stream
Zinc - micrograms per liter
10
8
6
4
2
TR01
TR02
TR03
TR04
TR05
TR06
TR07
Surface Stream Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Center Channel
Opposite Bank
Orange Symbols: Transects Upstream of Plant
Light Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Reporting Limit
Lighter shaded symbol - sample collected during winter pool

ATTACHMENT E.5-D - BOX AND TRANSECT PLOTS – STATISTICAL OUTLIER

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Box and Transect Plots
Tennessee River
Surface Stream Investigation
Watts Bar Fossil Plant - Spring City, Tennessee





APPENDIX E.6

STATISTICAL ANALYSIS OF SEDIMENT DATA

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Appendix E.6 - Statistical Analysis of Sediment Data

TDEC Commissioner's Order:
Environmental Assessment Report
Watts Bar Fossil Plant
Spring City, Tennessee

March 31, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

Revision Log

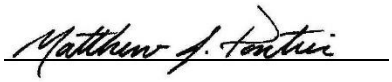
Revision	Description	Date
0	Submittal to TDEC	November 7, 2023
1	Addresses January 31, 2024 TDEC Review Comments and Issued for TDEC	March 31, 2024

Sign-off Sheet

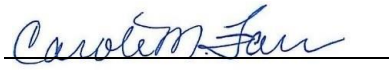
This document entitled Appendix E.6 - Statistical Analysis of Sediment Data was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by 

Chris La Londe, Senior Risk Assessor

Reviewed by 

Matt Pontier, Staff Engineer

Approved by 

Carole M. Farr, PG, Senior Principal Geologist

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ATTACHMENT E.6-A SUMMARY STATISTICS
ATTACHMENT E.6-B TRANSECT PLOTS

Abbreviations

CASRN	Chemical Abstracts Service Registry Number
CCR	Coal Combustion Residuals
CCR Parameters	The Constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations, Part 257
EAR	Environmental Assessment Report
EI	Environmental Investigation
ESV	Ecological Screening Level
IQR	Interquartile Range
NA	Not Available
%	Percent
PCA	Principal Component Analysis
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority
WBF Plant	Watts Bar Fossil Plant

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this appendix on behalf of the Tennessee Valley Authority (TVA) to summarize the statistical analyses performed on sediment data to support evaluations conducted for the Environmental Assessment Report (EAR) at the Watts Bar Fossil Plant (WBF Plant) located in Spring City, Tennessee. The sediment samples were collected between March and April 2019 from the Tennessee River in proximity to the WBF Plant. Further details regarding the sediment sampling, and laboratory data results are presented in Appendix J.3 and the WBF Plant *Benthic Investigation Sampling and Analysis Report* (Appendix J.4)**.**

For the Environmental Investigation (EI), sediment samples were collected from locations along sample transects or individual locations from the Tennessee River in proximity to the WBF Plant coal combustion residual (CCR) management units. Sample transects/location names and locations relative to WBF Plant CCR management units and the numbers of samples collected are presented in Table E.6-1. The constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04 (CCR Parameters) included in the statistical analysis are presented in Table E.6-2.

Table E.6-1 – Sediment Sample Transect/Locations

Water body	Transect/Location Name	Location Relative to WBF Plant CCR Management Units	Number of Samples
Tennessee River	TR04, TR05, TR05.5	Adjacent	3
	TR06, TR06.75, TR07	Downstream	4

Table E.6-2 – CCR Parameters Evaluated in Statistical Analysis

CCR Parameter	CASRN
CCR Rule Appendix III Parameters	
Boron	7440-42-8
Calcium	7440-70-2
Chloride	16887-00-6
Fluoride[1] (also Appendix IV)	16984-48-8
pH	NA
Sulfate	14808-79-8
CCR Rule Appendix IV Parameters	
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Lead	7439-92-1
Lithium	7439-93-2
Mercury	7439-97-6
Molybdenum	7439-98-7
Radium-226+228	13982-63-3/ 15262-20-1
Selenium	7782-49-2
Thallium	7440-28-0
TDEC Appendix I Parameters	
Copper	7440-50-8
Nickel	7440-02-0
Silver	7440-22-4
Vanadium	7440-62-2
Zinc	7440-66-6
Other	
% Ash	NA
Strontium	7440-24-6

Notes: CASRN - Chemical Abstracts Service Registry Number; CCR Rule - Title 40, Code of Federal Regulations, Part 257; NA – Not available; TDEC - Tennessee Department of Environment and Conservation

[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV CCR parameter. In this table, and in the results figures and tables for this report, fluoride has been grouped with the Appendix III CCR parameters only to avoid duplication.

The following sections present the methods and results from the general exploratory data analysis using summary statistics, data plots, and outlier screening, and a comparison of sediment results to Ecological Screening Levels (ESVs) that were developed for the EAR. The ESVs for the sediment data are provided in Table 1-3 and Appendix A.2.

Additional statistical analyses (principal component analysis [PCA] and hypothesis testing) may be warranted if the following conditions were met: 1) CCR Parameter concentrations were above ESVs, and 2) data were collected from transects/locations adjacent, and from transects/locations either upstream or downstream to the WBF Plant CCR management units.

2.0 METHODS

The statistical evaluation for the EI sediment data collected at the WBF Plant was conducted in three parts: 1) exploratory data analysis, 2) comparison of results to EAR screening levels, and 3) additional statistical analysis, when warranted.

2.1 EXPLORATORY DATA ANALYSIS

Exploratory data analysis is the initial step of statistical analysis. It utilizes simple summary statistics (e.g. mean, median, standard deviation, and percentiles) and graphical representations to identify important characteristics of an analytical dataset, such as the center of the data (mean, median), variation, distribution, spatial or temporal patterns, presence of outliers, and randomness.

2.1.1 Summary Statistics

Summary statistics were calculated for each CCR parameter grouped by water body and aggregated by the transect position relative to the WBF Plant CCR management units (adjacent and downstream). Summary statistics also were calculated for percent (%) ash and strontium. Summary statistics include information such as the total numbers of available samples, the frequencies of detection, ranges of reporting limits, minimum and maximum detected concentrations, mean concentrations, standard deviations, median concentrations and the 95th percentile concentrations. Summary statistics tables are presented in Attachment E.6-A.

2.1.2 Exploratory Data Plots

Exploratory data plots (transect plots) were constructed using the sediment results to support a visual review of the data. Box plots are commonly used to identify the center of the data, distribution, and variability, and to visually identify potential outliers. Except for TR07, only one sample was collected for each transect or individual location, therefore, box plots were not constructed for the sediment results.

Transect plots were constructed for sediment data collected in the Tennessee River and show individual sample results aggregated by transect position relative to the WBF Plant CCR management units (adjacent and downstream) and relative position within the water body (plant side bank or opposite-side bank). The symbols used in the transect plots indicate whether the reported result is a detected concentration (solid symbol) or a non-detect reported at the Method Detection Limit (hollow symbol).

Two transect plots were constructed for each CCR Parameter. One was a plot that included a reference line for the ESV for that parameter. In many cases, the sample results were much lower than the ESVs, so including the reference line induced a scaling effect that obscured patterns in the data. A second plot was produced for each CCR Parameter without a reference line in order to better identify patterns.

These plots are particularly useful in identifying potential patterns in the dataset (trends), frequency of detection, outliers, spatial differences relative to the WBF Plant CCR management units (adjacent and

downstream), and differences relative to the position in the water body (right bank [plant-side bank] versus left bank [opposite-side bank]). The transect plots are presented in Attachment E.6-B.

2.1.3 Outlier Screening

Outliers are data points that are abnormally high or low as compared to other measurements and may represent anomalous data or data errors. Outliers may also represent natural variations of CCR Parameter concentrations in environmental systems. Screening for outliers is a critical step because outliers can bias statistical estimates, statistical testing results, and inferences.

Outlier values were initially screened visually using the transect plots. If suspected visual outliers were identified, then Tukey's procedure was used to identify extreme outliers (Tukey 1977). This method relies on the Interquartile Range (IQR), which is defined as the 75th percentile value minus the 25th percentile value. Values were identified as potential outliers as follows:

- **Lower extreme outliers** are less than the 25th percentile minus 3 x IQR
- **Upper extreme outliers** are greater than the 75th percentile plus 3 x IQR.

Finally, when the potential outliers were identified visually and by Tukey's procedure, then statistical testing for outliers (Rosner's Test) was conducted to determine if those data points were statistically significant outliers.

Following confirmation of the outliers as statistically significant, a desktop evaluation was conducted to verify that the data points were not errors, (e.g., laboratory or transcriptional errors). Field forms, data validation reports, and other variables in the dataset that could influence analytical results also were evaluated at this point. If a verifiable error was discovered, the outlier was removed and, if possible, replaced with a corrected value.

In the absence of a verifiable error, additional lines of evidence were reviewed to determine final outlier disposition (e.g., frequency of detection, spatial and temporal variability). If an outlier was identified as suitable for removal from further statistical analysis, a clear and defensible rationale based on multiple lines of evidence was provided. In addition, values that were identified as outliers and removed from further evaluation in the present statistical analysis were retained in the historical database and will be reevaluated for inclusion or exclusion in future statistical analyses of this dataset. The results of the outlier screening for the WBF Plant sediment dataset are provided in Section 3.1.

2.2 COMPARISON OF SEDIMENT RESULTS TO ESVs

The analytical results for the sediment dataset were compared to ESVs, as provided in Table 1-3 and Appendix A.2. Comparisons were done graphically using transect plots for sample results from the Tennessee River (Attachment E.6-B). Analytical results were also compared to ESVs in tabular format and are presented in Tables in Appendix J.3.

Additional statistical analyses may be warranted if the following conditions were met: 1) CCR Parameter concentrations were above ESVs and 2) data were collected from transects/locations adjacent, and from transects/locations either upstream or downstream to the WBF Plant CCR management units.

These additional statistical evaluations may include:

- Formal hypothesis testing to identify differences between adjacent and downstream results, and
- PCA to identify the variables and individual samples that explain the greatest proportion of variability (provide the greatest amount of information) in the datasets.

The results are presented in Section 3.2.

3.0 RESULTS AND DISCUSSION

3.1 SUMMARY STATISTICS, EXPLORATORY DATA PLOTS, AND OUTLIER SCREENING

Summary statistics tables are presented in Attachment E.6-A and transect plots are presented in Attachment E.6-B. The summary statistics were aggregated by transect or individual sample location relative to the WBF Plant CCR management units (adjacent and downstream). The transect data plots were aggregated by transect location relative to the WBF Plant CCR management units (adjacent and downstream) and sample position in the water body (plant-side bank and opposite-side bank).

No outliers were identified in the WBF Plant sediment data set.

3.2 COMPARISON OF SEDIMENT RESULTS TO ESVs

No sediment results collected from the Tennessee River in proximity to the WBF Plant CCR management units exceeded either acute or chronic ESVs.

No additional statistical evaluation (PCA or Hypothesis testing) were warranted since no CCR parameter concentrations were identified above acute or chronic ESVs.

4.0 REFERENCES

StataCorp. (2017). Stata Graphics Reference Manual Stata: Release 15. Statistical Software. College Station, Texas: StataCorp LLC.

Tukey, J.W. (1977). *Exploratory Data Analysis*. Reading, Massachusetts: Addison-Wesley. 1977.

ATTACHMENT E.6-A
SUMMARY STATISTICS

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Summary Statistics - Tennessee River
Sediment Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Location Relative to CCR Management Units	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Percent Ash										
Ash	Adjacent	4/4	--	0.0%	1	5	3.8	1.9	4.5	5
	Downstream	4/4	--	0.0%	1	5	3.3	2.1	3.5	5
CCR Rule Appendix III Parameters										
Boron	Adjacent	3/3	--	0.0%	1.16	2.89	1.96	0.872	1.83	2.78
	Downstream	4/4	--	0.0%	1.03	2.36	1.72	0.62	1.75	2.32
Calcium	Adjacent	3/3	--	0.0%	1,420	9,500	5,000	4,120	4,080	8,960
	Downstream	4/4	--	0.0%	1,090	2,360	1,640	529	1,550	2,250
Chloride	Adjacent	0/3	(5.42 - 5.88)	100.0%	--	--	--	--	5.59	5.85
	Downstream	0/4	(5.43 - 6.19)	100.0%	--	--	--	--	5.77	6.14
pH(Lab)	Adjacent	3/3	--	0.0%	7.2	7.5	7.33	0.153	7.3	7.48
	Downstream	4/4	--	0.0%	7.3	7.6	7.38	0.15	7.3	7.56
Sulfate	Adjacent	3/3	--	0.0%	40.1	65.1	50.9	12.8	47.6	63.4
	Downstream	4/4	--	0.0%	25.4	48.3	39.3	10.1	41.7	47.8
CCR Rule Appendix IV Parameters										
Antimony	Adjacent	3/3	--	0.0%	0.0865	0.159	0.112	0.0405	0.0916	0.152
	Downstream	3/4	(0.0465 - 0.0465)	25.0%	0.0498	0.101	0.0673	0.0218	0.0609	0.0966
Arsenic	Adjacent	3/3	--	0.0%	2.41	4.59	3.55	1.09	3.64	4.5
	Downstream	4/4	--	0.0%	1.34	2.29	1.72	0.427	1.62	2.22
Barium	Adjacent	3/3	--	0.0%	75.7	106	91.9	15.3	94	105
	Downstream	4/4	--	0.0%	43.3	108	72.7	28.3	69.8	104
Beryllium	Adjacent	3/3	--	0.0%	0.608	0.884	0.771	0.145	0.821	0.878
	Downstream	4/4	--	0.0%	0.309	1.09	0.672	0.346	0.644	1.05
Cadmium	Adjacent	3/3	--	0.0%	0.0959	0.423	0.289	0.171	0.348	0.416
	Downstream	4/4	--	0.0%	0.0743	0.127	0.0923	0.0238	0.0839	0.121
Chromium	Adjacent	3/3	--	0.0%	13.8	17.9	15.3	2.26	14.2	17.5
	Downstream	4/4	--	0.0%	7.43	16.5	11.7	4.06	11.5	16.1
Cobalt	Adjacent	3/3	--	0.0%	8.45	11.3	9.56	1.53	8.92	11.1
	Downstream	4/4	--	0.0%	4.63	9.79	6.97	2.32	6.73	9.5
Fluoride	Adjacent	3/3	--	0.0%	0.95	1.32	1.17	0.195	1.24	1.31
	Downstream	2/4	(0.952 - 1)	50.0%	1.22	1.47	1.15	0.215	1.11	1.43
Lead	Adjacent	3/3	--	0.0%	9.41	21.2	15.6	5.91	16.1	20.7
	Downstream	4/4	--	0.0%	5.82	12	7.81	2.91	6.71	11.3
Lithium	Adjacent	3/3	--	0.0%	6.94	11.4	9.68	2.4	10.7	11.3
	Downstream	4/4	--	0.0%	5.52	16.9	10.7	5.15	10.1	16.3

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Summary Statistics - Tennessee River
Sediment Investigation
Watts Bar Fossil Plant - Spring City, Tennessee

Parameter	Location Relative to CCR Management Units	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Mercury	Adjacent	3/3	--	0.0%	0.0185	0.079	0.0492	0.0303	0.0501	0.0761
	Downstream	3/4	(0.0102 - 0.0102)	25.0%	0.0116	0.0298	0.0165	0.00783	0.013	0.0275
Molybdenum	Adjacent	3/3	--	0.0%	0.401	0.572	0.464	0.0942	0.418	0.557
	Downstream	4/4	--	0.0%	0.163	0.418	0.293	0.111	0.296	0.406
Radium-226+228	Adjacent	3/3	--	0.0%	2.04	2.96	2.49	0.46	2.46	2.91
	Downstream	4/4	--	0.0%	1.66	2.91	2.44	0.575	2.6	2.9
Selenium	Adjacent	3/3	--	0.0%	0.638	1.02	0.87	0.204	0.953	1.01
	Downstream	4/4	--	0.0%	0.43	1.12	0.781	0.375	0.788	1.12
Thallium	Adjacent	3/3	--	0.0%	0.151	0.215	0.174	0.0359	0.155	0.209
	Downstream	4/4	--	0.0%	0.0887	0.189	0.135	0.0449	0.131	0.184
TDEC Appendix I Parameters										
Copper	Adjacent	3/3	--	0.0%	9.35	30.3	17.5	11.2	12.8	28.6
	Downstream	4/4	--	0.0%	4.52	10.3	7.24	2.58	7.06	10
Nickel	Adjacent	3/3	--	0.0%	9.63	13.5	11.7	1.96	12.1	13.4
	Downstream	4/4	--	0.0%	5.8	14.3	9.78	3.84	9.51	13.9
Silver	Adjacent	3/3	--	0.0%	0.0263	0.0409	0.0313	0.00829	0.0268	0.0395
	Downstream	1/4	(0.0195 - 0.0216)	75.0%	0.0232	0.0232	0.0204	0.0016	0.0213	0.023
Vanadium	Adjacent	3/3	--	0.0%	17.7	26.1	20.9	4.52	19	25.4
	Downstream	4/4	--	0.0%	8.54	19	13.5	4.66	13.2	18.5
Zinc	Adjacent	3/3	--	0.0%	40.8	98.6	74	29.8	82.6	97
	Downstream	4/4	--	0.0%	33.9	58.9	45.9	10.5	45.4	57.3
Other Constituents										
Strontium	Adjacent	3/3	--	0.0%	5.63	13.6	10	4.05	10.9	13.3
	Downstream	4/4	--	0.0%	5.08	8.88	6.74	1.62	6.5	8.59

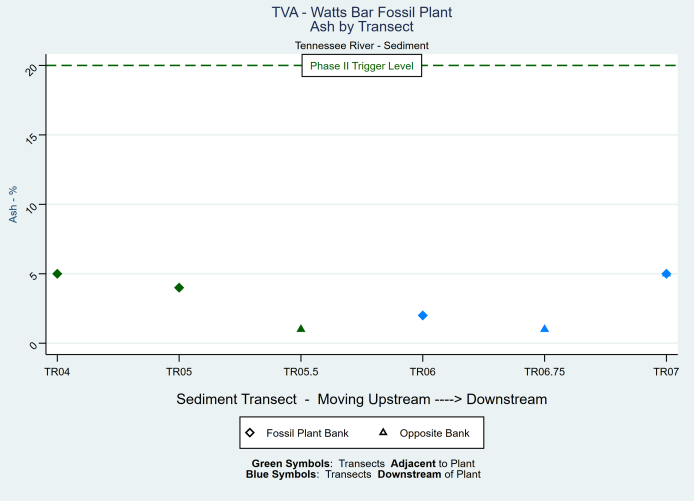
Notes:
CCR Rule - Title 40, Code of Federal Regulations, Part 257
TDEC - Tennessee Department of Environment and Conservation
% - percent
"--" - Not Applicable

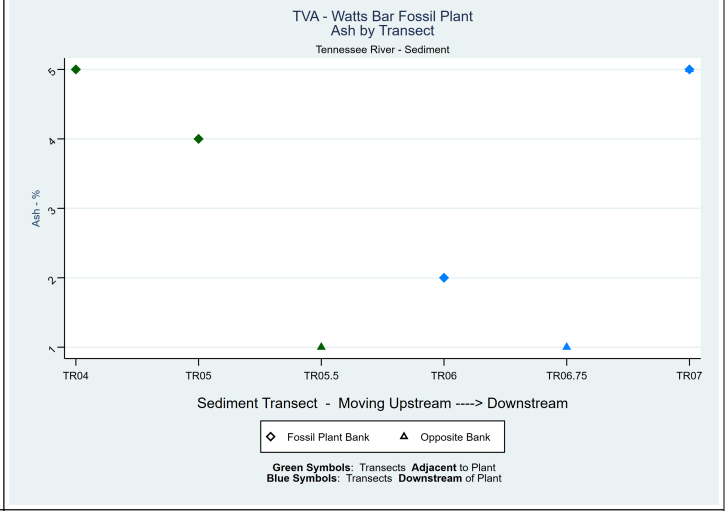
Statistical datasets were aggregated by location of transect relative to the CCR management units (upstream, adjacent, downstream)
Except for Ash, pH & Radium 226 + 228, all units are milligrams per kilogram (mg/kg)
Units for Ash are percent (%)
Units for pH are Standard Units (S.U.)
Units for Radium 226+228 are picocuries per gram (pCi/g)
All non-detects reported at the laboratory reporting limit
For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM).

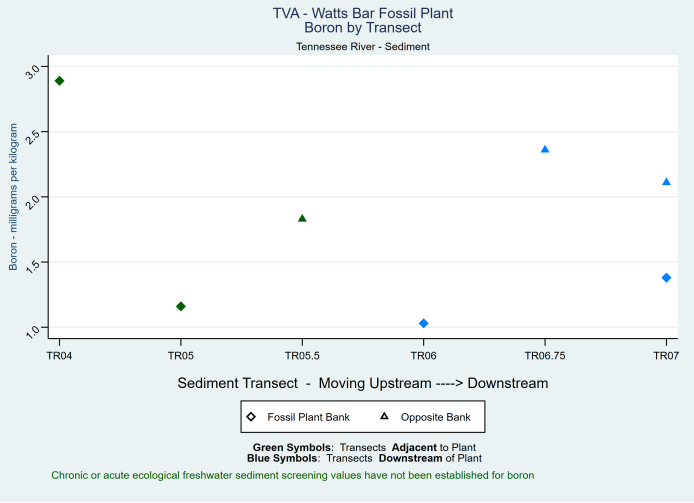
ATTCHMENT E.6-B
TRANSECT PLOTS

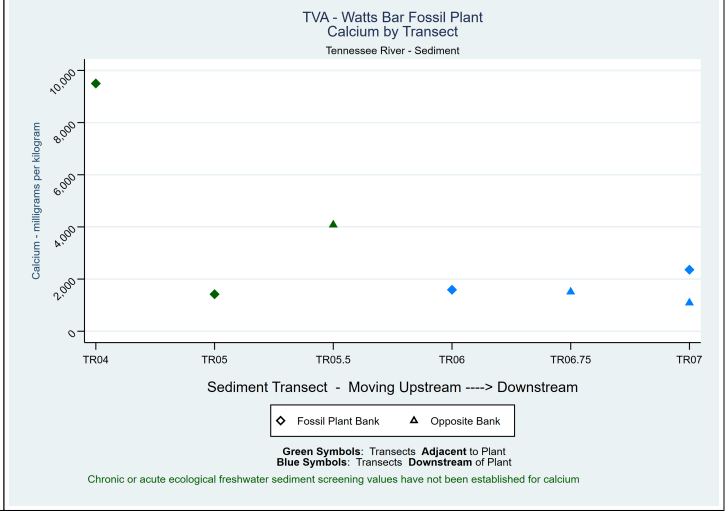
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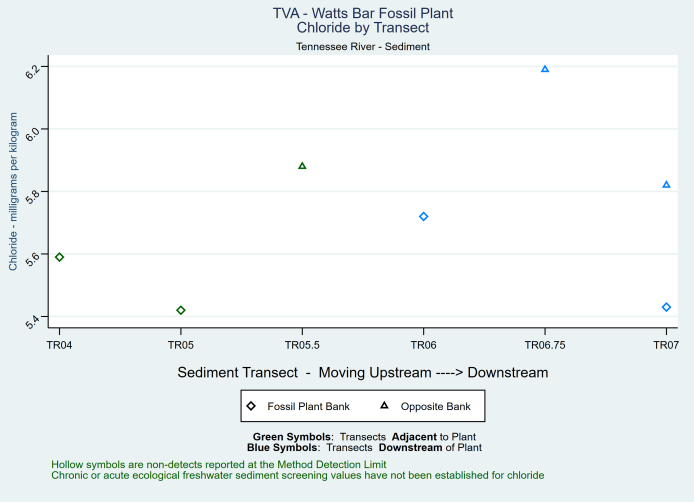
Transect Plots
CCR Rule Appendix III Parameters
Sediment Investigation - Tennessee River
Watts Bar Fossil Plant, Spring City, Tennessee

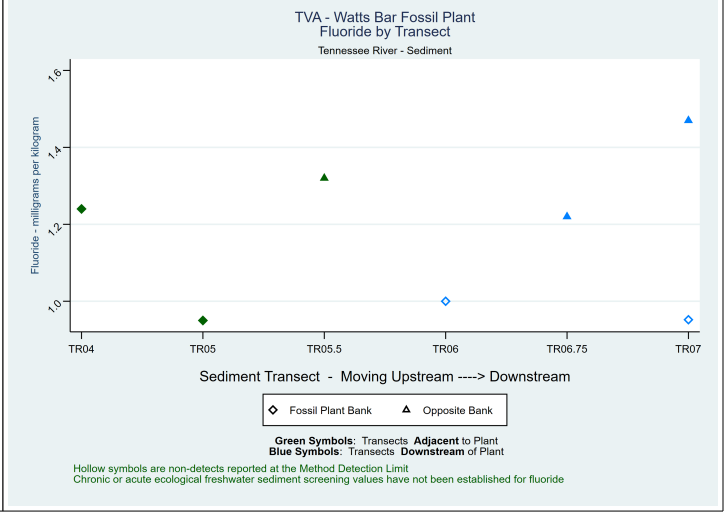




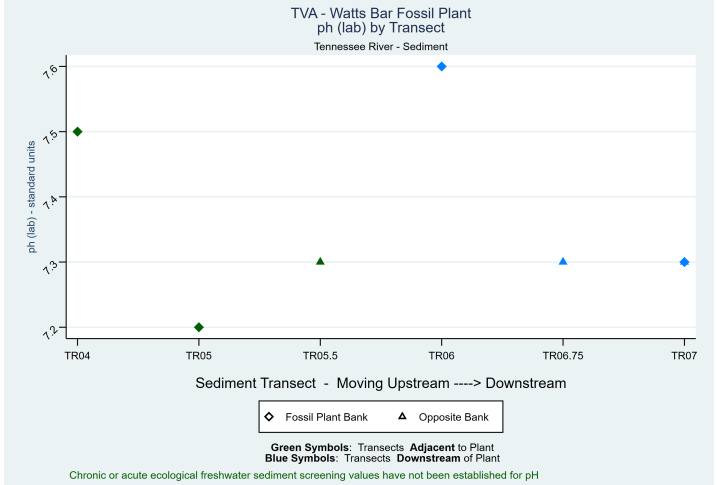


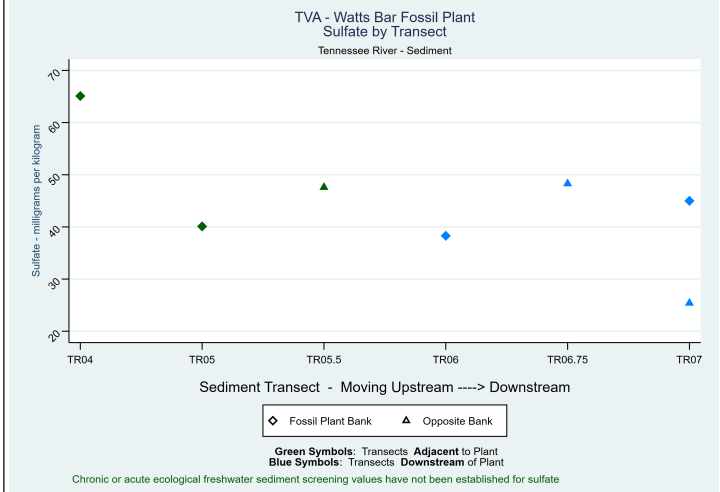






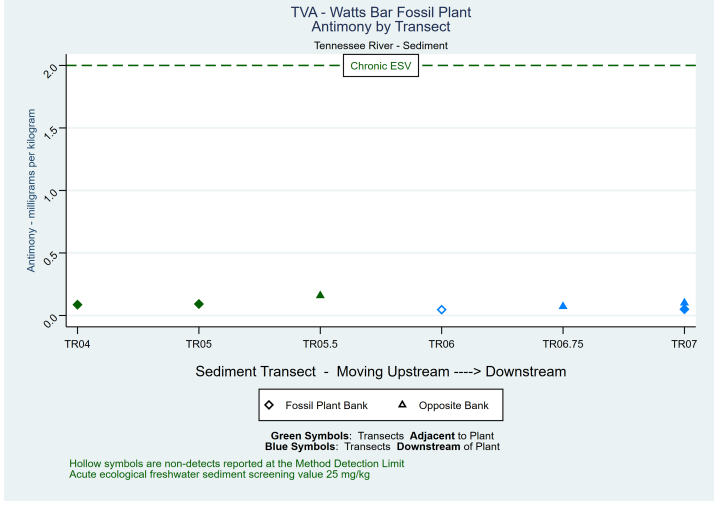
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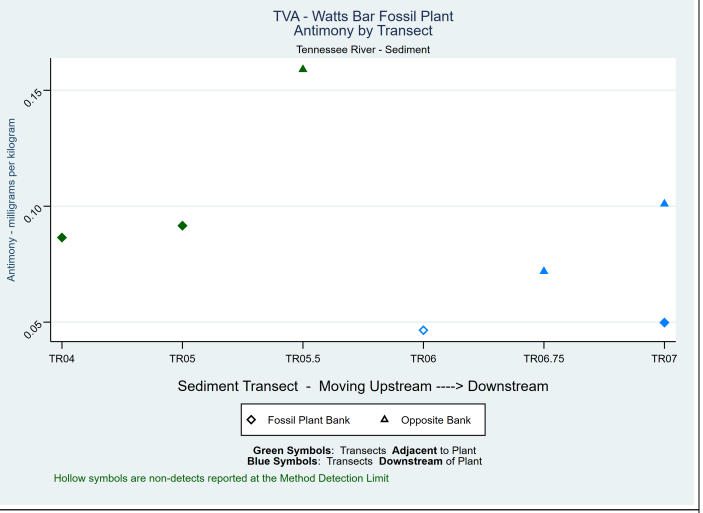

TVA - Watts Bar Fossil Plant
ph (lab) by Transect
Tennessee River - Sediment
ph (lab) - standard units
7.6
7.5
7.4
7.3
7.2
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Chronic or acute ecological freshwater sediment screening values have not been established for pH

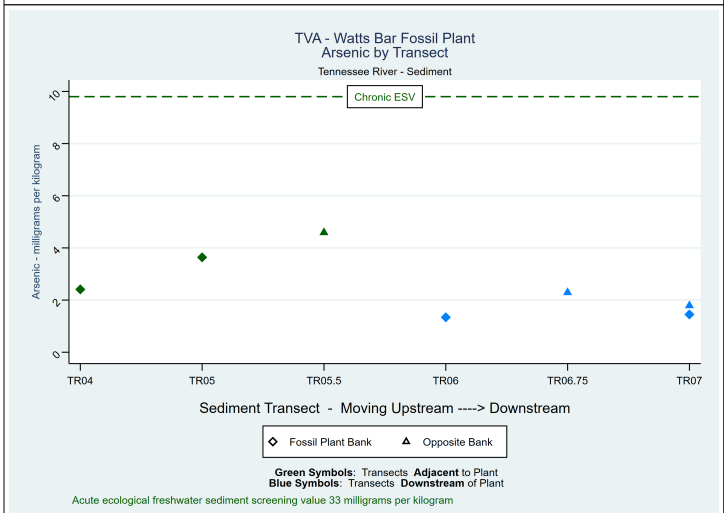

TVA - Watts Bar Fossil Plant
Sulfate by Transect
Tennessee River - Sediment
Sulfate - milligrams per kilogram
70
60
50
40
30
20
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Chronic or acute ecological freshwater sediment screening values have not been established for sulfate

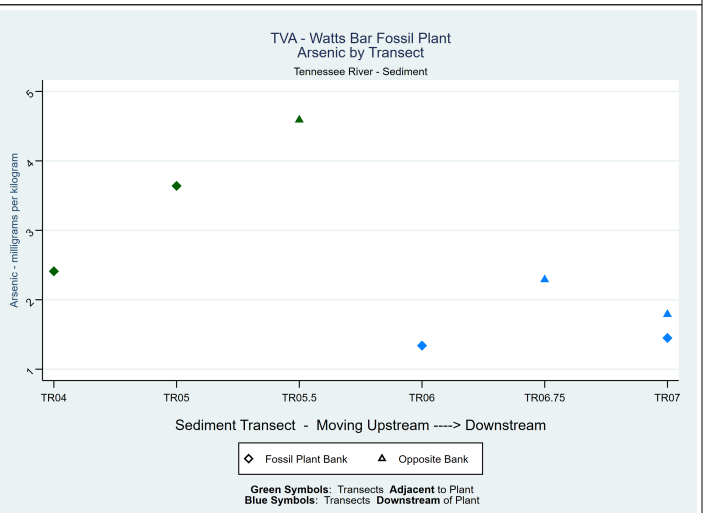
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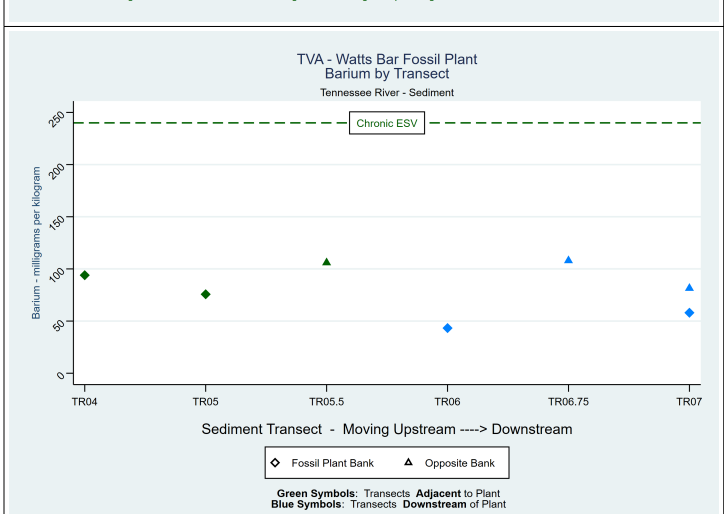
Transect Plots
CCR Rule Appendix IV Parameters
Sediment Investigation - Tennessee River
Watts Bar Fossil Plant, Spring City, Tennessee

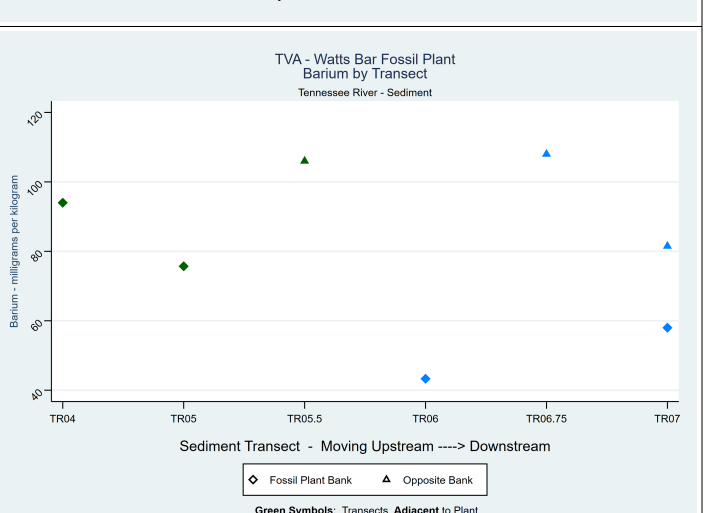




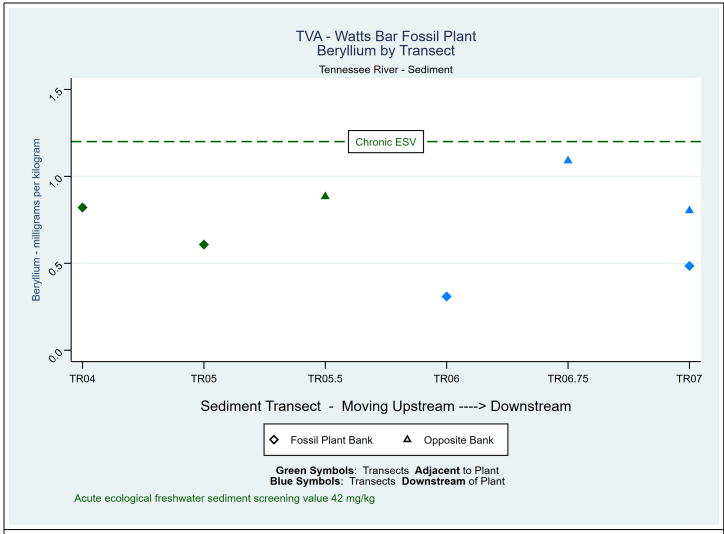


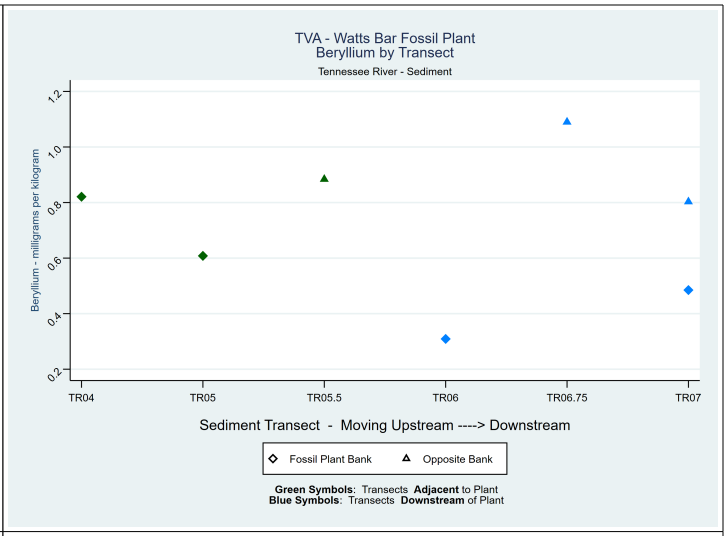


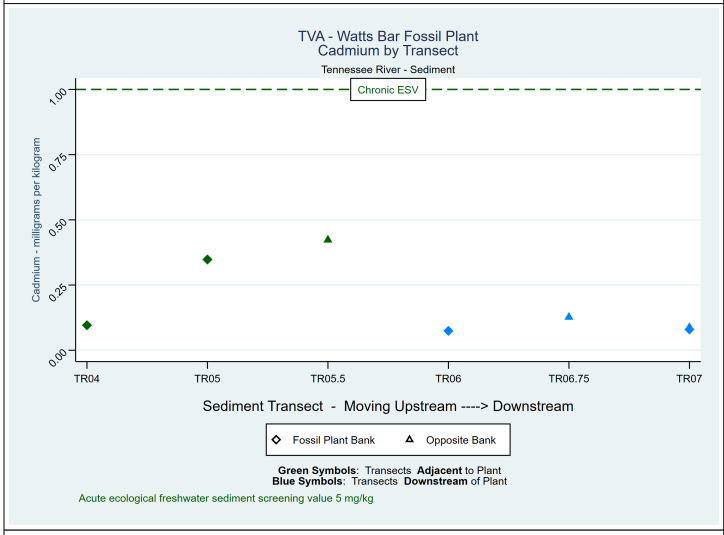


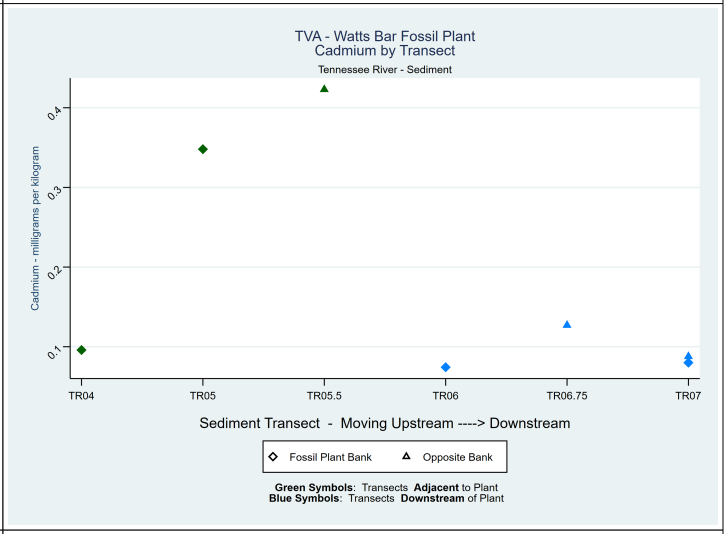


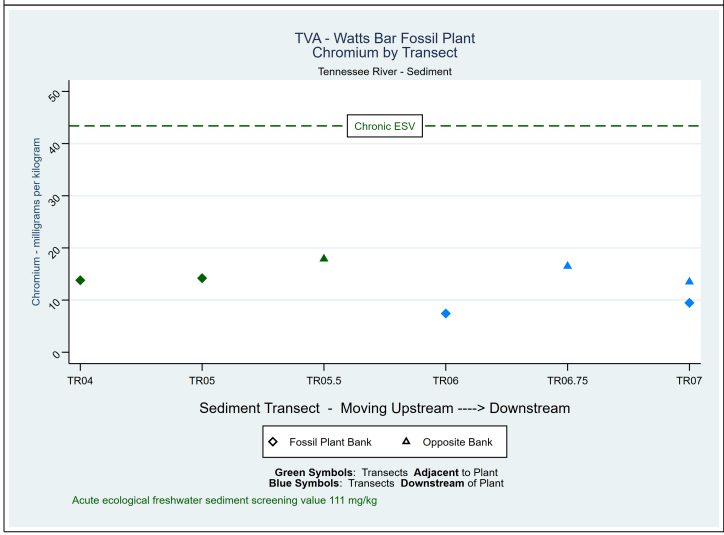
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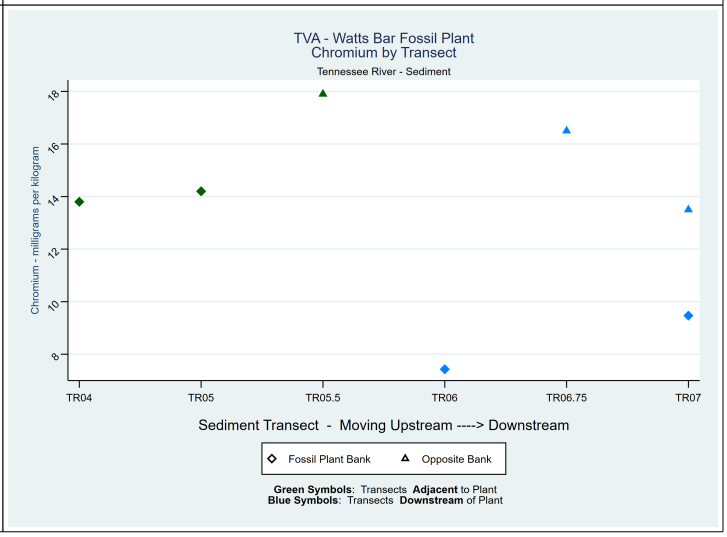

TVA - Watts Bar Fossil Plant
Beryllium by Transect
Tennessee River - Sediment
Beryllium - milligrams per kilogram
0.0
0.5
1.0
1.5
Chronic ESV
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Acute ecological freshwater sediment screening value 42 mg/kg

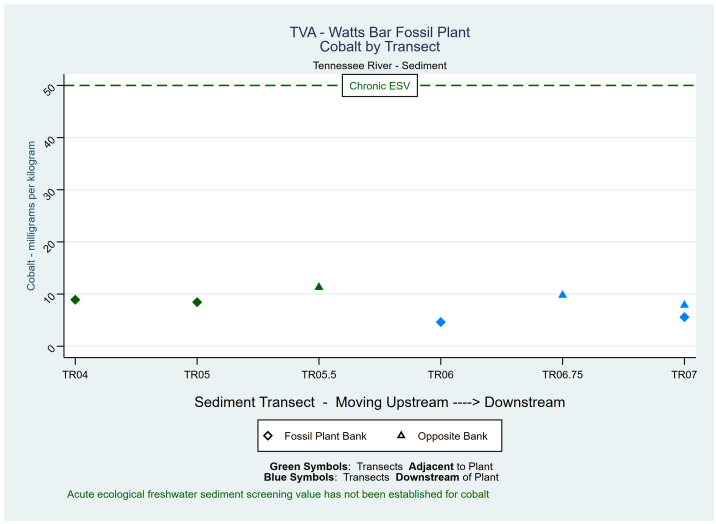

TVA - Watts Bar Fossil Plant
Beryllium by Transect
Tennessee River - Sediment
Beryllium - milligrams per kilogram
0.2
0.4
0.6
0.8
1.0
1.2
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

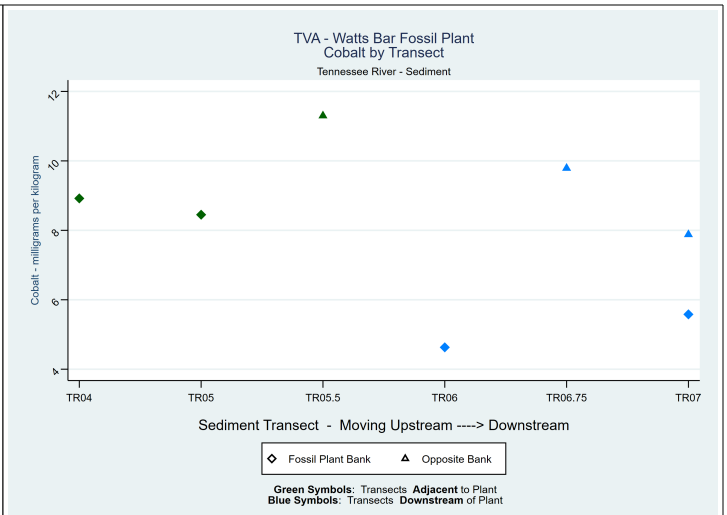

TVA - Watts Bar Fossil Plant
Cadmium by Transect
Tennessee River - Sediment
Cadmium - milligrams per kilogram
0.00
0.25
0.50
0.75
1.00
Chronic ESV
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Acute ecological freshwater sediment screening value 5 mg/kg

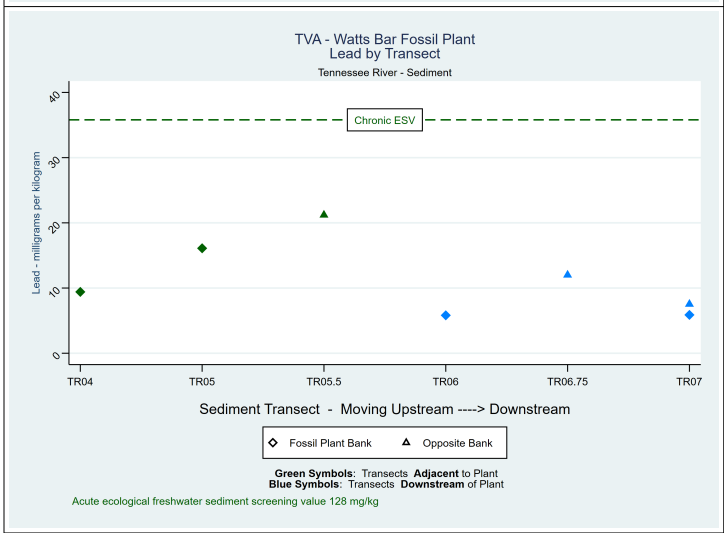

TVA - Watts Bar Fossil Plant
Cadmium by Transect
Tennessee River - Sediment
Cadmium - milligrams per kilogram
0.1
0.2
0.3
0.4
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

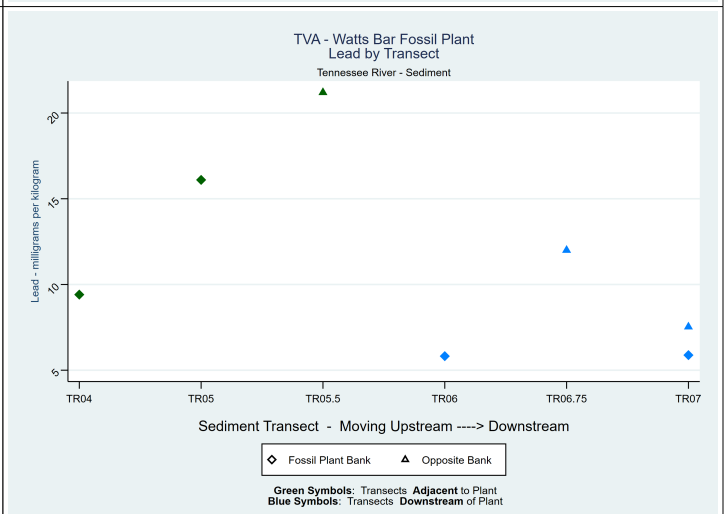

TVA - Watts Bar Fossil Plant
Chromium by Transect
Tennessee River - Sediment
Chromium - milligrams per kilogram
0
10
20
30
40
50
Chronic ESV
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Acute ecological freshwater sediment screening value 111 mg/kg


TVA - Watts Bar Fossil Plant
Chromium by Transect
Tennessee River - Sediment
Chromium - milligrams per kilogram
8
10
12
14
16
18
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

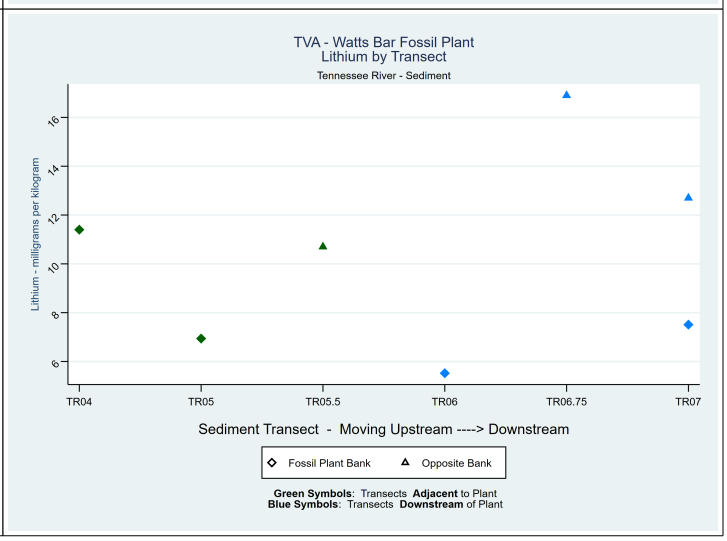




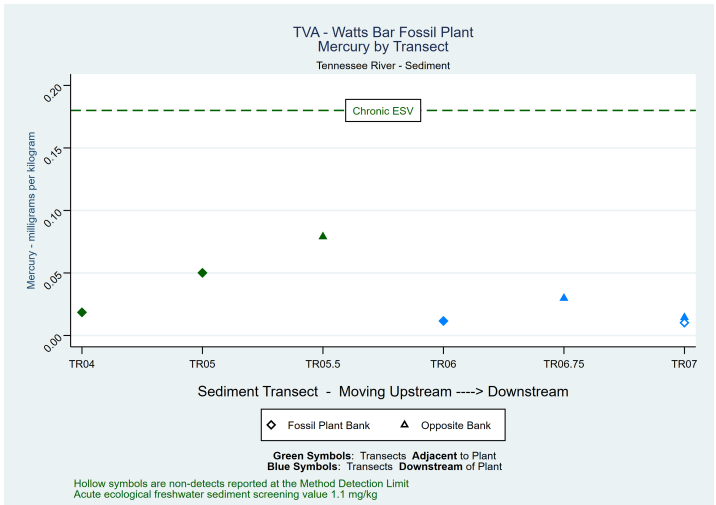


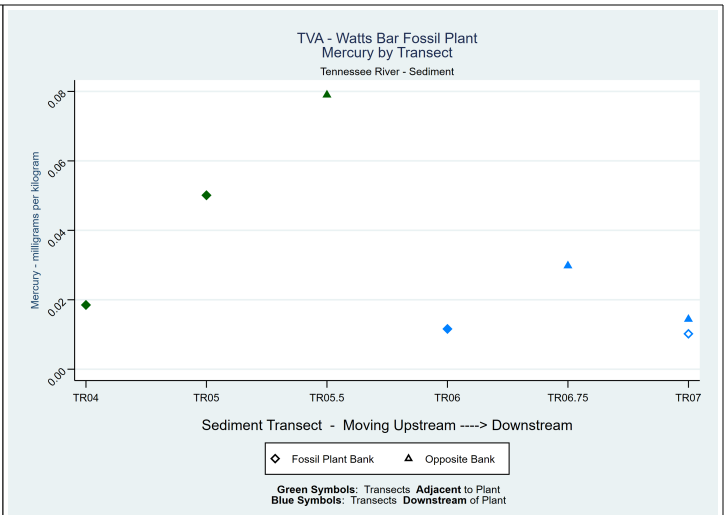


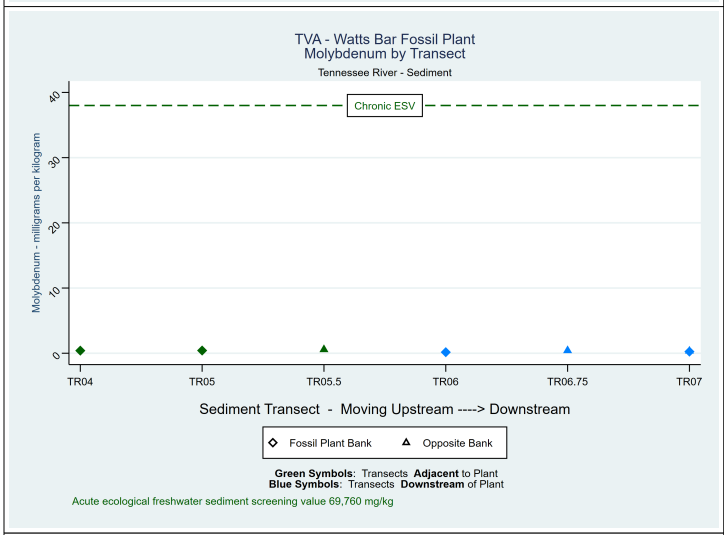
Chronic or Acute Ecological Screening Values have not been established for Lithium

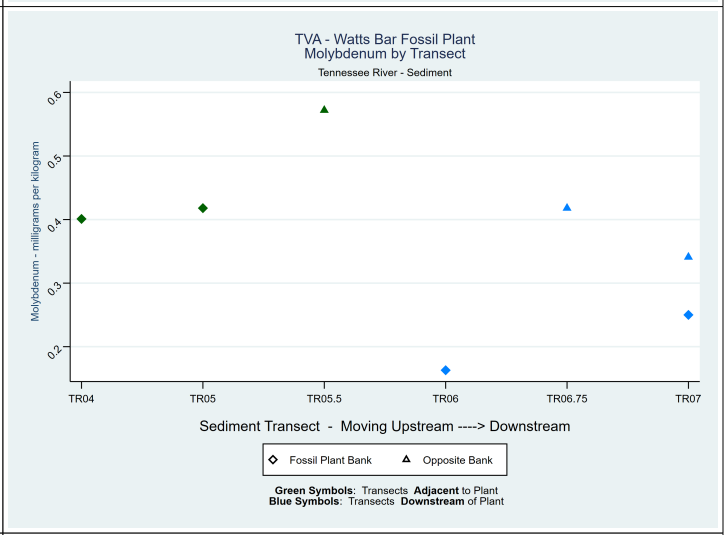


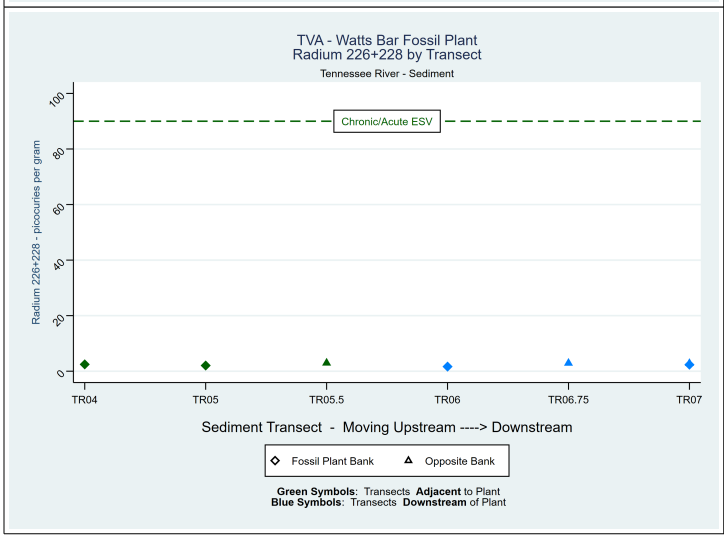
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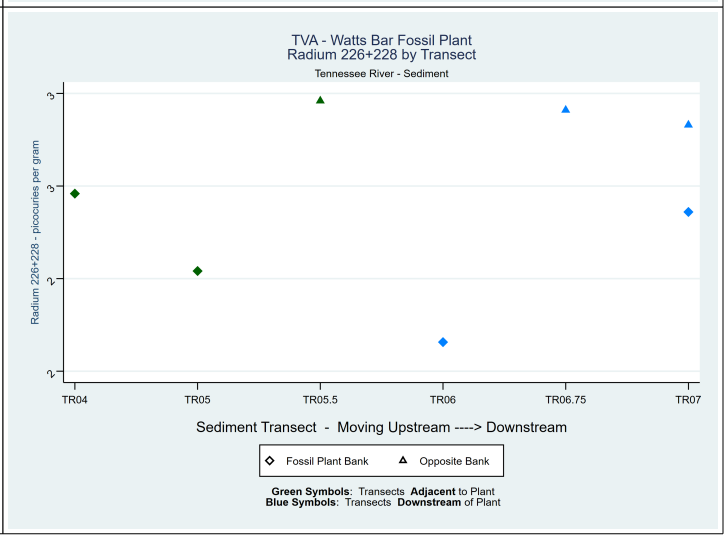

TVA - Watts Bar Fossil Plant
Mercury by Transect
Tennessee River - Sediment
Chronic ESV
Mercury - milligrams per kilogram
0.00
0.05
0.10
0.15
0.20
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Hollow symbols are non-detects reported at the Method Detection Limit
Acute ecological freshwater sediment screening value 1.1 mg/kg


TVA - Watts Bar Fossil Plant
Mercury by Transect
Tennessee River - Sediment
Mercury - milligrams per kilogram
0.00
0.02
0.04
0.06
0.08
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

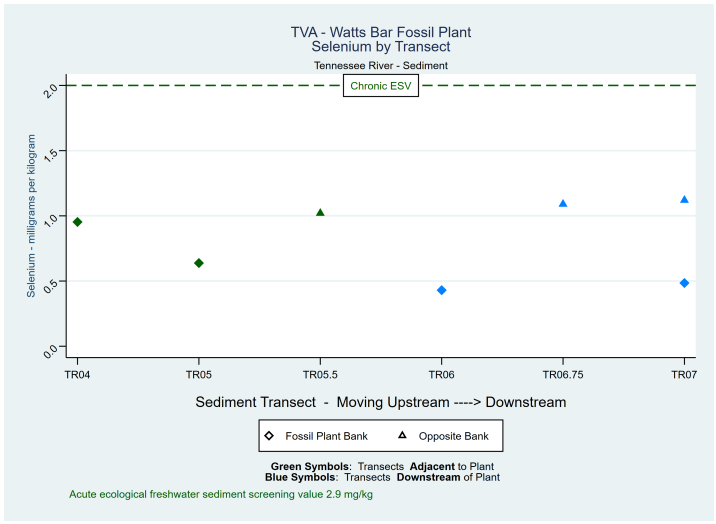

TVA - Watts Bar Fossil Plant
Molybdenum by Transect
Tennessee River - Sediment
Chronic ESV
Molybdenum - milligrams per kilogram
0
10
20
30
40
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Acute ecological freshwater sediment screening value 69,760 mg/kg

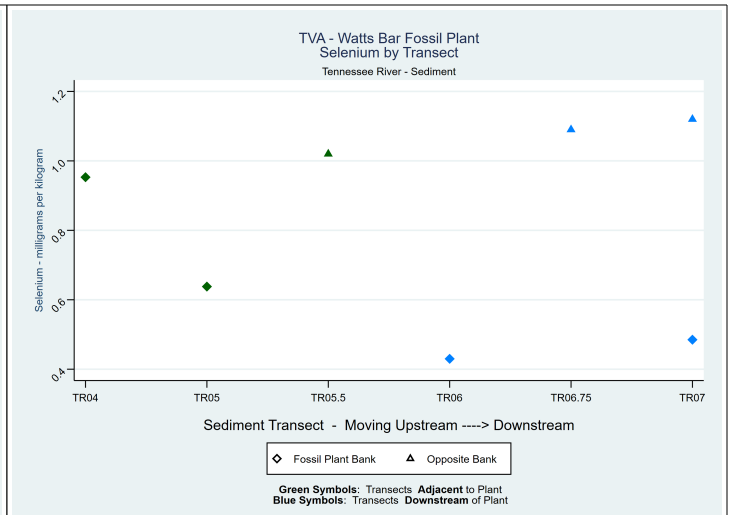

TVA - Watts Bar Fossil Plant
Molybdenum by Transect
Tennessee River - Sediment
Molybdenum - milligrams per kilogram
0.2
0.3
0.4
0.5
0.6
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

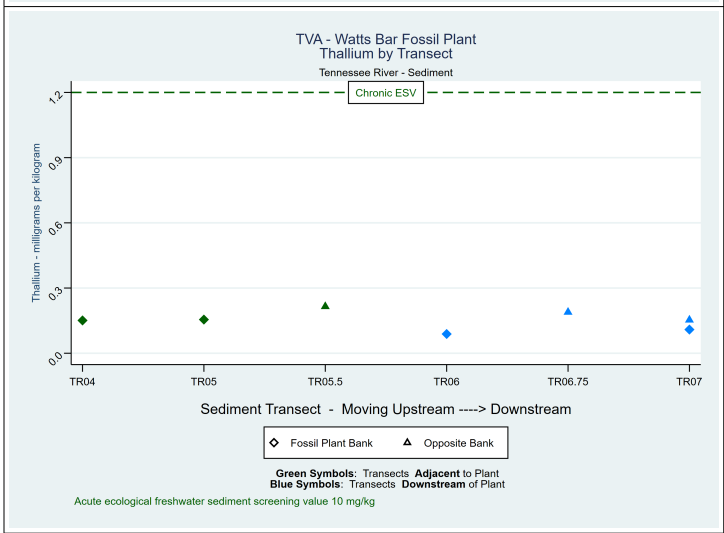

TVA - Watts Bar Fossil Plant
Radium 226+228 by Transect
Tennessee River - Sediment
Chronic/Acute ESV
Radium 226+228 - picocuries per gram
0
20
40
60
80
100
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

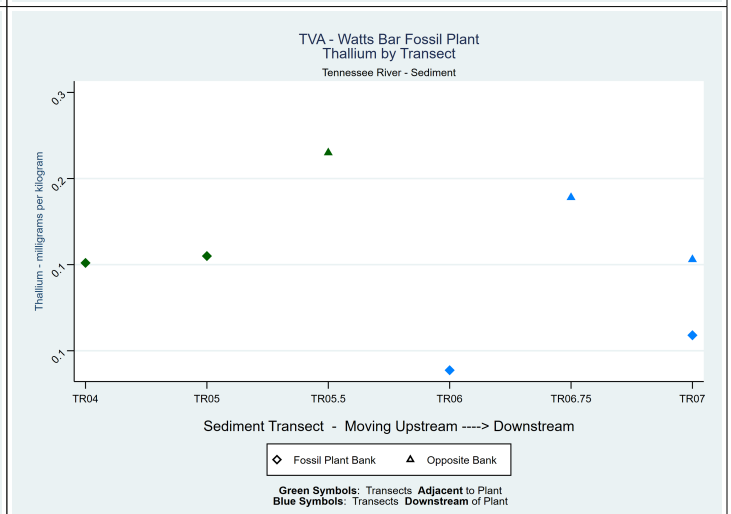

TVA - Watts Bar Fossil Plant
Radium 226+228 by Transect
Tennessee River - Sediment
Radium 226+228 - picocuries per gram
2
2
3
3
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

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TVA - Watts Bar Fossil Plant
Selenium by Transect
Tennessee River - Sediment
Chronic ESV
Selenium - milligrams per kilogram
0.0
0.5
1.0
1.5
2.0
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Acute ecological freshwater sediment screening value 2.9 mg/kg

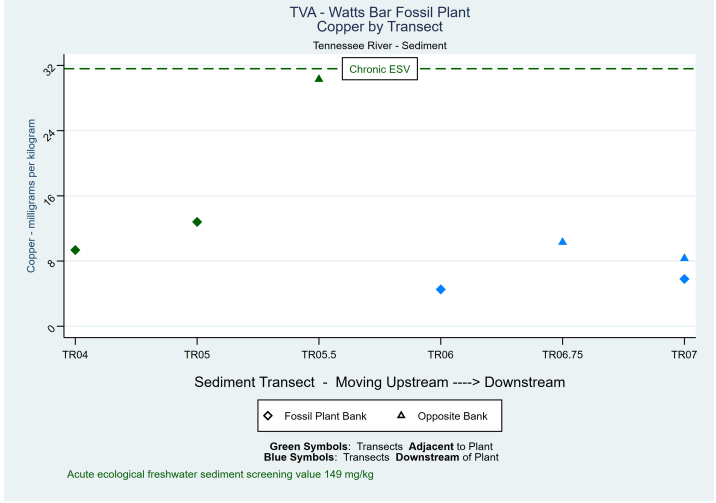

TVA - Watts Bar Fossil Plant
Selenium by Transect
Tennessee River - Sediment
Selenium - milligrams per kilogram
0.4
0.6
0.8
1.0
1.2
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

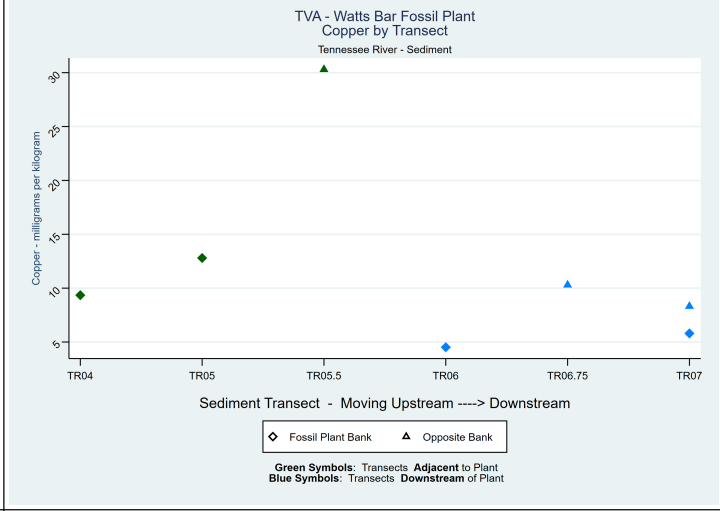

TVA - Watts Bar Fossil Plant
Thallium by Transect
Tennessee River - Sediment
Chronic ESV
Thallium - milligrams per kilogram
0.0
0.3
0.6
0.9
1.2
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Acute ecological freshwater sediment screening value 10 mg/kg

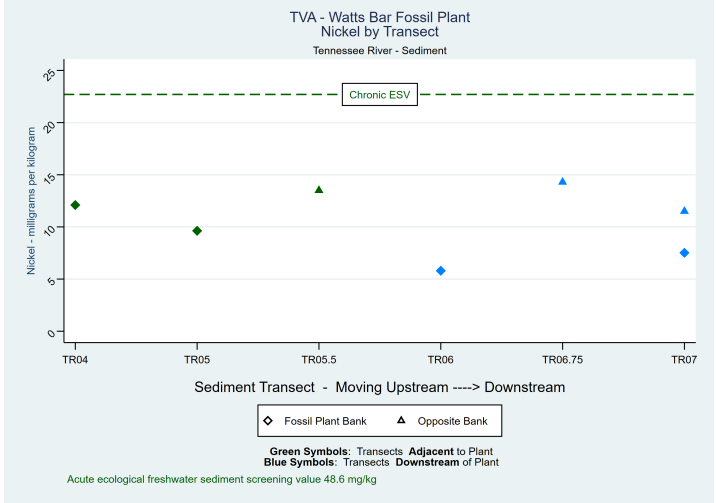

TVA - Watts Bar Fossil Plant
Thallium by Transect
Tennessee River - Sediment
Thallium - milligrams per kilogram
0.1
0.2
0.3
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

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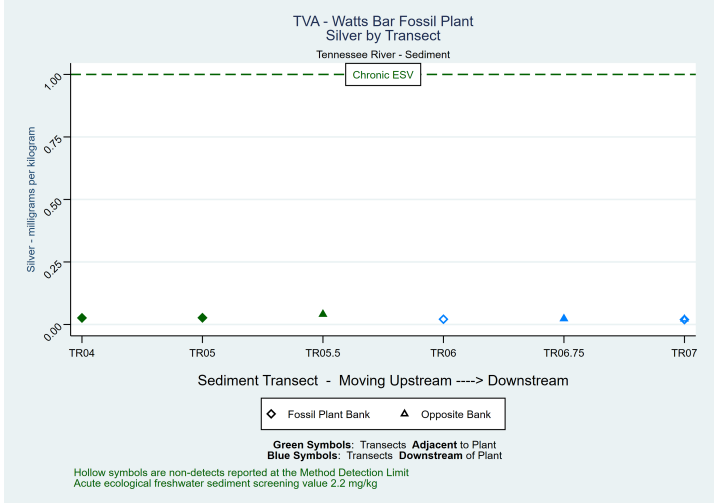
Transect Plots
TDEC Appendix I Parameters
Sediment Investigation - Tennessee River
Watts Bar Fossil Plant, Spring City, Tennessee

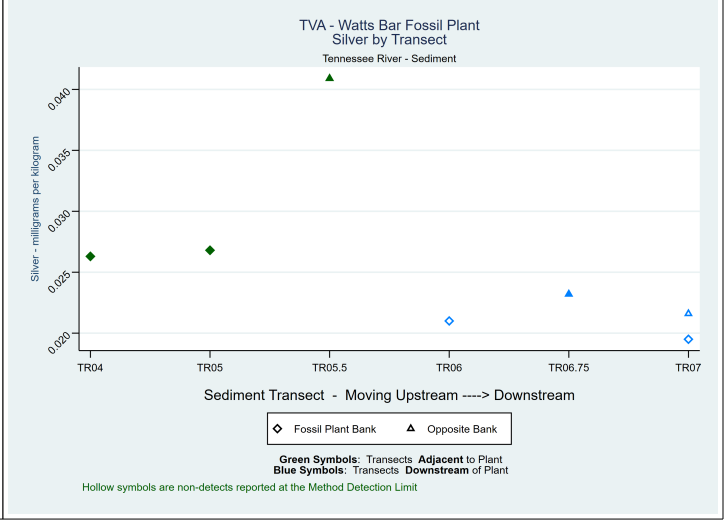




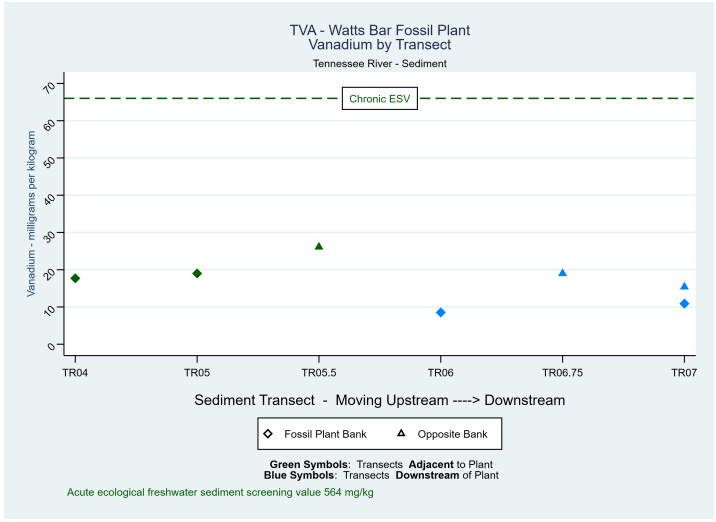




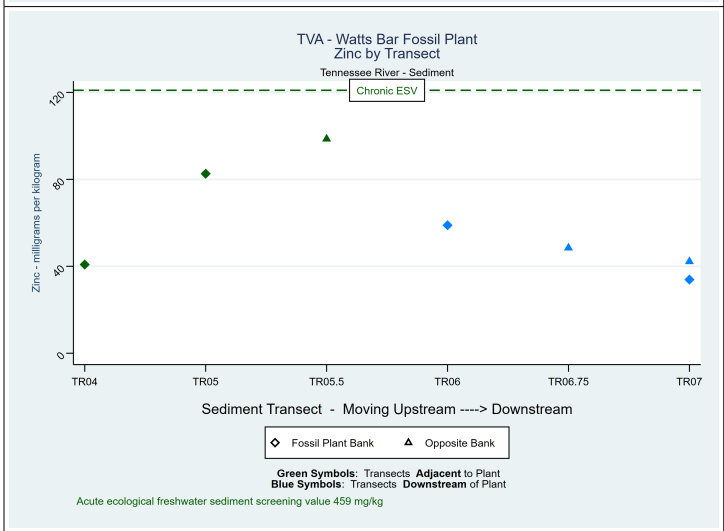


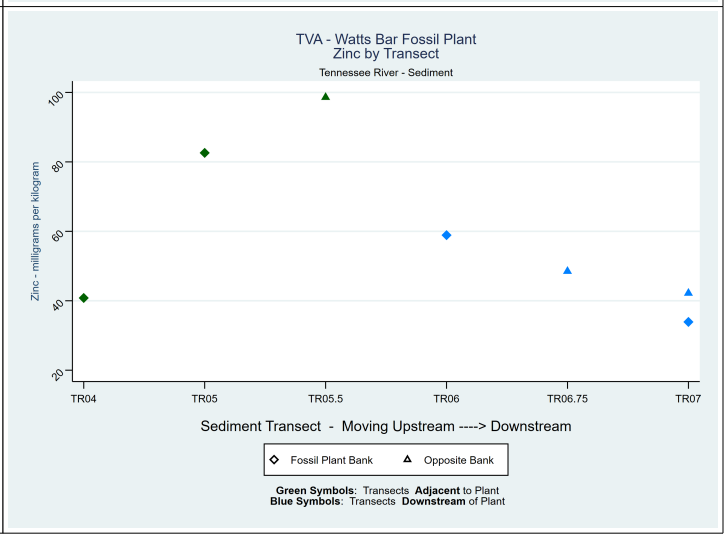


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TVA - Watts Bar Fossil Plant
Vanadium by Transect
Tennessee River - Sediment
Chronic ESV
Vanadium - milligrams per kilogram
0
10
20
30
40
50
60
70
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Acute ecological freshwater sediment screening value 564 mg/kg


TVA - Watts Bar Fossil Plant
Vanadium by Transect
Tennessee River - Sediment
Vanadium - milligrams per kilogram
10
15
20
25
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant


TVA - Watts Bar Fossil Plant
Zinc by Transect
Tennessee River - Sediment
Chronic ESV
Zinc - milligrams per kilogram
0
40
80
120
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant
Acute ecological freshwater sediment screening value 459 mg/kg


TVA - Watts Bar Fossil Plant
Zinc by Transect
Tennessee River - Sediment
Zinc - milligrams per kilogram
20
40
60
80
100
TR04
TR05
TR05.5
TR06
TR06.75
TR07
Sediment Transect - Moving Upstream ----> Downstream
Fossil Plant Bank
Opposite Bank
Green Symbols: Transects Adjacent to Plant
Blue Symbols: Transects Downstream of Plant

APPENDIX E.7

DATA EVALUATION OF FISH TISSUE SAMPLE DATA

DRAFT

Appendix E.7 - Data Evaluation of Fish Tissue Sample Data

TDEC Commissioner's Order:
Environmental Assessment Report
Watts Bar Fossil Plant
Spring City, Tennessee

March 31, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

Revision Log

Revision	Description	Date
0	Submittal to TDEC	November 7, 2023
1	Addresses January 31, 2024 TDEC Review Comments and Issued for TDEC	March 31, 2024

Sign-off Sheet

This document entitled Appendix E.7 - Data Evaluation of Fish Tissue Sample Data was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by 

Melissa Whitfield Aslund, PhD, Environmental Scientist

Reviewed by 

Chris La Londe, Risk Assessor

Approved by 

Carole M. Farr, Senior Principal Geologist

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Abbreviations

BG	Bluegill
CBR	Critical Body Residue
CC	Channel Catfish
CCR	Coal Combustion Residuals
CCR Rule	Title 40, Code of Federal Regulations, Part 257
EAR	Environmental Assessment Report
EI	Environmental Investigation
ESVs	Ecological Screening Values
LB	Largemouth Bass
LOAEL	Lowest Observed Adverse Effect Level
mg/kg	Milligrams per Kilogram
NOAEL	No Observed Adverse Effect Level
RS	Redear Sunfish
SH	Shad
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TRA	Tennessee River Adjacent
TRD	Tennessee River Downstream
TRU	Tennessee River Upstream
TVA	Tennessee Valley Authority
USEPA	United States Environmental Protection Agency
WBF Plant	Watts Bar Fossil Plant
WW	Wet Weight

APPENDIX E.7 - DATA EVALUATION OF FISH TISSUE SAMPLE DATA

March 31, 2024

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this appendix on behalf of the Tennessee Valley Authority (TVA) to summarize the data evaluation performed on fish tissue data to support the Environmental Assessment Report (EAR) at the Watts Bar Fossil Plant (WBF Plant) located in Spring City, Tennessee. Fish tissue samples were collected as part of the Tennessee Department of Environment and Conservation (TDEC) Order Environmental Investigation (EI) between April and May 2019 in the Tennessee River in proximity to the WBF Plant. Further details regarding the fish tissue sampling program and results are available in Appendix J.5 and the *Fish Tissue Sampling and Analysis Report* (Appendix J.6).

The water bodies, sampling locations, fish species, and tissue types included in this evaluation are summarized in Table E.7-1.

Table E.7-1 – Summary of Samples Collected and Included in Data Evaluation for Each Sampling Location, Fish Species, and Tissue Type

Water Body	Sample Location	Locations Relative to WBF CCR Units	Bluegill (BG)			Channel Catfish (CC)			Largemouth Bass (LB)			Redear Sunfish (RS)			Shad (SH)
			Muscle	Liver	Ovary	Muscle	Liver	Ovary	Muscle	Liver	Ovary	Muscle	Liver	Ovary	Whole Fish
Tennessee River	TRU	Upstream	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	TRA	Adjacent	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	TRD	Downstream	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: CCR - Coal Combustion Residuals, TRU – Tennessee River Upstream, TRA – Tennessee River Adjacent, TRD – Tennessee River Downstream

For each sampled waterbody, this data evaluation focused on constituents from one of the following two categories:

1. Constituents for which potential risks to aquatic life have been identified based on observations of concentrations greater than applicable EAR ecological screening values (ESVs, see Appendix A.2) in sediment or surface stream (excluding statistical outliers). Detailed comparisons of constituent concentrations in surface stream and sediment to the applicable ESVs are provided in Appendices E.5 and E.6, respectively.

2. Constituents with potential to bioaccumulate in fish tissues as identified by the United States Environmental Protection Agency (USEPA 2018).

The constituents identified for review in fish tissue for each sampled waterbody based on these criteria are summarized in Table E.7-2.

Table E.7-2 - Constituents Identified for Review in Fish Tissue for the Tennessee River

Water Body	Constituent	Rationale for Review in Fish Tissue
Tennessee River	Mercury	Bioaccumlative per USEPA (2018)
	Selenium	Bioaccumlative per USEPA (2018)

For the constituents identified in Table E.7-2 for the Tennessee River, the following sections present the methods and results from the data evaluation and comparison of fish tissue data to established screening levels for fish tissue critical body residue (CBR) No Observed Adverse Effect Levels (NOAELs) and Lowest Observed Adverse Effect Levels (LOAELs), where available, (see Table 1-5 and Appendix A.2 for list of CBRs identified as EAR screening levels for fish tissue concentrations).

2.0 METHODS

2.1 COMPARISON OF CONSTITUENT CONCENTRATIONS IN FISH TISSUES TO FISH TISSUE CRITICAL BODY RESIDUES

For the constituents identified in Table E.7-2 as requiring further review in the assessed water bodies in proximity to the WBF Plant, measured constituent concentrations (or reported detection limits, for samples where the constituent was not detected) for each analyzed fish species and tissue type were compared directly to the applicable CBRs presented in Appendix A.2.

3.0 RESULTS

Fish tissue samples taken in the three Tennessee River reaches were compared to CBR NOAELs and LOAELs for mercury and selenium. The reported fish tissue concentrations for these constituents are summarized and compared to their applicable CBRs in Table E.7-3 below. Additional information on the fish tissue results comparison to CBRs in the Tennessee River is included in Appendix J.5.

Table E.7-3 – Fish Tissue Concentrations for Mercury and Selenium in the Tennessee River

Constituent Type	Constituent	Sample Location	Gradient	Sample Concentration (mg/kg ww)*												
				Muscle				Liver				Ovary				Whole Fish
				BG	CC	LB	RS	BG	CC	LB	RS	BG	CC	LB	RS	SH
CCR Rule Appendix IV Constituents	Mercury	TRU	Upstream	0.07	0.11	0.2	0.06	0.033	0.27	0.081	0.045	<0.0076	<0.0071	0.011	<0.0071	0.02
		TRA	Adjacent	<0.0072	0.12	0.28	0.029	0.026	0.25	0.17	0.081	<0.0072	<0.0076	0.026	<0.0075	0.013
		TRD	Downstream	0.054	0.072	0.2	0.083	0.029	0.11	0.07	0.14	<0.0072	<0.0074	0.014	0.008	0.014
	Selenium	TRU	Upstream	1.4	0.78	1.5	2.1	1.3	1.2	1.1	1.1	2.3	2.2	2.4	2.6	1.7
		TRA	Adjacent	1.3	0.7	1.4	1.9	1.6	1.3	1.1	2.1	2.8	2.1	2.7	3.2	1.2
		TRD	Downstream	1.3	0.67	1.3	2	1.1	1.3	1	1.9	2.2	2.3	2.6	3.6	1.4

Notes: CCR Rule - Title 40, Code of Federal Regulations, Part 257; BG – Bluegill; CBR - Critical Body Residue; CC - Channel Catfish; LB - Largemouth Bass; RS - Redear Sunfish; SH – Shad; TRA – Tennessee River Adjacent; TRD – Tennessee River Downstream; TRU – Tennessee River Upstream; LOAEL – Lowest Observed Adverse Effect Level; mg/kg – milligram per kilogram, ww – wet weight; NOAEL - No Observed Adverse Effect Level;
*Selenium concentrations reported as mg/kg ww for liver tissue and mg/kg dry weight for whole body, muscle, and ovary to permit direct comparison to the selenium critical body residues (CBRs) for these tissues.

Legend
No applicable CBR
Concentration < CBR NOAEL
Concentration > CBR NOAEL
Concentration > CBR LOAEL

4.0 DISCUSSION

For the reviewed constituents, where fish tissue concentrations were higher than CBR NOAELs, there was generally minimal variability in constituent concentrations between the upstream, adjacent, and downstream sampling reaches in proximity to the WBF Plant. However, because of the former WBF Plant's proximity to the Watts Bar Dam, there was insufficient space to establish a sampling control area immediately upstream of the WBF Plant. Therefore, the upstream control sampling reach was established in the forebay area of the Watts Bar Dam, resulting in the downstream and adjacent sampling reaches being located in the Chickamauga Reservoir inflow zone and the upstream sampling reach being established in the Watts Bar Reservoir forebay zone. Because these two reservoir zone types have much different flow regimes and ecologies, any direct comparisons between the upstream and downstream reaches are inappropriate.

Further interpretation of the ecological implications of these tissue concentrations will be completed in the context of the Corrective Action/Risk Assessment Plan.

5.0 REFERENCES

United State Environmental Protection Agency. (2018). *Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update, Screening Values.*

APPENDIX C.2

EXPOSURE POINT CONCENTRATIONS

TABLE C.2-1 - CCR Material Data Summary and Exposure Point Concentrations for COPCs
Watts Bar Fossil Plant

COPC	Data Summary									Exposure Point Concentration		
	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects [a]	Maximum Reporting Limit for Non-Detects [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Median Concentration for Detects and Non-Detects	95% UCL [b]	ProUCL Method	EPC [c]
			%	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g		mg/kg or pCi/g
Ash Pond												
Arsenic	8	8	100	n/a	n/a	68.5	258	138	129	181	95% Student's-t	1.81E+02
Cadmium	8	8	100	n/a	n/a	1.21	3.35	1.90	1.70	n/a [d]	n/a	n/a
Cobalt	8	8	100	n/a	n/a	9.60	20.9	13.7	13.5	15.9	95% Student's-t	1.59E+01
Radium-226	8	8	100	n/a	n/a	2.56	4.40	3.37	3.44	n/a [d]	n/a	n/a
Thallium	8	8	100	n/a	n/a	2.65	9.30	5.07	4.73	6.62	95% Student's-t	6.62E+00
Vanadium	8	8	100	n/a	n/a	50.5	121	75.5	73.0	91.1	95% Student's-t	9.11E+01
Slag Disposal Area												
Arsenic	13	13	100	n/a	n/a	5.81	205	84.0	109	120	95% Student's-t	1.20E+02
Cadmium	13	12	92.3	0.0224	0.0224	0.0283	5.64	1.47	0.208	2.24	95% KM (t)	2.24E+00
Cobalt	13	13	100	n/a	n/a	7.67	18.3	12.6	12.4	14.2	95% Student's-t	1.42E+01
Radium-226	13	13	100	n/a	n/a	0.634	6.69	2.96	2.98	3.83	95% Student's-t	3.83E+00
Thallium	13	13	100	n/a	n/a	0.243	10.9	3.99	4.48	5.75	95% Student's-t	5.75E+00
Vanadium	13	13	100	n/a	n/a	7.55	226	78.0	49.2	108	95% Student's-t	1.08E+02

Notes:

%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
USEPA	United States Environmental Protection Agency
EPC	exposure point concentration
KM	Kaplan Meier
mg/kg	milligrams per kilogram
n/a	not applicable
pCi/g	picocuries per gram (radium-226 and radium-228 only)
UCL	upper confidence limit of the mean concentration

[a] Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a COPC is less than 100%.

[b] Calculated using USEPA's ProUCL version 5.2 (USEPA 2022a) for COPCs with a minimum of five detected results.

[c] The EPC for a COPC with five or more detected results is equal to the lower of the UCL of the mean concentration as recommended by ProUCL (USEPA 2022a) or the maximum detected concentration. For a COPC at a location where the UCL of the mean concentration could not be calculated, the EPC is equal to the maximum detected concentration if there are less than 10 samples or the lower of the maximum detected concentration or median concentration if there are 10 or more samples.

[d] 95% UCLs and human health risks were not estimated for this constituent because the maximum detected concentration in samples collected from this exposure unit does not exceed the respective screening level presented in Table 4-1.

TABLE C.2-2 - Fish Filet Tissue Data Summary and Exposure Point Concentrations for COPCs
Watts Bar Fossil Plant

	Data Summary									Exposure Point Concentration		
COPC	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects [a]	Maximum Reporting Limit for Non-Detects [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Median Concentration for Detects and Non-Detects	95% UCL [b]	ProUCL Method	EPC [c]
			%	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww	mg/kg-ww		mg/kg-ww
Adjacent Tennessee River												
Arsenic	4	4	100	n/a	n/a	0.075	0.16	0.121	0.125	NC	n/a	1.60E-01
Copper	4	2	50.000	0.27	0.28	0.48	0.53	0.505	0.380	n/a [d]	n/a	n/a
Mercury	4	3	75.000	0.0072	0.0072	0.029	0.28	0.143	0.0745	NC	n/a	2.80E-01

Notes:

%	percent
COPC	constituent of potential concern
USEPA	United States Environmental Protection Agency
EPC	exposure point concentration
mg/kg-ww	milligrams per kilogram wet weight
n/a	not applicable
NC	not calculated
UCL	upper confidence limit of the mean concentration

[a] Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a COPC is less than 100%.

[b] Calculated using USEPA's ProUCL version 5.2 (USEPA 2022a) for COPCs with a minimum of five detected results.

[c] The EPC for a COPC with five or more detected results is equal to the lower of the UCL of the mean concentration as recommended by ProUCL (USEPA 2022a) or the maximum detected concentration. For a COPC at a location where the UCL of the mean concentration could not be calculated, the EPC is equal to the maximum detected concentration if there are less than 10 samples or the lower of the maximum detected concentration or median concentration if there are 10 or more samples.

[d] 95% UCLs and human health risks were not estimated for this constituent because the maximum detected concentration in samples collected from this exposure unit does not exceed the respective screening level presented in Table 4-5.

APPENDIX C.3

ProUCL OUTPUTS

APPENDIX C.3-1

ProUCL OUTPUTS

HUMAN HEALTH RISK ASSESSMENT

DRAFT

CCR MATERIAL

UCL Statistics for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.2 12/5/2022 10:04:58 AM
From File	20210312_CCRMC_ProUCL(20210217)_byCCRunit_f.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic (wbf_ap)

General Statistics

Total Number of Observations	8	Number of Distinct Observations	8
		Number of Missing Observations	0
Minimum	68.5	Mean	138
Maximum	258	Median	129
SD	64.19	Std. Error of Mean	22.69
Coefficient of Variation	0.465	Skewness	0.854

Note: Sample size is small (e.g., <10), if data are collected using incremental sampling methodology (ISM) approach,
refer also to ITRC Tech Reg Guide on ISM (ITRC 2020 and ITRC 2012) for additional guidance,
but note that ITRC may recommend the t-UCL or the Chebyshev UCL for small sample sizes (n < 7).
The Chebyshev UCL often results in gross overestimates of the mean.
Refer to the ProUCL 5.2 Technical Guide for a discussion of the Chebyshev UCL.

Normal GOF Test

Shapiro Wilk Test Statistic	0.931	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.749	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.15	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.333	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Note GOF tests may be unreliable for small sample sizes

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	180.9	95% Adjusted-CLT UCL (Chen-1995)	182.6
		95% Modified-t UCL (Johnson-1978)	182.1

Gamma GOF Test

A-D Test Statistic	0.204	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.719	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.153	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.295	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Note GOF tests may be unreliable for small sample sizes

Gamma Statistics

k hat (MLE)	5.528	k star (bias corrected MLE)	3.538
Theta hat (MLE)	24.96	Theta star (bias corrected MLE)	38.99

nu hat (MLE)	88.44	nu star (bias corrected)	56.61
MLE Mean (bias corrected)	138	MLE Sd (bias corrected)	73.34
		Approximate Chi Square Value (0.05)	40.32
Adjusted Level of Significance	0.0195	Adjusted Chi Square Value	36.87

Assuming Gamma Distribution

95% Approximate Gamma UCL	193.7	95% Adjusted Gamma UCL	211.8

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.964	**Shapiro Wilk Lognormal GOF Test**	
10% Shapiro Wilk Critical Value	0.851	Data appear Lognormal at 10% Significance Level	
Lilliefors Test Statistic	0.132	**Lilliefors Lognormal GOF Test**	
10% Lilliefors Critical Value	0.265	Data appear Lognormal at 10% Significance Level	

Data appear Lognormal at 10% Significance Level

Note GOF tests may be unreliable for small sample sizes

Lognormal Statistics

Minimum of Logged Data	4.227	Mean of logged Data	4.834
Maximum of Logged Data	5.553	SD of logged Data	0.462

Assuming Lognormal Distribution

95% H-UCL	208.7	90% Chebyshev (MVUE) UCL	206.1
95% Chebyshev (MVUE) UCL	237	97.5% Chebyshev (MVUE) UCL	279.8
99% Chebyshev (MVUE) UCL	364.1		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	175.3	95% BCA Bootstrap UCL	178.3
95% Standard Bootstrap UCL	173.5	95% Bootstrap-t UCL	192.3
95% Hall's Bootstrap UCL	189.2	95% Percentile Bootstrap UCL	176
90% Chebyshev(Mean, Sd) UCL	206	95% Chebyshev(Mean, Sd) UCL	236.9
97.5% Chebyshev(Mean, Sd) UCL	279.7	99% Chebyshev(Mean, Sd) UCL	363.7

Suggested UCL to Use

95% Student's-t UCL	180.9

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Arsenic (wbf_sda)

General Statistics

Total Number of Observations	13	Number of Distinct Observations	13
		Number of Missing Observations	0
Minimum	5.81	Mean	84.04
Maximum	205	Median	109

SD	71.74	Std. Error of Mean	19.9
Coefficient of Variation	0.854	Skewness	0.194

Normal GOF Test

Shapiro Wilk Test Statistic	0.858	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.814	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.233	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.271	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	119.5	95% Adjusted-CLT UCL (Chen-1995)	117.9
		95% Modified-t UCL (Johnson-1978)	119.7

Gamma GOF Test

A-D Test Statistic	0.95	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.762	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.266	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.244	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.919	k star (bias corrected MLE)	0.758
Theta hat (MLE)	91.49	Theta star (bias corrected MLE)	110.9
nu hat (MLE)	23.88	nu star (bias corrected)	19.71
MLE Mean (bias corrected)	84.04	MLE Sd (bias corrected)	96.54
		Approximate Chi Square Value (0.05)	10.63
Adjusted Level of Significance	0.0301	Adjusted Chi Square Value	9.696

Assuming Gamma Distribution

95% Approximate Gamma UCL	155.7	95% Adjusted Gamma UCL	170.8

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.834	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.889	Data Not Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.281	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.215	Data Not Lognormal at 10% Significance Level

Data Not Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.76	Mean of logged Data	3.797
Maximum of Logged Data	5.323	SD of logged Data	1.373

Assuming Lognormal Distribution

95% H-UCL	463.4	90% Chebyshev (MVUE) UCL	229.5
95% Chebyshev (MVUE) UCL	287.5	97.5% Chebyshev (MVUE) UCL	368.1
99% Chebyshev (MVUE) UCL	526.3		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	116.8	95% BCA Bootstrap UCL	117
95% Standard Bootstrap UCL	115.2	95% Bootstrap-t UCL	120
95% Hall's Bootstrap UCL	113.9	95% Percentile Bootstrap UCL	116.1
90% Chebyshev(Mean, Sd) UCL	143.7	95% Chebyshev(Mean, Sd) UCL	170.8
97.5% Chebyshev(Mean, Sd) UCL	208.3	99% Chebyshev(Mean, Sd) UCL	282

Suggested UCL to Use

95% Student's-t UCL 119.5

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Cadmium (wbf_sda)

General Statistics

Total Number of Observations	13	Number of Distinct Observations	13
Number of Detects	12	Number of Non-Detects	1
Number of Distinct Detects	12	Number of Distinct Non-Detects	1
Minimum Detect	0.0283	Minimum Non-Detect	0.0224
Maximum Detect	5.64	Maximum Non-Detect	0.0224
Variance Detects	3.265	Percent Non-Detects	7.692%
Mean Detects	1.47	SD Detects	1.807
Median Detects	0.774	CV Detects	1.229
Skewness Detects	1.389	Kurtosis Detects	1.386
Mean of Logged Detects	-0.753	SD of Logged Detects	1.874

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.802	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.805	Detected Data Not Normal at 1% Significance Level
Lilliefors Test Statistic	0.258	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.281	Detected Data appear Normal at 1% Significance Level

Detected Data appear Approximate Normal at 1% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	1.359	KM Standard Error of Mean	0.494
90KM SD	1.706	95% KM (BCA) UCL	2.186
95% KM (t) UCL	2.24	95% KM (Percentile Bootstrap) UCL	2.205
95% KM (z) UCL	2.172	95% KM Bootstrap t UCL	2.791
90% KM Chebyshev UCL	2.842	95% KM Chebyshev UCL	3.514
97.5% KM Chebyshev UCL	4.446	99% KM Chebyshev UCL	6.277

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.475	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.781	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.231	**Kolmogorov-Smirnov GOF**

5% K-S Critical Value	0.258	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.55	k star (bias corrected MLE)	0.468
Theta hat (MLE)	2.674	Theta star (bias corrected MLE)	3.142
nu hat (MLE)	13.2	nu star (bias corrected)	11.23
Mean (detects)	1.47		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	1.358
Maximum	5.64	Median	0.208
SD	1.777	CV	1.308
k hat (MLE)	0.473	k star (bias corrected MLE)	0.415
Theta hat (MLE)	2.872	Theta star (bias corrected MLE)	3.273
nu hat (MLE)	12.29	nu star (bias corrected)	10.79
Adjusted Level of Significance (β)	0.0301		
Approximate Chi Square Value (10.79, α)	4.441	Adjusted Chi Square Value (10.79, β)	3.877
95% Gamma Approximate UCL	3.299	95% Gamma Adjusted UCL	3.779

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	1.359	SD (KM)	1.706
Variance (KM)	2.912	SE of Mean (KM)	0.494
k hat (KM)	0.634	k star (KM)	0.539
nu hat (KM)	16.49	nu star (KM)	14.02
theta hat (KM)	2.142	theta star (KM)	2.52
80% gamma percentile (KM)	2.238	90% gamma percentile (KM)	3.619
95% gamma percentile (KM)	5.082	99% gamma percentile (KM)	8.654

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (14.02, α)	6.585	Adjusted Chi Square Value (14.02, β)	5.874
95% KM Approximate Gamma UCL	2.893	95% KM Adjusted Gamma UCL	3.244

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.908	**Shapiro Wilk GOF Test**
10% Shapiro Wilk Critical Value	0.883	Detected Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.212	**Lilliefors GOF Test**
10% Lilliefors Critical Value	0.223	Detected Data appear Lognormal at 10% Significance Level

Detected Data appear Lognormal at 10% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	1.358	Mean in Log Scale	-1.1
SD in Original Scale	1.777	SD in Log Scale	2.187
95% t UCL (assumes normality of ROS data)	2.236	95% Percentile Bootstrap UCL	2.191
95% BCA Bootstrap UCL	2.375	95% Bootstrap t UCL	2.714

95% H-UCL (Log ROS)	98.03

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-0.987	KM Geo Mean	0.373
KM SD (logged)	1.905	95% Critical H Value (KM-Log)	4.571
KM Standard Error of Mean (logged)	0.552	95% H-UCL (KM -Log)	28.28
KM SD (logged)	1.905	95% Critical H Value (KM-Log)	4.571
KM Standard Error of Mean (logged)	0.552		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	1.358	Mean in Log Scale	-1.04
SD in Original Scale	1.777	SD in Log Scale	2.072
95% t UCL (Assumes normality)	2.236	95% H-Stat UCL	59.01

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Detected Data appear Approximate Normal Distributed at 1% Significance Level

Suggested UCL to Use

95% KM (t) UCL	2.24

The calculated UCLs are based on assumptions that the data were collected in a random and unbiased manner.
Please verify the data were collected from random locations.
If the data were collected using judgmental or other non-random methods,
then contact a statistician to correctly calculate UCLs.

When a data set follows an approximate distribution passing only one of the GOF tests,
it is suggested to use a UCL based upon a distribution passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Cobalt (wbf_ap)

General Statistics

Total Number of Observations	8	Number of Distinct Observations	8
		Number of Missing Observations	0
Minimum	9.6	Mean	13.69
Maximum	20.9	Median	13.45
SD	3.332	Std. Error of Mean	1.178
Coefficient of Variation	0.243	Skewness	1.503

Note: Sample size is small (e.g., <10), if data are collected using incremental sampling methodology (ISM) approach,
refer also to ITRC Tech Reg Guide on ISM (ITRC 2020 and ITRC 2012) for additional guidance,
but note that ITRC may recommend the t-UCL or the Chebyshev UCL for small sample sizes (n < 7).
The Chebyshev UCL often results in gross overestimates of the mean.
Refer to the ProUCL 5.2 Technical Guide for a discussion of the Chebyshev UCL.

Normal GOF Test

Shapiro Wilk Test Statistic	0.868	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.749	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.256	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.333	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Note GOF tests may be unreliable for small sample sizes

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	15.92	95% Adjusted-CLT UCL (Chen-1995)	16.29
		95% Modified-t UCL (Johnson-1978)	16.02

Gamma GOF Test

A-D Test Statistic	0.393	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.716	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.217	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.294	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Note GOF tests may be unreliable for small sample sizes

Gamma Statistics

k hat (MLE)	21.68	k star (bias corrected MLE)	13.63
Theta hat (MLE)	0.631	Theta star (bias corrected MLE)	1.004
nu hat (MLE)	346.8	nu star (bias corrected)	218.1
MLE Mean (bias corrected)	13.69	MLE Sd (bias corrected)	3.707
		Approximate Chi Square Value (0.05)	184.9
Adjusted Level of Significance	0.0195	Adjusted Chi Square Value	177.2

Assuming Gamma Distribution

95% Approximate Gamma UCL	16.14	95% Adjusted Gamma UCL	16.85

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.936	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.851	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.212	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.265	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Note GOF tests may be unreliable for small sample sizes

Lognormal Statistics

Minimum of Logged Data	2.262	Mean of logged Data	2.593
Maximum of Logged Data	3.04	SD of logged Data	0.225

Assuming Lognormal Distribution

95% H-UCL	16.22	90% Chebyshev (MVUE) UCL	16.95
95% Chebyshev (MVUE) UCL	18.43	97.5% Chebyshev (MVUE) UCL	20.49
99% Chebyshev (MVUE) UCL	24.54		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	15.63	95% BCA Bootstrap UCL	16.24
95% Standard Bootstrap UCL	15.54	95% Bootstrap-t UCL	16.85
95% Hall's Bootstrap UCL	25.98	95% Percentile Bootstrap UCL	15.76
90% Chebyshev(Mean, Sd) UCL	17.22	95% Chebyshev(Mean, Sd) UCL	18.82
97.5% Chebyshev(Mean, Sd) UCL	21.04	99% Chebyshev(Mean, Sd) UCL	25.41

Suggested UCL to Use

95% Student's-t UCL 15.92

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Cobalt (wbf_sda)

General Statistics

Total Number of Observations	13	Number of Distinct Observations	12
		Number of Missing Observations	0
Minimum	7.67	Mean	12.63
Maximum	18.3	Median	12.4
SD	3.178	Std. Error of Mean	0.881
Coefficient of Variation	0.252	Skewness	0.195

Normal GOF Test

Shapiro Wilk Test Statistic	0.969	**Shapiro Wilk GOF Test**	
1% Shapiro Wilk Critical Value	0.814	Data appear Normal at 1% Significance Level	
Lilliefors Test Statistic	0.131	**Lilliefors GOF Test**	
1% Lilliefors Critical Value	0.271	Data appear Normal at 1% Significance Level	

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	14.2	95% Adjusted-CLT UCL (Chen-1995)	14.13
		95% Modified-t UCL (Johnson-1978)	14.21

Gamma GOF Test

A-D Test Statistic	0.227	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.733	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.133	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.236	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	16.72	k star (bias corrected MLE)	12.91
Theta hat (MLE)	0.755	Theta star (bias corrected MLE)	0.978

nu hat (MLE)	434.7	nu star (bias corrected)	335.7
MLE Mean (bias corrected)	12.63	MLE Sd (bias corrected)	3.514
		Approximate Chi Square Value (0.05)	294.3
Adjusted Level of Significance	0.0301	Adjusted Chi Square Value	288.7

Assuming Gamma Distribution

95% Approximate Gamma UCL	14.41	95% Adjusted Gamma UCL	14.68

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.968	**Shapiro Wilk Lognormal GOF Test**	
10% Shapiro Wilk Critical Value	0.889	Data appear Lognormal at 10% Significance Level	
Lilliefors Test Statistic	0.148	**Lilliefors Lognormal GOF Test**	
10% Lilliefors Critical Value	0.215	Data appear Lognormal at 10% Significance Level	

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.037	Mean of logged Data	2.506
Maximum of Logged Data	2.907	SD of logged Data	0.259

Assuming Lognormal Distribution

95% H-UCL	14.57	90% Chebyshev (MVUE) UCL	15.37
95% Chebyshev (MVUE) UCL	16.61	97.5% Chebyshev (MVUE) UCL	18.34
99% Chebyshev (MVUE) UCL	21.72		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	14.08	95% BCA Bootstrap UCL	14.09
95% Standard Bootstrap UCL	14	95% Bootstrap-t UCL	14.21
95% Hall's Bootstrap UCL	14.07	95% Percentile Bootstrap UCL	14.04
90% Chebyshev(Mean, Sd) UCL	15.27	95% Chebyshev(Mean, Sd) UCL	16.47
97.5% Chebyshev(Mean, Sd) UCL	18.13	99% Chebyshev(Mean, Sd) UCL	21.4

Suggested UCL to Use

95% Student's-t UCL	14.2

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Radium-226 (wbf_sda)

General Statistics

Total Number of Observations	13	Number of Distinct Observations	13
		Number of Missing Observations	0
Minimum	0.634	Mean	2.962
Maximum	6.69	Median	2.98
SD	1.762	Std. Error of Mean	0.489

Coefficient of Variation	0.595	Skewness	0.8

Normal GOF Test

Shapiro Wilk Test Statistic	0.914	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.814	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.247	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.271	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	3.833	95% Adjusted-CLT UCL (Chen-1995)	3.882
		95% Modified-t UCL (Johnson-1978)	3.851

Gamma GOF Test

A-D Test Statistic	0.404	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.74	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.173	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.238	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.871	k star (bias corrected MLE)	2.26
Theta hat (MLE)	1.032	Theta star (bias corrected MLE)	1.311
nu hat (MLE)	74.65	nu star (bias corrected)	58.76
MLE Mean (bias corrected)	2.962	MLE Sd (bias corrected)	1.97
		Approximate Chi Square Value (0.05)	42.13
Adjusted Level of Significance	0.0301	Adjusted Chi Square Value	40.13

Assuming Gamma Distribution

95% Approximate Gamma UCL	4.13	95% Adjusted Gamma UCL	4.336

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.936	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.889	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.206	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.215	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.456	Mean of logged Data	0.902
Maximum of Logged Data	1.901	SD of logged Data	0.668

Assuming Lognormal Distribution

95% H-UCL	4.824	90% Chebyshev (MVUE) UCL	4.769
95% Chebyshev (MVUE) UCL	5.562	97.5% Chebyshev (MVUE) UCL	6.662
99% Chebyshev (MVUE) UCL	8.823		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	3.766	95% BCA Bootstrap UCL	3.89
95% Standard Bootstrap UCL	3.733	95% Bootstrap-t UCL	4.031
95% Hall's Bootstrap UCL	4.047	95% Percentile Bootstrap UCL	3.746
90% Chebyshev(Mean, Sd) UCL	4.428	95% Chebyshev(Mean, Sd) UCL	5.093
97.5% Chebyshev(Mean, Sd) UCL	6.015	99% Chebyshev(Mean, Sd) UCL	7.826

Suggested UCL to Use

95% Student's-t UCL	3.833

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Thallium (wbf_ap)

General Statistics

Total Number of Observations	8	Number of Distinct Observations	8
		Number of Missing Observations	0
Minimum	2.65	Mean	5.074
Maximum	9.3	Median	4.725
SD	2.312	Std. Error of Mean	0.817
Coefficient of Variation	0.456	Skewness	0.895

Note: Sample size is small (e.g., <10), if data are collected using incremental sampling methodology (ISM) approach,
refer also to ITRC Tech Reg Guide on ISM (ITRC 2020 and ITRC 2012) for additional guidance,
but note that ITRC may recommend the t-UCL or the Chebyshev UCL for small sample sizes (n < 7).
The Chebyshev UCL often results in gross overestimates of the mean.
Refer to the ProUCL 5.2 Technical Guide for a discussion of the Chebyshev UCL.

Normal GOF Test

Shapiro Wilk Test Statistic	0.907	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.749	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.175	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.333	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level
Note GOF tests may be unreliable for small sample sizes

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	6.622	95% Adjusted-CLT UCL (Chen-1995)	6.695
		95% Modified-t UCL (Johnson-1978)	6.665

Gamma GOF Test

A-D Test Statistic	0.302	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.718	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.194	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.295	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Note GOF tests may be unreliable for small sample sizes

Gamma Statistics

k hat (MLE)	5.922	k star (bias corrected MLE)	3.784
Theta hat (MLE)	0.857	Theta star (bias corrected MLE)	1.341
nu hat (MLE)	94.75	nu star (bias corrected)	60.55
MLE Mean (bias corrected)	5.074	MLE Sd (bias corrected)	2.608
		Approximate Chi Square Value (0.05)	43.66
Adjusted Level of Significance	0.0195	Adjusted Chi Square Value	40.05

Assuming Gamma Distribution

95% Approximate Gamma UCL	7.037	95% Adjusted Gamma UCL	7.67

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.946	**Shapiro Wilk Lognormal GOF Test**	
10% Shapiro Wilk Critical Value	0.851	Data appear Lognormal at 10% Significance Level	
Lilliefors Test Statistic	0.18	**Lilliefors Lognormal GOF Test**	
10% Lilliefors Critical Value	0.265	Data appear Lognormal at 10% Significance Level	

Data appear Lognormal at 10% Significance Level

Note GOF tests may be unreliable for small sample sizes

Lognormal Statistics

Minimum of Logged Data	0.975	Mean of logged Data	1.537
Maximum of Logged Data	2.23	SD of logged Data	0.442

Assuming Lognormal Distribution

95% H-UCL	7.479	90% Chebyshev (MVUE) UCL	7.454
95% Chebyshev (MVUE) UCL	8.538	97.5% Chebyshev (MVUE) UCL	10.04
99% Chebyshev (MVUE) UCL	13		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	6.418	95% BCA Bootstrap UCL	6.595
95% Standard Bootstrap UCL	6.354	95% Bootstrap-t UCL	7.178
95% Hall's Bootstrap UCL	7.533	95% Percentile Bootstrap UCL	6.431
90% Chebyshev(Mean, Sd) UCL	7.526	95% Chebyshev(Mean, Sd) UCL	8.636
97.5% Chebyshev(Mean, Sd) UCL	10.18	99% Chebyshev(Mean, Sd) UCL	13.21

Suggested UCL to Use

95% Student's-t UCL	6.622

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Thallium (wbf_sda)

General Statistics

Total Number of Observations	13	Number of Distinct Observations	13
		Number of Missing Observations	0
Minimum	0.243	Mean	3.987
Maximum	10.9	Median	4.48
SD	3.555	Std. Error of Mean	0.986
Coefficient of Variation	0.892	Skewness	0.554

Normal GOF Test

Shapiro Wilk Test Statistic	0.899	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.814	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.208	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.271	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	5.745	95% Adjusted-CLT UCL (Chen-1995)	5.771
		95% Modified-t UCL (Johnson-1978)	5.77

Gamma GOF Test

A-D Test Statistic	0.536	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.762	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.217	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.244	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.91	k star (bias corrected MLE)	0.751
Theta hat (MLE)	4.381	Theta star (bias corrected MLE)	5.306
nu hat (MLE)	23.66	nu star (bias corrected)	19.54
MLE Mean (bias corrected)	3.987	MLE Sd (bias corrected)	4.6
		Approximate Chi Square Value (0.05)	10.51
Adjusted Level of Significance	0.0301	Adjusted Chi Square Value	9.579

Assuming Gamma Distribution

95% Approximate Gamma UCL	7.411	95% Adjusted Gamma UCL	8.132

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.881	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.889	Data Not Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.246	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.215	Data Not Lognormal at 10% Significance Level

Data Not Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.415	Mean of logged Data	0.742
Maximum of Logged Data	2.389	SD of logged Data	1.385

Assuming Lognormal Distribution

95% H-UCL	22.73	90% Chebyshev (MVUE) UCL	11.03
95% Chebyshev (MVUE) UCL	13.83	97.5% Chebyshev (MVUE) UCL	17.72
99% Chebyshev (MVUE) UCL	25.36		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	5.609	95% BCA Bootstrap UCL	5.766
95% Standard Bootstrap UCL	5.539	95% Bootstrap-t UCL	5.901
95% Hall's Bootstrap UCL	5.696	95% Percentile Bootstrap UCL	5.602
90% Chebyshev(Mean, Sd) UCL	6.945	95% Chebyshev(Mean, Sd) UCL	8.285
97.5% Chebyshev(Mean, Sd) UCL	10.14	99% Chebyshev(Mean, Sd) UCL	13.8

Suggested UCL to Use

95% Student's-t UCL 5.745

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Vanadium (wbf_ap)

General Statistics

Total Number of Observations	8	Number of Distinct Observations	8
		Number of Missing Observations	0
Minimum	50.5	Mean	75.53
Maximum	121	Median	72.95
SD	23.3	Std. Error of Mean	8.239
Coefficient of Variation	0.309	Skewness	0.999

Note: Sample size is small (e.g., <10), if data are collected using incremental sampling methodology (ISM) approach,
refer also to ITRC Tech Reg Guide on ISM (ITRC 2020 and ITRC 2012) for additional guidance,
but note that ITRC may recommend the t-UCL or the Chebyshev UCL for small sample sizes (n < 7).
The Chebyshev UCL often results in gross overestimates of the mean.
Refer to the ProUCL 5.2 Technical Guide for a discussion of the Chebyshev UCL.

Normal GOF Test

Shapiro Wilk Test Statistic	0.905	**Shapiro Wilk GOF Test**	
1% Shapiro Wilk Critical Value	0.749	Data appear Normal at 1% Significance Level	
Lilliefors Test Statistic	0.183	**Lilliefors GOF Test**	
1% Lilliefors Critical Value	0.333	Data appear Normal at 1% Significance Level	

Data appear Normal at 1% Significance Level
Note GOF tests may be unreliable for small sample sizes

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	91.13	95% Adjusted-CLT UCL (Chen-1995)	92.19

95% Modified-t UCL (Johnson-1978)	91.62

Gamma GOF Test

A-D Test Statistic	0.306	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.715	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.163	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.294	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Note GOF tests may be unreliable for small sample sizes

Gamma Statistics

k hat (MLE)	13.02	k star (bias corrected MLE)	8.218
Theta hat (MLE)	5.802	Theta star (bias corrected MLE)	9.19
nu hat (MLE)	208.3	nu star (bias corrected)	131.5
MLE Mean (bias corrected)	75.53	MLE Sd (bias corrected)	26.34
		Approximate Chi Square Value (0.05)	106
Adjusted Level of Significance	0.0195	Adjusted Chi Square Value	100.2

Assuming Gamma Distribution

95% Approximate Gamma UCL	93.69	95% Adjusted Gamma UCL	99.09

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.945	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.851	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.148	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.265	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Note GOF tests may be unreliable for small sample sizes

Lognormal Statistics

Minimum of Logged Data	3.922	Mean of logged Data	4.286
Maximum of Logged Data	4.796	SD of logged Data	0.294

Assuming Lognormal Distribution

95% H-UCL	95.27	90% Chebyshev (MVUE) UCL	99.05
95% Chebyshev (MVUE) UCL	109.7	97.5% Chebyshev (MVUE) UCL	124.6
99% Chebyshev (MVUE) UCL	153.8		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	89.08	95% BCA Bootstrap UCL	90.84
95% Standard Bootstrap UCL	88.39	95% Bootstrap-t UCL	96.48
95% Hall's Bootstrap UCL	94.13	95% Percentile Bootstrap UCL	89.14
90% Chebyshev(Mean, Sd) UCL	100.2	95% Chebyshev(Mean, Sd) UCL	111.4
97.5% Chebyshev(Mean, Sd) UCL	127	99% Chebyshev(Mean, Sd) UCL	157.5

Suggested UCL to Use

95% Student's-t UCL	91.13

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Vanadium (wbf_sda)

General Statistics

Total Number of Observations	13	Number of Distinct Observations	13
		Number of Missing Observations	0
Minimum	7.55	Mean	77.99
Maximum	226	Median	49.2
SD	61.07	Std. Error of Mean	16.94
Coefficient of Variation	0.783	Skewness	1.302

Normal GOF Test

Shapiro Wilk Test Statistic	0.877	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.814	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.22	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.271	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	108.2	95% Adjusted-CLT UCL (Chen-1995)	112.4
		95% Modified-t UCL (Johnson-1978)	109.2

Gamma GOF Test

A-D Test Statistic	0.276	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.747	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.159	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.24	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.766	k star (bias corrected MLE)	1.41
Theta hat (MLE)	44.17	Theta star (bias corrected MLE)	55.33
nu hat (MLE)	45.91	nu star (bias corrected)	36.65
MLE Mean (bias corrected)	77.99	MLE Sd (bias corrected)	65.69
		Approximate Chi Square Value (0.05)	23.79
Adjusted Level of Significance	0.0301	Adjusted Chi Square Value	22.32

Assuming Gamma Distribution

95% Approximate Gamma UCL	120.1	95% Adjusted Gamma UCL	128

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.949	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.889	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.156	**Lilliefors Lognormal GOF Test**

10% Lilliefors Critical Value	0.215	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.022	Mean of logged Data	4.047
Maximum of Logged Data	5.421	SD of logged Data	0.887

Assuming Lognormal Distribution

95% H-UCL	167.6	90% Chebyshev (MVUE) UCL	145.8
95% Chebyshev (MVUE) UCL	174.9	97.5% Chebyshev (MVUE) UCL	215.3
99% Chebyshev (MVUE) UCL	294.6		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	105.8	95% BCA Bootstrap UCL	113.1
95% Standard Bootstrap UCL	105	95% Bootstrap-t UCL	121.5
95% Hall's Bootstrap UCL	126.9	95% Percentile Bootstrap UCL	106.7
90% Chebyshev(Mean, Sd) UCL	128.8	95% Chebyshev(Mean, Sd) UCL	151.8
97.5% Chebyshev(Mean, Sd) UCL	183.8	99% Chebyshev(Mean, Sd) UCL	246.5

Suggested UCL to Use

95% Student's-t UCL	108.2

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

APPENDIX D – HUMAN HEALTH RISK ASSESSMENT CALCULATIONS

APPENDIX D.1

EXAMPLE HUMAN HEALTH RISK CALCULATIONS

DRAFT

Appendix D.1 – Example Human Health Risk Calculations

Human Health and Ecological Risk Assessment
Watts Bar Fossil Plant
Spring City, Tennessee

March 17, 2025

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

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APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Exposure Dose Equations
March 17, 2025

This appendix provides equations used to estimate exposure doses for all receptors with potentially complete pathways and example calculations for deriving the human health exposure, carcinogenic risk, and noncancer hazard estimates presented in the Watts Bar Fossil Plant Human Health Risk Assessment (HHRA). Calculation methods differ for chemical and radionuclide constituents of potential concern (COPCs). Example calculations for chemical COPCs are provided for onsite workers exposed to arsenic in coal combustion residuals (CCR) material and consumers of locally caught sport fish exposed to arsenic in fish tissue. Example calculations for radionuclide COPCs are provided for onsite workers exposed to radium-226 in CCR material.

1.0 EXPOSURE DOSE EQUATIONS

1.1 CCR MATERIAL

1.1.1 Onsite Worker Incidental Ingestion of CCR Material

Incidental Ingestion Dose for Carcinogenic Risk Estimates (milligrams [mg] per kilogram [kg] per day [mg/kg-day]) =

$$\frac{C_{CCR} \times IR_{CCR} \times EF_w \times ED_w \times RBA \times CF}{BW_w \times AT_c}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

IR_{CCR} = Ingestion rate of CCR material (mg/day)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

RBA = Relative bioavailability factor (unitless)

CF = Conversion factor (kg/mg)

BW_w = Body weight (kg)

AT_C = Averaging time (cancer) (days)

Incidental Ingestion Dose for Noncancer Hazard Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times IR_{CCR} \times EF_w \times ED_w \times RBA \times CF}{BW_w \times AT_{NCw}}$$

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Exposure Dose Equations
March 17, 2025

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

IR_{CCR} = Ingestion rate of CCR material (mg/day)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

RBA = Relative bioavailability factor (unitless)

CF = Conversion factor (kg/mg)

BW_w = Body weight (kg)

AT_{NCw} = Averaging time (noncancer) (days)

1.1.2 Onsite Worker Dermal Contact with CCR Material

Dermal Absorption Dose for Carcinogenic Risk Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times AF_w \times ABS \times SA_w \times EF_w \times ED_w \times CF}{BW_w \times AT_c}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

AF_w = Adherence factor of CCR material to skin (mg/square centimeter [cm^2])

ABS = Dermal absorption factor (unitless)

SA_w = Skin surface area available for contact (cm^2)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

CF = Conversion factor (kg/mg)

BW_w = Body weight (kg)

AT_c = Averaging time (cancer) (days)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Exposure Dose Equations
March 17, 2025

Dermal Absorption Dose for Noncancer Hazard Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times AF_w \times ABS \times SA_w \times EF_w \times ED_w \times CF}{BW_w \times AT_{NCw}}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

AF_w = Adherence factor of CCR material to skin (mg/cm^2)

ABS = Dermal absorption factor (unitless)

SA_w = Skin surface area available for contact (cm^2)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

CF = Conversion factor (kg/mg)

BW_w = Body weight (kg)

AT_{NCw} = Averaging time (noncancer) (days)

1.1.3 Onsite Worker Inhalation of Particulates

Inhalation of Particulates Concentration for Carcinogenic Risk Estimates (micrograms [µg] per cubic meters [m^3] [µg/m^3]) =

$$\frac{C_{CCR} \times \left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times EF_w \times ED_w}{AT_c \times CF}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

PEF = Particulate emission factor (m^3/kg)

ET_w = Exposure time (hours/day)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

AT_c = Averaging time (cancer) (days)

CF = Conversion factor (mg/µg)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Exposure Dose Equations
March 17, 2025

Inhalation of Particulates Concentration for Noncancer Hazard Estimates (mg/m^3) =

$$\frac{C_{CCR} \times \left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times EF_w \times ED_w}{AT_{NCw}}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

PEF = Particulate emission factor (m^3/kg)

ET_w = Exposure time (hours/day)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

AT_{NCw} = Averaging time (noncancer) (days)

1.2 FISH

1.2.1 Recreational User - Consumer of Locally-Caught Sport Fish

Ingestion Dose for Carcinogenic Risk Estimates (mg/kg-day) =

$$\frac{C_{fish} \times F_{inorg} \times IF_{fish} \times CF}{AT_C}$$

Where:

$$IF_{fish} = \frac{ED_{fish\text{-}c} \times EF_{fish\text{-}c} \times IR_{fish\text{-}c}}{BW_{fish\text{-}c}} + \frac{ED_{fish\text{-}y} \times EF_{fish\text{-}y} \times IR_{fish\text{-}y}}{BW_{fish\text{-}y}} + \frac{ED_{fish\text{-}a} \times EF_{fish\text{-}a} \times IR_{fish\text{-}a}}{BW_{fish\text{-}a}};$$

and

C_{fish} = Chemical concentration in fish (mg/kg-wet weight [ww])

F_{inorg} = Factor of 0.1 to adjust for the percent of inorganic arsenic in the total arsenic EPC (unitless). This factor does not apply to other CCR Parameters.

IF_{fish} = Age-adjusted fish ingestion factor (mg/kg-ww)

CF = Conversion factor (kg/mg)

AT_C = Averaging time (cancer) (days)

$ED_{fish\text{-}c}$ = Child (0 to <6 years old) exposure duration (years)

$EF_{fish\text{-}c}$ = Child (0 to <6 years old) exposure frequency (days/year)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Exposure Dose Equations
March 17, 2025

$IR_{fish\text{-}c}$ = Child (0 to <6 years old) fish consumption rate (mg-ww/day)

$BW_{fish\text{-}c}$ = Child (0 to <6 years old) body weight (kg)

$ED_{fish\text{-}y}$ = Adolescent (6 to <16 years old) exposure duration (years)

$EF_{fish\text{-}y}$ = Adolescent (6 to <16 years old) exposure frequency (days/year)

$IR_{fish\text{-}y}$ = Adolescent (6 to <16 years old) fish consumption rate (mg-ww/day)

$BW_{fish\text{-}y}$ = Adolescent (6 to <16 years old) body weight (kg)

$ED_{fish\text{-}a}$ = Adult (16 to <26 years old) exposure duration (years)

$EF_{fish\text{-}a}$ = Adult (16 to <26 years old) exposure frequency (days/year)

$IR_{fish\text{-}a}$ = Adult (16 to <26 years old) fish consumption rate (mg-ww/day)

$BW_{fish\text{-}a}$ = Adult (16 to <26 years old) body weight (kg)

Ingestion Dose for Noncancer Hazard Estimates for a child (0 to <6 years old) (mg/kg-day) =

$$\frac{C_{fish} \times F_{inorg} \times ED_{fish\text{-}c} \times EF_{fish\text{-}c} \times IR_{fish\text{-}c} \times CF}{AT_{NCfish\text{-}c} \times BW_{fish\text{-}c}}$$

Where:

C_{fish} = Chemical concentration in fish (mg/kg-ww)

F_{inorg} = Factor of 0.1 to adjust for the percent of inorganic arsenic in the total arsenic EPC (unitless). This factor does not apply to other CCR Parameters.

$ED_{fish\text{-}c}$ = Child (0 to <6 years old) exposure duration (years)

$EF_{fish\text{-}c}$ = Child (0 to <6 years old) exposure frequency (days/year)

$IR_{fish\text{-}c}$ = Child (0 to <6 years old) fish consumption rate (mg-ww/day)

CF = Conversion factor (kg/mg)

$AT_{NCfish\text{-}c}$= Averaging time (noncancer) (days)

$BW_{fish\text{-}c}$ = Child (0 to <6 years old) body weight (kg)

2.0 EXAMPLE CALCULATIONS

2.1 CALCULATED INGESTION AND DERMAL EXPOSURE DOSES AND INHALATION CONCENTRATIONS FOR CHEMICAL COPCS

Examples of the methods used to calculate ingestion and dermal exposure doses and inhalation concentrations of arsenic in CCR material and fish are provided below. These calculations serve as examples for other COPCs. Exposure point concentrations and exposure assumptions used in these calculations are summarized in Sections 5.1.2 and 5.1.3 of the human health and ecological risk assessment (HHERA) report. The tables referenced in this appendix are presented in the HHERA report.

2.1.1 Arsenic in CCR Material

2.1.1.1 Onsite Worker Incidental Ingestion of CCR Material

Incidental Ingestion Dose for Carcinogenic Risk Estimates (milligrams [mg]/kilogram [kg]-day) =

$$\frac{C_{CCR} \times IR_{CCR} \times EF_w \times ED_w \times RBA \times CF}{BW_w \times AT_c}$$

Where:

C_{CCR}	= Arsenic concentration in the Ash Pond (mg/kg-ww)	= 181 (Table C.2-1)
IR_{CCR}	= Ingestion rate of CCR material (mg-ww/day)	= 330 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
RBA	= Arsenic relative bioavailability factor (unitless)	= 0.6 (Table 5-2)
CF	= Conversion factor (kg/mg)	= $1x10^{-6}$ (Table 5-2)
BW_w	= Body weight (kg)	= 80 (Table 5-2)
AT_C	= Averaging time (cancer) (days)	= 25,550 (Table 5-2)

Result:

Incidental ingestion dose (cancer) (mg/kg-day)	= $3.50x10^{-7}$ (Appendix D.2)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Example Calculations
March 17, 2025

Incidental Ingestion Dose for Noncancer Hazard Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times IR_{CCR} \times EF_w \times ED_w \times RBA \times CF}{BW_w \times AT_{NCw}}$$

Where:

C_{CCR}	= Arsenic concentration in the Ash Pond (mg/kg-ww)	= 181 (Table C.2-1)
IR_{CCR}	= Ingestion rate of CCR material (mg-ww/day)	= 330 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
RBA	= Arsenic relative bioavailability factor (unitless)	= 0.6 (Table 5-2)
CF	= Conversion factor (kg/mg)	= $1x10^{-6}$ (Table 5-2)
BW_w	= Body weight (kg)	= 80 (Table 5-2)
AT_{NCw}	= Averaging time (noncancer) (days)	= 28 (Table 5-2)

Result:

Incidental ingestion dose (noncancer) (mg/kg-day)	= $3.20x10^{-4}$ (Appendix D.2)

2.1.1.2 Onsite Worker Dermal Contact with CCR Material

Dermal Absorption Dose for Carcinogenic Risk Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times AF_w \times ABS \times SA_w \times EF_w \times ED_w \times CF}{BW_w \times AT_c}$$

Where:

C_{CCR}	= Arsenic concentration in the Ash Pond (mg/kg)	= 181 (Table C.2-1)
AF_w	= Adherence factor of CCR material to skin (mg/square centimeter [cm^2])	= 0.3 (Table 5-2)
ABS	= Arsenic dermal absorption factor (unitless)	= 0.03 (RAGS Part E)
SA_w	= Skin surface area available for contact (cm^2)	= 3,527 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
CF	= Conversion factor (kg/mg)	= $1x10^{-6}$ (Table 5-2)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Example Calculations
March 17, 2025

BW_w	= Body weight (kg)	= 80 (Table 5-2)
AT_c	= Averaging time (cancer)	= 25,550 (Table 5-2)

Result:

Dermal absorption dose (cancer) (mg/kg-day)	= 5.62×10^{-8} (Appendix D.2)

Dermal Absorption Dose for Noncancer Hazard Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times AF_w \times ABS \times SA_w \times EF_w \times ED_w \times CF}{BW_w \times AT_{NCw}}$$

Where:

C_{CCR}	= Arsenic concentration in the Ash Pond (mg/kg)	= 181 (Table C.2-1)
AF_w	= Adherence factor of CCR material to skin (mg/cm^2)	= 0.3 (Table 5-2)
ABS	= Arsenic dermal absorption factor (unitless)	= 0.03 (RAGS Part E)
SA_w	= Skin surface area available for contact (cm^2)	= 3,527 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
CF	= Conversion factor (kg/mg)	= 1×10^{-6} (Table 5-2)
BW_w	= Body weight (kg)	= 80 (Table 5-2)
AT_{NCw}	= Averaging time (noncancer)	= 28 (Table 5-2)

Result:

Dermal absorption dose (noncancer) (mg/kg-day)	= 5.13×10^{-5} (Appendix D.2)

2.1.1.3 Onsite Worker Inhalation of Particulates

Inhalation of Particulates Concentration for Carcinogenic Risk Estimates (micrograms [µg] per cubic meters [m^3] [$\mu g/m^3$]) =

$$\frac{C_{CCR} \times \left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1 \text{ day}}{24 \text{ Hours}}\right) \times EF_w \times ED_w}{AT_c \times CF}$$

Where:

C_{CCR}	= Arsenic concentration in the Ash Pond (mg/kg)	= 181 (Table C.2-1)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Example Calculations
March 17, 2025

PEF	= Particulate emission factor (m^3/kg)	= $1.36x10^{+9}$ (Table 5-2)
ET_w	= Exposure time (hours/day)	= 8 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
AT_C	= Averaging time (cancer) (days)	= 25,550 (Table 5-2)
CF	= Conversion factor (mg/µg)	= $1x10^{-3}$ (Table 5-2)

Result:

Inhalation of particulates concentration (cancer) (µg/m^3) = $3.47x10^{-8}$ (Appendix D.2)

Inhalation of Particulates Concentration for Noncancer Hazard Estimates (mg/m^3) =

$$\frac{C_{CCR} \times \left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times EF_w \times ED_w}{AT_{NCw}}$$

Where:

C_{CCR}	= Arsenic concentration in the Ash Pond (mg/kg)	= 181 (Table C.2-1)
PEF	= Particulate emission factor (m^3/kg)	= $1.36x10^{+9}$ (Table 5-2)
ET_w	= Exposure time (hours/day)	= 8 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
AT_{NCw}	= Averaging time (noncancer) (days)	= 28 (Table 5-2)

Result:

Inhalation of particulates concentration (noncancer) (mg/m^3) = $3.17x10^{-8}$ (Appendix D.2)

2.1.2 Arsenic in Fish

2.1.2.1 Recreational User - Consumer of Locally-Caught Sport Fish

Ingestion Dose for Carcinogenic Risk Estimates (mg/kg-day) =

$$\frac{C_{fish} \times F_{inorg} \times IF_{fish} \times CF}{AT_C}$$

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Example Calculations
March 17, 2025

Where:

$$IF_{fish} = \frac{ED_{fish\text{-}c} \times EF_{fish\text{-}c} \times IR_{fish\text{-}c}}{BW_{fish\text{-}c}} + \frac{ED_{fish\text{-}y} \times EF_{fish\text{-}y} \times IR_{fish\text{-}y}}{BW_{fish\text{-}y}} + \frac{ED_{fish\text{-}a} \times EF_{fish\text{-}a} \times IR_{fish\text{-}a}}{BW_{fish\text{-}a}};$$

and

C_{fish}	= Arsenic concentration in fish filet from Adjacent Tennessee River (mg/kg-ww)	= 0.160 (Table C.2-2)
F_{inorg}	= Factor to adjust for the percent of inorganic arsenic in the total arsenic EPC (unitless). This factor does not apply to other CCR Parameters.	= 0.1 (Appendix D.2)
IF_{fish}	= Age-adjusted fish ingestion factor (mg/kg-ww)	= 3,659,912 (calculated)
CF	= Conversion factor (10^{-6} kg/mg)	= $1x10^{-6}$ (Table 5-2)
AT_C	= Averaging time (cancer) (days)	= 25,550 (Table 5-2)
$ED_{fish\text{-}c}$	= Child (0 to <6) exposure duration (years)	= 6 (Table 5-2)
$EF_{fish\text{-}c}$	= Child (0 to <6) exposure frequency (days/year)	= 350 (Table 5-2)
$IR_{fish\text{-}c}$	= Child (0 to <6) fish consumption rate (mg-ww/day)	= 8,700 (Table 5-2)
$BW_{fish\text{-}c}$	= Child (0 to <6) body weight (kg)	= 15 (Table 5-2)
$ED_{fish\text{-}y}$	= Adolescent (6 to <16) exposure duration (years)	= 10 (Table 5-2)
$EF_{fish\text{-}y}$	= Adolescent (6 to <16) exposure frequency (days/year)	= 350 (Table 5-2)
$IR_{fish\text{-}y}$	= Adolescent (6 to <16) fish consumption rate (mg-ww/day)	= 12,800 (Table 5-2)
$BW_{fish\text{-}y}$	= Adolescent (6 to <16) body weight (kg)	= 44.3 (Table 5-2)
$ED_{fish\text{-}a}$	= Adult (16 to <26) exposure duration (years)	= 10 (Table 5-2)
$EF_{fish\text{-}a}$	= Adult (16 to <26) exposure frequency (days/year)	= 350 (Table 5-2)
$IR_{fish\text{-}a}$	= Adult (16 to <26) fish consumption rate (mg-ww/day)	= 32,700 (Table 5-2)
$BW_{fish\text{-}a}$	= Adult (16 to <26) body weight (kg)	= 80 (Table 5-2)

Result:

Ingestion dose (cancer) (mg/kg-day) = $2.29x10^{-6}$ (Appendix D.2)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Example Calculations
March 17, 2025

Ingestion Dose for Noncancer Hazard Estimates for a child (0 to <6) (mg/kg-day) =

$$\frac{C_{fish} \times F_{inorg} \times ED_{fish\text{-}c} \times EF_{fish\text{-}c} \times IR_{fish\text{-}c} \times CF}{AT_{NCfish\text{-}c} \times BW_{fish\text{-}c}}$$

Where:

C_{fish}	= Arsenic concentration in fish fillet from Adjacent Tennessee River (mg/kg-ww)	= 0.160 mg/kg (Table C.2-2)
F_{inorg}	= Factor to adjust for the percent of inorganic arsenic in the total arsenic EPC (unitless). This factor does not apply to other CCR Parameters.	= 0.1 (Section Appendix D.2)
$ED_{fish\text{-}c}$	= Child (0 to <6) exposure duration (years)	= 6 years (Table 5-2)
$EF_{fish\text{-}c}$	= Child (0 to <6) exposure frequency (days/year)	= 350 (Table 5-2)
$IR_{fish\text{-}c}$	= Child (0 to <6) fish consumption rate (mg-ww/day)	= 8,700 (Table 5-2)
CF	= Conversion factor (10^{-6} kg/mg)	= $1x10^{-6}$ (Table 5-2)
$AT_{NCfish\text{-}c}$	= Averaging time (noncancer) (days)	= 2,190 (Table 5-2)
$BW_{fish\text{-}c}$	= Child (0 to <6) body weight (kg)	= 15 (Table 5-2)

Result:

Ingestion dose (noncancer) (mg/kg-day)	= $8.90x10^{-6}$ (Appendix D.2)

2.2 CALCULATED CANCER RISK AND NONCANCER HAZARD FOR CHEMICAL COPCS

Examples of the methods used to calculate incremental lifetime cancer risks (ILCRs) and noncancer hazard quotients (HQs) for arsenic in CCR material are provided below. These calculations serve as examples for other COPCs and exposure media. Incidental soil ingestion ILCR and HQ equations are applicable to ingestion of fish by consumers of locally-caught sport fish. Toxicity values used in these calculations are summarized in Section 5.2 of the HHERA report.

2.2.1 Quantification of Arsenic ILCR

2.2.1.1 Onsite Worker Incidental Ingestion of CCR Material

Incidental Ingestion ILCR (unitless) = Incidental ingestion dose (cancer) x CSF_o

Where:

Incidental ingestion dose (cancer) (mg/kg-day)	= $3.50x10^{-7}$ (Appendix D.2)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Example Calculations
March 17, 2025

CSF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$ = 1.5 (Table 5-3)

Result:

Incidental ingestion ILCR (unitless) = $5.3x10^{-7}$ (Appendix D.2)

2.2.1.2 Onsite Worker Dermal Contact with CCR Material

Dermal Absorption ILCR (unitless) = Dermal absorption dose (cancer) x CSF_d

Where:

Dermal absorption dose (cancer) (mg/kg-day) = $5.62x10^{-8}$ (Appendix D.2)

CSF_d = Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$ = 1.5 (Table 5-3)

Result:

Dermal Absorption ILCR (unitless) = $8.4x10^{-8}$ (Appendix D.2)

2.2.1.3 Onsite Worker Inhalation of Particulates

Inhalation of Particulates ILCR (unitless) = Inhalation of particulates concentration (cancer) x IUR_i

Where:

Inhalation of particulates dose (cancer) $(\mu g/m^3)$ = $3.47x10^{-8}$ (Appendix D.2)

IUR_i = Inhalation unit risk $(\mu g/m^3)^{-1}$ = 0.0043 (Table 5-3)

Result:

Inhalation of particulates ILCR (unitless) = $1.5x10^{-10}$ (Appendix D.2)

2.2.1.4 Onsite Worker Exposed to CCR Material COPC-Specific ILCR

Arsenic COPC-Specific ILCR (unitless) =

Incidental ingestion ILCR + Dermal absorption ILCR + Inhalation of particulates ILCR

Where:

Incidental ingestion ILCR = $5.3x10^{-7}$ (Appendix D.2)

Dermal absorption ILCR = $8.4x10^{-8}$ (Appendix D.2)

Inhalation of particulates ILCR = $1.5x10^{-10}$ (Appendix D.2)

Result:

Arsenic COPC-Specific ILCR (unitless) = 6.1×10^{-7} (Appendix D.2)

2.2.2 Quantification of Arsenic Noncancer Hazard

2.2.2.1 Onsite Worker Incidental Ingestion of CCR Material

$$\text{Incidental Ingestion HQ (unitless)} = \frac{\text{Incidental ingestion dose (noncancer)}}{RfD_o}$$

Where:

Incidental ingestion dose (noncancer) (mg/kg-day) = 3.20×10^{-4} (Appendix D.2)

RfD_o = Oral reference dose (mg/kg-day) = 0.00030 (Table 5-3)

Result:

Incidental ingestion HQ (unitless) = 1.1 (Appendix D.2)

2.2.2.2 Onsite Worker Dermal Contact with CCR Material

$$\text{Dermal Absorption HQ (unitless)} = \frac{\text{Dermal absorption dose (noncancer)}}{RfD_d}$$

Where:

Dermal absorption dose (noncancer) (mg/kg-day) = 5.13×10^{-5} (Appendix D.2)

RfD_d = Dermal reference dose (mg/kg-day) = 0.00030 (Table 5-3)

Result:

Dermal absorption HQ (unitless) = 0.17 (Appendix D.2)

2.2.2.3 Onsite Worker Inhalation of Particulates

$$\text{Inhalation of particulates HQ (unitless)} = \frac{\text{Inhalation of particulates concentration (noncancer)}}{RfC_i}$$

Where:

Inhalation of particulates concentration (noncancer) (mg/m^3) = 3.17×10^{-8} (Appendix D.2)

RfC_i = Inhalation reference concentration (mg/m^3) = $1.5x10^{-5}$ (Table 5-3)

Result:

Inhalation of particulates HQ (unitless) = 0.0021 (Appendix D.2)

2.2.2.4 Onsite Worker Exposed to CCR Material Noncancer HQ

Arsenic HQ (unitless) =

Incidental ingestion HQ + Dermal absorption HQ + Inhalation of particulates HQ

Where:

Incidental ingestion HQ = 1.1 (Appendix D.2)

Dermal absorption HQ = 0.17 (Appendix D.2)

Inhalation of particulates HQ = 0.0021 (Appendix D.2)

Result:

Arsenic COPC-Specific HQ (unitless) = 1.2 (Appendix D.2)

2.3 CALCULATED CANCER RISKS FOR RADIONUCLIDE COPCS

Examples of the methods used to calculate an ILCR for radium-226 in CCR material is provided below. This calculation serves as an example for other radionuclide COPCs and exposure media.

2.3.1 Quantification of Radium-226 ILCR

Onsite Worker Radionuclide ILCR (unitless) =

$$\frac{C_{CCR}}{PRG \times TR}$$

Where:

C_{CCR} = Radium-226 activity in the Slag Disposal Area [picocuries per gram (pCi/g)] = 3.83 (Appendix D.3)

PRG = preliminary remediation goal (pCi/g) = 7.18 (Appendix D.3)

TR = target cancer risk (unitless) = $1.0x10^{-6}$ (Appendix D.3)

Result:

Onsite Worker Radionuclide ILCR (unitless) = $5.3x10^{-7}$ (Appendix D.3)



APPENDIX D.2

HUMAN HEALTH RISK CALCULATIONS FOR CHEMICALS

TABLE D.2-1 - Cancer Risk Calculations for an Onsite Worker Exposed to Chemical COPCs in CCR Material
Watts Bar Fossil Plant

CCR Unit/COPC	EPC [a] CCR Material	Exposure Dose/Concentration Ingestion	Exposure Dose/Concentration Dermal	Exposure Dose/Concentration Inhalation	Cancer Slope Factor Oral	Cancer Slope Factor Dermal	Unit Risk Inhalation	ILCR [b] Pathway-Specific Soil Ingestion	ILCR [b] Pathway-Specific Dermal Contact	ILCR [b] Pathway-Specific Inhalation	ILCR [b] COPC-Specific
	mg/kg	mg/kg-d	mg/kg-d	µg/m^3	(mg/kg-d)$^{-1}$	(mg/kg-d)$^{-1}$	(µg/m^3)$^{-1}$	unitless	unitless	unitless	unitless
Ash Pond											
Arsenic	1.81E+02	3.50E-07	5.62E-08	3.47E-08	1.5E+00	1.5E+00	4.3E-03	5.3E-07	8.4E-08	1.5E-10	6.1E-07
Cobalt	1.59E+01	5.14E-08	n/a	3.05E-09	-	-	9.0E-03	n/a	n/a	2.7E-11	2.7E-11
									Cumulative ILCR:		6E-07
Slag Disposal Area											
Arsenic	1.20E+02	2.32E-07	3.71E-08	2.29E-08	1.5E+00	1.5E+00	4.3E-03	3.5E-07	5.6E-08	9.9E-11	4.0E-07
Cadmium	2.24E+00	7.23E-09	2.32E-11	4.30E-10	-	-	1.8E-03	n/a	n/a	7.7E-13	7.7E-13
Cobalt	1.42E+01	4.59E-08	n/a	2.72E-09	-	-	9.0E-03	n/a	n/a	2.5E-11	2.5E-11
										Cumulative ILCR:	4E-07

Notes:

-	not available
%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
EPC	exposure point concentration
ILCR	incremental lifetime cancer risk
µg/m^3	micrograms per cubic meter
mg/kg	milligrams per kilogram
mg/kg-d	milligrams per kilogram per day
n/a	not applicable
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

[b] Risks shown only for carcinogenic COPCs with available doses and toxicity values.

TABLE D.2-2 - Noncancer Hazard Calculations for an Onsite Worker Exposed to Chemical COPCs in CCR Material
Watts Bar Fossil Plant

CCR Unit/COPC	EPC [a] CCR Material	Exposure Dose/Concentration			Subchronic Reference Dose		Subchronic Reference Concentration	Hazard Quotient [b] Pathway-Specific			
		Ingestion	Dermal	Inhalation	Oral	Dermal	Inhalation	Soil Ingestion	Dermal Contact	Inhalation	COPC-Specific
	mg/kg	mg/kg-d	mg/kg-d	mg/m^3	mg/kg-d	mg/kg-d	mg/m^3	unitless	unitless	unitless	unitless
Ash Pond											
Arsenic	1.81E+02	3.20E-04	5.13E-05	3.17E-08	3.0E-04	3.0E-04	1.5E-05	1.1E+00	1.7E-01	2.1E-03	1.2
Cobalt	1.59E+01	4.69E-05	n/a	2.79E-09	3.0E-03	3.0E-03	2.0E-05	1.6E-02	n/a	1.4E-04	0.016
Thallium	6.62E+00	1.95E-05	n/a	1.16E-09	4.0E-05	4.0E-05	-	4.9E-01	n/a	n/a	0.49
Vanadium	9.11E+01	2.69E-04	n/a	1.60E-08	1.0E-02	2.6E-04	1.0E-04	2.7E-02	n/a	1.6E-04	0.027
										HI:	**2**
										Maximum TO HI [c]:	**2**
Slag Disposal Area											
Arsenic	1.20E+02	2.11E-04	3.39E-05	2.09E-08	3.0E-04	3.0E-04	1.5E-05	7.0E-01	1.1E-01	1.4E-03	0.82
Cadmium	2.24E+00	6.60E-06	2.12E-08	3.92E-10	5.0E-04	1.3E-05	1.0E-05	1.3E-02	1.7E-03	3.9E-05	0.015
Cobalt	1.42E+01	4.18E-05	n/a	2.49E-09	3.0E-03	3.0E-03	2.0E-05	1.4E-02	n/a	1.2E-04	0.014
Thallium	5.75E+00	1.69E-05	n/a	1.01E-09	4.0E-05	4.0E-05	-	4.2E-01	n/a	n/a	0.42
Vanadium	1.08E+02	3.19E-04	n/a	1.89E-08	1.0E-02	2.6E-04	1.0E-04	3.2E-02	n/a	1.9E-04	0.032
										HI:	1

Notes:

-	not available
%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
EPC	exposure point concentration
HI	hazard index
mg/kg	milligrams per kilogram
mg/kg-d	milligrams per kilogram per day
mg/m^3	milligrams per cubic meter
n/a	not available/applicable
TO	target organ
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the noncancer threshold.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

[b] Hazards shown only for noncarcinogenic COPCs with available doses and toxicity values.

[c] Maximum target organ HIs are shown only when the HI for all COPCs is greater than 1. A target organ HI is the sum of the hazard quotients for COPCs that affect the same target organ.

TABLE D.2-3 - Cancer Risk Calculations for a Recreational User - Consumer of Locally-Caught Sport Fish
Watts Bar Fossil Plant

Surface Stream/COPC	EPC [a] Fish Filet	Exposure Dose [b] Ingestion	Cancer Slope Factor Oral	ILCR [c] COPC-Specific
	mg/kg-ww	mg/kg-d	$(mg/kg-d)^{-1}$	unitless
Adjacent Tennessee River				
Arsenic	1.60E-01	2.29E-06	1.5E+00	3.4E-06
			Cumulative ILCR:	3E-06

Notes:

%	percent
COPC	constituent of potential concern
EPC	exposure point concentration
ILCR	incremental lifetime cancer risk
mg/kg-ww	milligrams per kilogram wet weight
mg/kg-d	milligrams per kilogram per day
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

[b] A factor of 10% is applied in the ingestion dose calculation to adjust for the % of inorganic arsenic in the total arsenic EPC. Arsenic in fish tissue is predominately in the form of organic arsenic compounds which are of very low toxicity (USEPA 2000b). Since fish filet samples collected under the TDEC Order were not speciated for different forms of arsenic, it was assumed that 10% of the total reported concentration is inorganic (Schoof and Yager 2007).

[c] Risks shown only for carcinogenic COPCs with available doses and toxicity values.

TABLE D.2-4 - Noncancer Hazard Calculations for a Recreational User (Child) - Consumer of Locally-Caught Sport Fish
Watts Bar Fossil Plant

Surface Stream/COPC	EPC [a] Fish Filet	Exposure Dose [b] Ingestion	Chronic Reference Dose Oral	Hazard Quotient [c] COPC-Specific
	mg/kg-ww	mg/kg-d	mg/kg-d	unitless
Adjacent Tennessee River				
Arsenic	1.60E-01	8.90E-06	3.0E-04	0.030
Mercury	2.80E-01	1.56E-04	1.0E-04	**1.6**
			HI:	**2**
			Maximum TO HI [d]:	**2**

Notes:

%	percent
COPC	constituent of potential concern
EPC	exposure point concentration
HI	hazard index
mg/kg-ww	milligrams per kilogram wet weight
mg/kg-d	milligrams per kilogram per day
TO	target organ
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the noncancer threshold.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

[b] A factor of 10% is applied in the ingestion dose calculation to adjust for the % of inorganic arsenic in the total arsenic EPC. Arsenic in fish tissue is predominately in the form of organic arsenic compounds which are of very low toxicity (USEPA 2000b). Since fish filet samples collected under the TDEC Order were not speciated for different forms of arsenic, it was assumed that 10% of the total reported concentration is inorganic (Schoof and Yager 2007).

[c] Hazards shown only for noncarcinogenic COPCs with available doses and toxicity values. The methyl mercury chronic reference dose was used for mercury.

[d] Maximum target organ HIs are shown only when the HI for all COPCs is greater than 1. A target organ HI is the sum of the hazard quotients for COPCs that affect the same target organ.

APPENDIX D.3

HUMAN HEALTH RISK CALCULATIONS FOR RADIONUCLIDES

TABLE D.3-1 - USEPA PRG Calculator for Radionuclides Input for Onsite Worker
Watts Bar Fossil Plant

Variable	Default Value	Form-input Value
Onsite Worker Exposed to CCR Material	Outdoor Worker Soil Default Value	Onsite Worker
A (PEF Dispersion Constant)	16.2302	16.2302
B (PEF Dispersion Constant)	18.7762	18.7762
City (Climate Zone)	Default	Default
C (PEF Dispersion Constant)	216.108	216.108
Cover layer thickness for GSF (gamma shielding factor) cm	0 cm	0 cm
F(x) (function dependent on U_m/U_t) unitless	0.194	0.194
PEF (particulate emission factor) m^3/kg	1359344438	1359344438
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	93.77
A_s (acres)	0.5	0.5
Slab size for ACF (area correction factor) m^2	1000000 m^2	2000 m^2
ED_{ow} (exposure duration - outdoor worker) yr	25	1
EF_{ow} (exposure frequency - outdoor worker) day/yr	225	20
ET_{ow} (exposure time - outdoor worker) hr/day	8	8
IRA_{ow} (inhalation rate - outdoor worker) m^3/day	60	60
IRS_{ow} (soil intake rate - outdoor worker) mg/day	100	330
t_{ow} (time - outdoor worker) yr	25	1
TR (target cancer risk) unitless	0.000001	0.000001
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Notes:

cm	centimeters
USEPA	United States Environmental Protection Agency
g	grams
g/m^2-s per kg/m^3	grams per square meter - second per kilogram per cubic meter
hr	hours
kg	kilograms
m/s	meter(s) per second
m^2	square meters
m^3	cubic meters
m^3/kg	cubic meter(s) per kilogram
mg	milligrams
PRG	Preliminary Remediation Goal
yr	year(s)
	site-specific value

TABLE D.3-2 - Human Health Cancer Risk Estimates for Exposure to Radionuclides in CCR Material
Watts Bar Fossil Plant

Exposure Scenario/ Exposure Unit/COPC	EPC [a]	PRG	ILCR
	pCi/g	pCi/g	unitless
Onsite Worker Exposed to CCR Material			
Slag Disposal Area			
Radium-226	3.83E+00	7.18E+00	5.3E-07
		Cumulative ILCR:	5E-07
		State of Tennessee Acceptable Cancer Risk	1E-05

Notes:

%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
EPC	exposure point concentration
ILCR	incremental lifetime cancer risk
pCi/g	picocuries per gram
PRG	preliminary remediation goal
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

APPENDIX E

UPDATED ARSENIC TOXICITY FACTORS

DRAFT

Stantec

Memo

To:	Brandon Boyd; Roy Quinn TVA	From:	Stantec Consulting Services Inc. Lexington, Kentucky
Project/File:	TDEC Order Fossil Plants	Date:	December 5, 2025

Reference: USEPA's Updated Arsenic Toxicity Factors – Implications for TVA Risk Assessments

As requested by Tennessee Valley Authority (TVA), Stantec Consulting Services Inc. (Stantec) reviewed the United States Environmental Protection Agency's (USEPA's) updated toxicity values for inorganic arsenic and assessed their implications for the Human Health and Ecological Risk Assessments (HHERAs) previously completed under the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order). The HHERAs were prepared by Stantec on behalf of TVA for the Bull Run Fossil Plant, Cumberland Fossil Plant, Johnsonville Fossil Plant, John Sevier Fossil Plant, Kingston Fossil Plant, and Watts Bar Fossil Plant. While the updated toxicity values (a 5-fold decrease in the noncancer reference dose and a 21-fold increase in the cancer slope factor) result in higher calculated risk estimates, the overall conclusions of the HHERAs remain unchanged.

1 Updated Arsenic Toxicity Factors

At the request of USEPA national programs, USEPA's Integrated Risk Information System (IRIS) Program initiated review of the health effects database for inorganic arsenic in 2019 following a well-defined multi-step peer-review process (USEPA 2024a). IRIS published their updated *Toxicological Review of Inorganic Arsenic* on January 13, 2025 (USEPA 2025). The 2025 report summarizes and evaluates new information on health effects and dose-response relationships for human populations exposed to inorganic arsenic published since the previous Toxicological Review in 1995. USEPA derived updated cancer slope factors (CSF) and noncancer reference doses (RfD) for human exposures to inorganic arsenic from (predominately) dietary sources. USEPA determined that the weight of evidence did not support revising the 1995 inhalation toxicity factors.

USEPA's basis for the updated inorganic arsenic toxicity factors is briefly summarized below.

1.1 Cancer Toxicity Assessment

Decades of epidemiological studies have established that inorganic arsenic is a human carcinogen under some circumstances of exposure. Skin, lung, and bladder cancer are well documented outcomes in populations living in geological areas with naturally occurring "high arsenic" levels in drinking water and dietary sources. The focus of the IRIS assessment was to update quantitative estimates of cancer risk using dose-response models developed since 1995. The modeling focused on estimated increases in mean lifetime extra risks for bladder and lung cancer in populations exposed to inorganic arsenic in the "low dose" range in drinking water.

USEPA (2024a) defines the CSF as “an estimate of the increased cancer risk from oral exposure to a dose of 1 milligram per kilogram per day (mg/kg-day) for a lifetime”. The updated 2025 CSF is 32 per mg/kg-d, which is 21 times higher than the previous 1995 CSF of 1.5 per mg/kg-day. The higher the CSF, the greater the chances of developing cancer for each incremental increase in daily dose of a carcinogen. In other words, USEPA’s (2025) assessment concluded that inorganic arsenic is a stronger carcinogen than indicated previously in 1995.

Cancer risk (expressed as an incremental lifetime cancer risk [ILCR]) is calculated by multiplying the receptor’s estimated daily dose of inorganic arsenic averaged over a 70-year lifetime (lifetime average daily dose [LADD]) by the CSF: ILCR = LADD (mg/kg-day) x CSF (32 per mg arsenic/kg-day). The doses cancel resulting in a unitless estimate of the receptor’s chances of getting cancer during their lifetime resulting from the dose used in the model. Risk is typically expressed as X chance in 1 million up to X chance in ten thousand (XE-06 up to XE-04). USEPA (1991) policy clarifying the role of the baseline risk assessment in Superfund remedy selection defines a cancer risk management range of 1E-06 to 1E-04. Estimated cancer risks less than 1E-06 typically do not require further action or evaluation; while estimated risks of 1E-04 or greater require considering actions to mitigate the source of risk. In practice, USEPA programs such as RCRA and many states’ regulatory programs, including TDEC (2024), use an estimated risk of 1E-05 (the midpoint of the OSWER risk management range) as the regulatory target for considering further action. Applying the updated inorganic arsenic CSF will result in higher estimates of cancer risk than would have been derived using the previous CSF, and likely more frequent instances of risk estimates requiring additional evaluation.

1.2 Noncancer Toxicity Assessment

The IRIS program reviewed studies of noncancer health effects associated with inorganic arsenic in human populations and selected increased incidence of diabetes and ischemic heart disease (IHD) as the basis for developing an overall RfD. USEPA (2024a) defines the RfD as “an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.” USEPA states that confidence in the RfD is medium-high, based on high confidence in the diabetes specific RfD and medium-high confidence in the IHD organ/system-specific RfD. According to USEPA (2025) the final RfD is expected to be protective against all noncancer adverse health effects associated with inorganic arsenic for all members of the population. The RfD is expressed as the daily intake of inorganic arsenic per kg body weight of the receptor (mg/kg-day).

The updated 2025 RfD is 0.00006 mg/kg-day (or 6E-05 mg/kg-day). This is five times lower than the previous 1991 RfD of 0.0003 mg/kg-day (or 3E-04 mg/kg-day). USEPA (2025) concluded that “*On the basis of a robust epidemiological evidence base, the currently available evidence demonstrates that As causes diseases of the circulatory system (DCS) and diabetes in humans given sufficient exposure conditions*”. The previous RfD published on IRIS in 1991 was based on hyperpigmentation, keratosis, and possible vascular complications in human populations exposed to inorganic arsenic in drinking water.

Noncancer hazard is expressed as the Hazard Quotient (HQ) for a single constituent. The HQ is calculated by dividing the receptor average daily dose (ADD) by the RfD: HQ = ADD (mg/kg-d) / RfD (mg/kg-d). If the

resulting HQ is less than 1, then the receptor's exposure is less than the RfD and generally no further evaluation is warranted. If the resulting quotient is greater than 1, then further evaluation or action is generally warranted.

2 Implications of the Updated Arsenic Toxicity Factors for TVA TDEC Order Risk Assessments and Management Decisions in the CARA

IRIS assessments are an important source of toxicity information for the USEPA, state and local health agencies, other federal agencies, and international health organizations. The USEPA stated that the mission of the IRIS program is to develop impartial toxicity information, independent of its regulatory use in setting national standards and cleaning up hazardous sites. While IRIS toxicity factors are not regulatory standards, they often influence regulatory programs and risk management decisions (USEPA 2024a). The updated 2025 inorganic arsenic toxicity factors have implications for the interpretation of risk assessments, especially those concerning coal combustion residuals (CCR), given that USEPA's justification for the 2015 CCR Rule centered on cancer risks from inorganic arsenic in groundwater used as drinking water.

2.1 CARA Plan - Groundwater Protection Standards (GWPS)

As of June 2025, there are no indications that USEPA (2025b) is planning to revise the current federal drinking water maximum contaminant level (MCL) for inorganic arsenic, which is set at 10 micrograms per Liter (µg/L) (USEPA 2018). MCLs are enforceable standards for public drinking water supplies developed by the USEPA Office of Drinking Water and promulgated through the Chemical Contaminant Rules (USEPA 2024b). The Groundwater Protection Standard (GWPS) for inorganic arsenic under the federal CCR Rule and Tennessee (TN) Rules (TDEC 2024) is the MCL. The GWPS for inorganic arsenic and related management decisions in the Corrective Action/Risk Assessment (CARA) Plan, prepared for each of the six TVA fossil plants listed earlier, are not expected to change in the near future as a result of the updated toxicity factors.

2.2 Evaluation of Human Receptors in the TDEC Order Risk Assessments

Because the IRIS toxicity factors apply to human health, the following sections provide an overview of the implications for the Onsite Worker, the Offsite Resident, and the Recreational Swimmer, Beachcomber, and Consumer of Locally Caught Fish. Since these toxicity values do not apply to ecological receptors, the methods for evaluating ecological risk and the conclusions of the TVA's TDEC Order ecological risk assessments will not change.

2.2.1 Onsite Short-Term Worker Exposure to CCR Material in Closed Units

A quantitative comparison of the risk estimates using previous and updated arsenic toxicity values for the Onsite Worker exposed to Area of Interest soil and CCR material is provided in Table 1. Application of the 2025 RfD for inorganic arsenic in evaluating short-term worker exposure to CCR material during repair activities in closed CCR units results in increased numerical estimates of noncancer HQ to be greater than 1. However, this increase does not alter the overall conclusions of the risk assessments. As described in the HHERA reports for the Watts Bar Fossil Plant (Stantec 2025a) and John Sevier Fossil Plant (Stantec

2025b), potential exposures and associated risks for short-term workers are effectively managed through adherence to standard health and safety protocols, and the determination of no unacceptable risk for this receptor remains valid.

2.2.2 Offsite Residential Use of Surface Water and Recreator – Swimmer

Inorganic arsenic concentrations in surface water bodies used for domestic potable supply and recreational water contact were found to be below both the current federal MCL and TN water quality criteria (10 µg/L) for use of surface stream water as a domestic potable source (TDEC 2024). These concentrations were consistent across samples collected upstream, adjacent to, and downstream of TVA's fossil plants. As there have been no changes to the applicable drinking water standards, the evaluation of offsite residential use of surface stream water as a domestic potable source, as well as the assessment of recreational swimmer exposure, remains unchanged in the TVA TDEC Order risk assessments.

2.2.3 Recreational Beachcomber – Contact with Seasonally Exposed Sediment

A quantitative comparison of the risk estimates using previous and updated arsenic toxicity values for the Recreational Beachcomber exposed to sediment is provided in Table 2. Using the 2025 CSF and RfD for inorganic arsenic to assess exposure of adult and child recreational beachcombers to CCR constituents in seasonally exposed stream sediment results in higher numerical estimates of cancer risk and noncancer hazard. Nonetheless, these increases do not affect the conclusions of the risk assessments. Inorganic arsenic concentrations in sediment samples collected adjacent to and downstream of TVA fossil plants were comparable to those collected from upstream background reference transects, indicating no incremental increase in risk associated with the CCR units[1]. Further, inorganic arsenic concentrations in surface stream sediment aligned with the site-specific background threshold values (BTVs) derived from samples of unimpacted soils[2]. Residential receptors typically have more frequent contact with soil than recreational beachcombers have with seasonally exposed surface stream sediment. Given that concentrations of inorganic arsenic in surface stream sediments were within the range of site-specific background soil concentrations, and no incremental increases in concentrations were observed at adjacent and downstream sediment locations compared to upstream, the risk characterization for this receptor remains unchanged.

2.2.4 Recreational Receptor - Consuming Locally Caught Fish

Incorporating the updated 2025 CSF for inorganic arsenic into the evaluation of risks from ingestion of locally caught fish increases the quantitative cancer risk estimates but does not alter the conclusions of the risk assessments. According to the 2025 Toxicological Review, the USEPA does not consider fish and shellfish to be significant sources of inorganic arsenic exposure, as arsenic in these organisms is predominantly present in organic forms such as arsenobetaine, arsenosugars, and arsenolipids, which are

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[1] Supporting information is documented in the Statistical Analysis of Sediment Appendix of applicable Environmental Assessment Reports (TVA 2023a, 2023b, 2024b, 2024c, 2025).
[2] Background soil data summary tables are provided in the Statistical Analysis of Background Soil Data Appendix of the Environmental Assessment Reports (TVA 2023a, 2023b, 2024a, 2024b, 2024c, 2025).

not toxic to humans. Speciation analyses of fish filet tissue samples from the Emory, Clinch, and Tennessee Rivers during the Kingston Recovery Project confirmed that arsenic was almost exclusively in organic forms (Jacobs 2012). Consequently, inorganic arsenic was not identified as a constituent of potential concern in most samples (Jacobs 2012). For conservatism, the TVA TDEC Order risk assessments assumed that 10% of arsenic (total) detected in fish filet was inorganic, a precedent-based approach intended to overestimate potential exposure (Schoof and Yager 2007). Arsenic (total) concentrations in fish were similar across upstream, adjacent, and downstream sampling locations, and no incremental increase in receptor risk was identified for fish consumption near TVA fossil plants.

3 References

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Sincerely,

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TABLE 1 - Comparison of Risk Estimates for Updated Arsenic Toxicity Values for Onsite Workers Exposed to Arsenic in AOI Soil and CCR Material

	Onsite Worker			
	Previous Toxicity Values		Updated Toxicity Values	
Medium/CCR Unit	ILCR	Hazard Quotient	ILCR	Hazard Quotient
	unitless	unitless	unitless	unitless
Bull Run Fossil Plant				
CCR Material				
Bottom Ash Disposal Area	1.7E-07	0.34	3.5E-06	1.7
Dry Fly Ash Stack	2.3E-07	0.46	4.9E-06	2.3
Gypsum Disposal Area - Sluiced Ash	1.8E-07	0.36	3.8E-06	1.8
Main Ash Pond	1.4E-07	0.28	2.9E-06	1.4
Railroad Loop Disposal Area	1.9E-07	0.38	4.0E-06	1.9
Cumberland Fossil Plant				
CCR Material				
Dry Ash Stack	1.3E-07	0.26	2.8E-06	1.3
Gypsum Storage Area - Sluiced Ash	1.7E-07	0.35	3.7E-06	1.8
Stilling Pond (including Retention Pond)	2.5E-07	0.51	5.4E-06	2.6
Johnsonville Fossil Plant				
AOI Soil				
AOI01	7.5E-08	0.15	1.6E-06	0.76
AOI02	1.0E-07	0.21	2.2E-06	1.0
CCR Material				
Ash Disposal Area 1	9.3E-08	0.19	2.0E-06	0.94
DuPont Road Dredge Cell	2.7E-07	0.54	5.7E-06	2.7
South Rail Loop Area 4	2.9E-07	0.59	6.2E-06	3.0
Active Ash Pond 2	2.6E-07	0.53	5.5E-06	2.6
Former Coal Yard	1.8E-07	0.37	3.9E-06	1.9
John Sevier Fossil Plant				
CCR Material				
Ash Disposal Area J - Stacked Ash	3.4E-07	0.70	7.3E-06	3.5
Ash Disposal Area J - Sluiced Ash	6.7E-07	1.4	1.4E-05	6.8
Bottom Ash Pond	3.9E-07	0.80	8.4E-06	4.0
Dry Fly Ash Stack	3.3E-07	0.66	6.9E-06	3.3
Highway 70 Borrow Area	2.9E-07	0.59	6.2E-06	2.9

TABLE 1 - Comparison of Risk Estimates for Updated Arsenic Toxicity Values for Onsite Workers Exposed to Arsenic in AOI Soil and CCR Material

	Onsite Worker			
	Previous Toxicity Values		Updated Toxicity Values	
Medium/CCR Unit	ILCR	Hazard Quotient	ILCR	Hazard Quotient
	unitless	unitless	unitless	unitless
Kingston Fossil Plant				
CCR Material				
Interim Ash Staging Area	1.9E-07	0.39	4.0E-06	1.9
Sluice Trench and Area East of Sluice Trench	1.7E-07	0.34	3.5E-06	1.7
Stilling Pond	2.7E-07	0.55	5.8E-06	2.8
Watts Bar Fossil Plant				
CCR Material				
Ash Pond	6.1E-07	1.2	1.3E-05	6.2
Slag Disposal Area	4.0E-07	0.82	8.6E-06	4.1
State of Tennessee Acceptable Cancer Risk and Noncancer Threshold:			1E-05	1

Notes:

AOI	area of interest
CCR	coal combustion residuals
ILCR	incremental lifetime cancer risk

TABLE 2 - Comparison of Risk Estimates for Updated Arsenic Toxicity Values for a Recreational User - Beachcomber Exposed to Arsenic in Sediment

	Recreational User - Beachcomber			
	Previous Toxicity Values		Updated Toxicity Values	
Surface Stream	ILCR[a]	Hazard Quotient[b]	ILCR[a]	Hazard Quotient[b]
	unitless	unitless	unitless	unitless
Bull Run Fossil Plant Clinch River	2.1E-06	0.031	4.6E-05	0.16
Cumberland Fossil Plant Wells Creek	1.2E-06	0.018	2.6E-05	0.091
Johnsonville Fossil Plant Tennessee River	1.2E-06	0.017	2.5E-05	0.086
John Sevier Fossil Plant Downstream Holston River	1.3E-06	0.019	2.7E-05	0.093
State of Tennessee Acceptable Cancer Risk and Noncancer Threshold:			1E-05	1

Notes:

ILCR incremental lifetime cancer risk

Risk estimates were not calculated for the Kingston Fossil Plant and Watts Bar Fossil Plant

[a] ILCRs are estimated for an age-adjusted composite adult, child, and adolescent

[b] HQs are estimated for the most sensitive recreational receptor (i.e., a child)